SPECIAL PUBLICATION 535
Volume 1, Part 1

Catalog of National Bureau of Standards Publications 1966-1976

Citations and Abstracts

U.S. Department of Commerce

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau's technical work is performed by the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology.

THE NATIONAL MEASUREMENT LABORATORY provides the national system of physical and chemical and materials measurement; coordinates the system with measurement systems of other nations and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce; conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government Agencies; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The Laboratory consists of the following centers:

Absolute Physical Quantities[2] — Radiation Research — Thermodynamics and Molecular Science — Analytical Chemistry — Materials Science.

THE NATIONAL ENGINEERING LABORATORY provides technology and technical services to users in the public and private sectors to address national needs and to solve national problems in the public interest; conducts research in engineering and applied science in support of objectives in these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; develops engineering data and measurement capabilities; provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user. The Laboratory consists of the following centers:

Applied Mathematics — Electronics and Electrical Engineering[2] — Mechanical Engineering and Process Technology[2] — Building Technology — Fire Research — Consumer Product Technology — Field Methods

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides scientific and technical services to aid Federal Agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in Government operations in accordance with Public Law 89-306 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing Federal ADP standards guidelines, and managing Federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to Federal Agencies; and provides the technical foundation for computer-related policies of the Federal Government. The Institute consists of the following divisions:

Systems and Software — Computer Systems Engineering — Information Technology

[1]Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2]Some divisions within the center are located at Boulder, Colorado, 80303.

The National Bureau of Standards was reorganized, effective April 9, 1978.

Volume 1, Part 1: Citations and Abstracts

Catalog of National Bureau of Standards Publications, 1966-1976

Consolidated reprint of citations and abstracts from NBS SP305, and its Supplements 1-8

Betty L. Burris and Rebecca J. Morehouse, Editors

Technical Information and Publications Division
National Bureau of Standards
Washington, DC 20234

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

Dr. Sidney Harman, Under Secretary
Jordan J. Baruch, Assistant Secretary
for Science and Technology

NATIONAL BUREAU OF STANDARDS
Ernest Ambler, Director

Issued 1978

Library of Congress Catalog Number: 78-600145

National Bureau of Standards Special Publication
535, Volume 1, Part 1

Consolidated reprint of citations and abstracts from
NBS SP305, and its Supplements 1-8, 1966-1976

Nat. Bur. Stand. (U.S.) Spec. Publ. 535, Vol. 1,
Pt. 1, 800 pages (1978)

CODEN: XNBSAV

Issued 1978

U.S. Government Printing Office
Washington: 1978

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. (Order by SD Stock No. 003–003–02010–9). Price $23.75 per 2 part set; sold in sets only. (Add 25 percent additional for other than U.S. mailing.)

PREFACE

Throughout the history of the National Bureau of Standards, publications have served as the single most effective means for conveying results of Bureau research to the Bureau's diverse audiences. Much of this research has lasting value, and publications reporting Bureau work of many years ago are still consulted by current researchers. Because of these facts, NBS is issuing this catalog of Bureau publications from 1966 through 1976. Each of the two volumes may be used separately, or they may be used to complement each other. Volume 1 consists of abstracts and a full bibliographic citation for each paper. It is an accumulation of the complete citations originally appearing in the NBS annual publications catalogs: NBS SP305 and its Supplements 1 through 8. It also contains availability information not only for currently in-print papers but also for NBS publications series which are no longer in print. Volume 2 consists of a permuted key word index for all papers. See the "Guide to Users of This Publication" for more details on how to most effectively use each volume.

The NBS publications series (presently consisting of 11 non-periodicals and 3 periodicals) provides a matrix which makes it possible to issue each NBS paper in a medium best calculated to reach its most interested specific audience. Throughout the years, this matrix has evolved to reflect changing emphases in Bureau work. Some former publications series have been eliminated; some have been modified; new ones have been created. The "Miscellaneous Publications" series, for example, was superseded by "Special Publications" in 1970. The NBS Journal of Research evolved into three publications, each reporting work in a different discipline, and now has further evolved to the present single volume which reports work in all NBS technical areas. NBS publications series, past and present, are listed and described. (Currently active NBS publications series are described more briefly on the inside back cover of this catalog's two volumes.)

One final note, as the years pass we have constantly attempted to expand the usefulness and comprehensiveness of our *annual* publications catalog. To this end, we have utilized new computer technology as it became available—for composition as well as for cataloging purposes. In earlier years we were only able to include the overall abstract for a conference or symposium Proceedings. For the past several years we have been able to include, in addition, abstracts for the individual papers presented. Also, for the past several years we have been able to include information on Patents, Grant/Contract Reports, and other items which we had not been able to cover previously —all this toward the end of increasing the catalog's usefulness in communicating NBS work to the public.

We hope this summary of former NBS effort will facilitate the work of those who use it. This two-volume catalog of NBS publications covering calendar years 1966 through 1976 will be updated by the annual catalog supplements. The 1977 supplement is currently available as NBS SP305, Supplement 9. (See Section 2.2.)

W. R. Tilley, Chief
Technical Information and
Publications Division

CONTENTS

FOR VOL. 1, PART 1 AND PART 2, VOL. 2

FOR VOL. 1, PART 1 ONLY

FOR VOL. 1, PART 2 ONLY

FOR VOL. 2 ONLY

A GUIDE TO USERS OF THIS PUBLICATION

This 11-year record of NBS publications is available in two volumes, each of which may be used independently.

Volume 1, issued in two parts because of its length, consists of abstracts for publications issued by NBS from 1966 through 1976. It also contains general availability information for current and out-of-print NBS publications and a general overview of the NBS publications program. Frequently, the full abstract will satisfy the user's need for information and preclude the need for further research or for acquiring the full paper. Volume 1 reports papers by NBS publications series, as shown in its Table of Contents. If the user does know the NBS publications series involved but does not know the year of publication, this format will be especially useful.

Volume 2, also issued in two parts, consists of a permuted key word index. The key words for each publication or paper are arranged by shifting each group of key words so that each key word, in turn, appears alphabetically followed by the other key words in that group. Volume 2, which also contains the availability and overview information for current and out-of-print NBS publications, may be used in three ways:

(a) as a reference to the abstract given in Volume 1 of this catalog (for papers reported in the annual catalogs, SP305 and Supplements 1 through 8);

(b) as a reference to the abstract in the appropriate annual NBS publications catalog (if available to the reader; see list in Section 2.3);

(c) as a reference to the paper itself, available in a regional depository library, from the National Technical Information Service, or from the original publisher or publication medium, if the paper is still in print. (See availability information in Section 2.).

If the reader does not know the NBS publications series or title of the paper, or is interested in a specific subject matter area, the key word format of Volume 2 will prove useful.

Tables of the abbreviations used to identify various NBS publications series are given below. The tables include the Volume 1 page numbers on which the series listings begin.

SYMBOLS FOR NBS PUBLICATIONS

A. Symbols for the Periodicals

NBS Journal of Research	Index Symbol			Issue Date	Volume 1 Page
	Vol.	Sec.	No.		
Section A	J. Res. 70 through 80	A	1 through 6	July 1966 through December 1976	1
Section B	J. Res. 70 through 80	B	1 through 4	July 1966 through December 1976	88
Section C	J. Res. 70 through 76	C	1 through 4	July 1966 through June 1972	124

Journal of Physical and Chemical Reference Data	Index Symbol		Issue Date	Page
	Vol.	No.		
	JPCRD 1 through 5	1 through 4	January 1972 through December 1976	145

DIMENSIONS/NBS	Index Symbol		Issue Date	Page
	Vol.	No.		
	DIM/NBS 57 through 60	1 through 12	January 1973 through December 1976	162

B. Symbols for the Nonperiodicals

NBS Nonperiodical Series	Index Symbol	Page
Monographs	Monogr.	174
Handbooks	H	188
Miscellaneous Publications	MP	192
Special Publications	SP	195
Applied Mathematics Series	AMS	497
National Standard Reference Data Series	NSRDS	498
Building Science Series	BSS	507
Federal Information Processing Standards	FIPS PUBS	531
Commercial Standards	CS	537
Simplified Practice Recommendations	SPR	537
Voluntary Product Standards	PS	537
Technical Notes	TN	545
Consumer Information Series	CIS	645
NBS Interagency Reports	NBSIR	646
Grantee/Contractor Reports and Patents	GCR and/or U.S. Patent	735

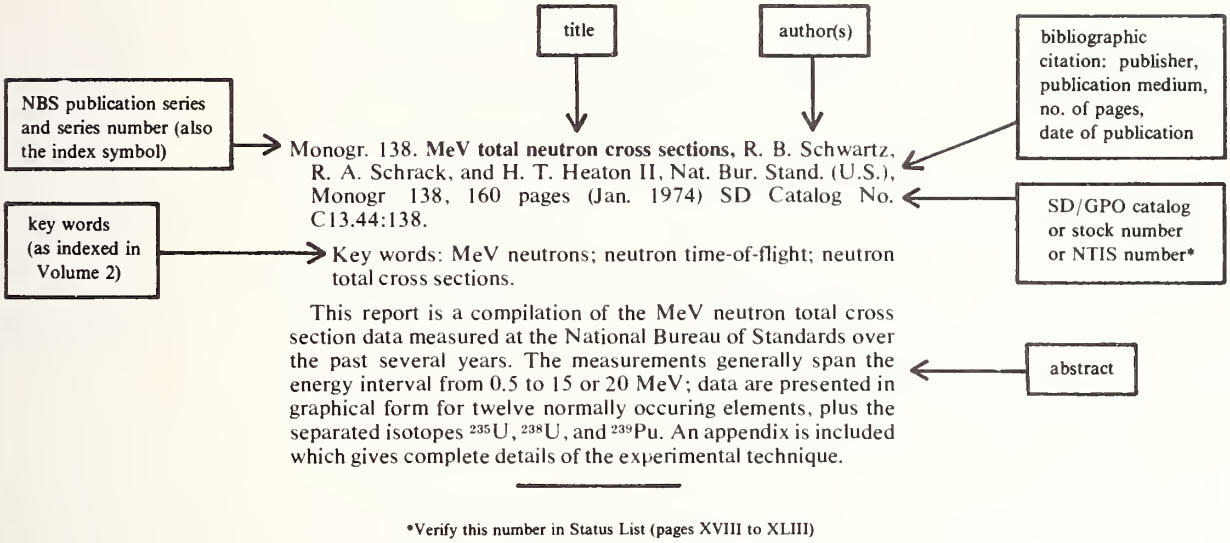
C. Symbols for the Papers Published in Non-NBS Media (1966–1976)

NBS Papers Published in Non-NBS Media	Index Symbol	Volume 1, Page
Professional Journals, Books, Book Chapters, Proceedings, etc.	Arabic numbers: 9150 through 16658	754

SAMPLE
ENTRIES
FROM
VOLUMES
1 AND 2
FOLLOW

CATALOG ENTRIES: HOW TO READ THEM

A. Sample Entries from Volume 1



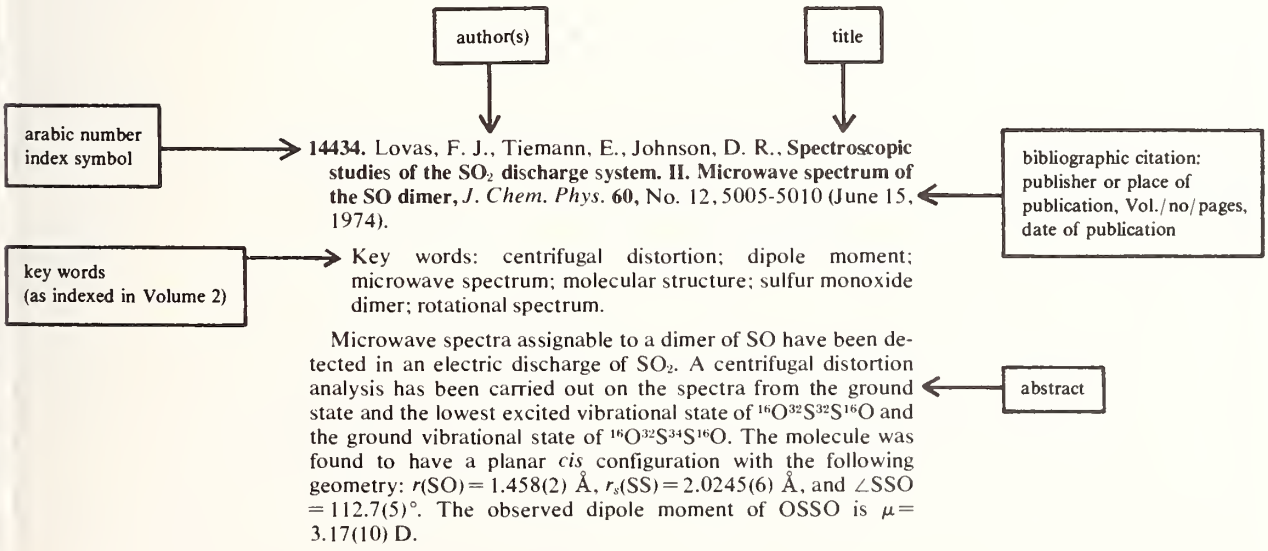
Monogr. 138. **MeV total neutron cross sections,** R. B. Schwartz, R. A. Schrack, and H. T. Heaton II, Nat. Bur. Stand. (U.S.), Monogr 138, 160 pages (Jan. 1974) SD Catalog No. C13.44:138.

Key words: MeV neutrons; neutron time-of-flight; neutron total cross sections.

This report is a compilation of the MeV neutron total cross section data measured at the National Bureau of Standards over the past several years. The measurements generally span the energy interval from 0.5 to 15 or 20 MeV; data are presented in graphical form for twelve normally occuring elements, plus the separated isotopes ^{235}U, ^{238}U, and ^{239}Pu. An appendix is included which gives complete details of the experimental technique.

*Verify this number in Status List (pages XVIII to XLIII)

Example of NBS published paper. (See Section 2 for status and availability.)



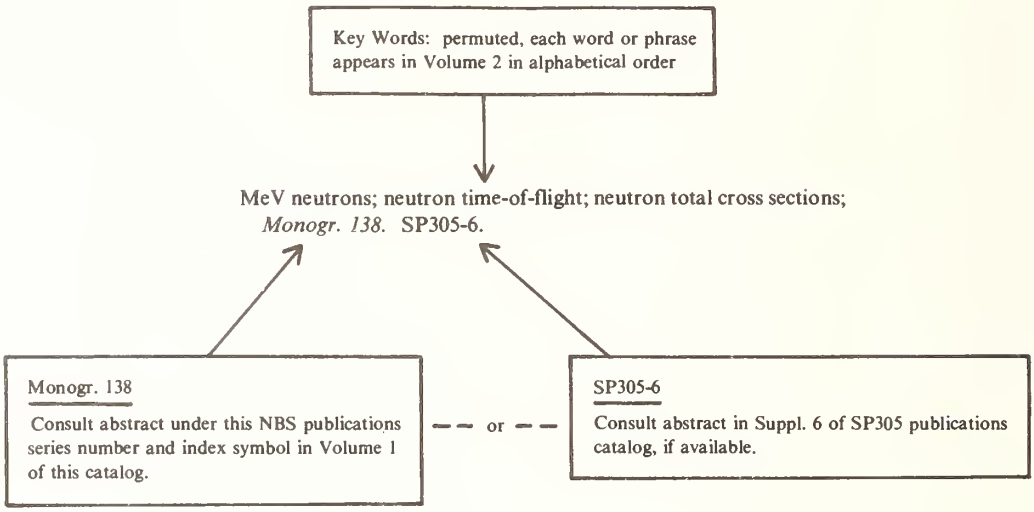
14434. Lovas, F. J., Tiemann, E., Johnson, D. R., **Spectroscopic studies of the SO_2 discharge system. II. Microwave spectrum of the SO dimer,** *J. Chem. Phys.* **60,** No. 12, 5005-5010 (June 15, 1974).

Key words: centrifugal distortion; dipole moment; microwave spectrum; molecular structure; sulfur monoxide dimer; rotational spectrum.

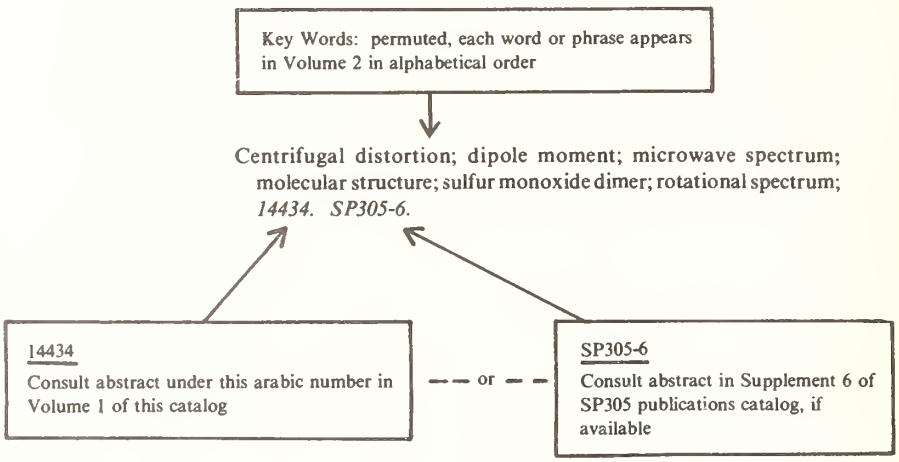
Microwave spectra assignable to a dimer of SO have been detected in an electric discharge of SO_2. A centrifugal distortion analysis has been carried out on the spectra from the ground state and the lowest excited vibrational state of $^{16}O^{32}S^{32}S^{16}O$ and the ground vibrational state of $^{16}O^{32}S^{34}S^{16}O$. The molecule was found to have a planar *cis* configuration with the following geometry: $r(SO) = 1.458(2)$ Å, $r_s(SS) = 2.0245(6)$ Å, and $\angle SSO = 112.7(5)°$. The observed dipole moment of OSSO is $\mu = 3.17(10)$ D.

Example of NBS paper published in non-NBS medium

B. Sample Entries from Volume 2.



Example of NBS published paper. (See Section 2 for status and availability.)



Example of NBS paper published in non-NBS medium

1. NBS PUBLICATION PROGRAM

1.1. INTRODUCTION

The formal publications of the National Bureau of Standards provide the primary means of communicating the results of NBS programs to its varied technical audiences as well as to the general public. Publications thus constitute a major end product of the Bureau's efforts. These take the form of the Bureau's periodicals, its nonperiodical series, interagency reports, and articles in the journals of professional organizations and technological associations.

The various media in which the results of NBS programs appear are as follows:

1.2. PERIODICALS

1.2.1. JOURNAL OF RESEARCH

Since July 1977, the Journal of Research has been published on a single-volume, bi-monthly basis. See the inside back cover for a description of the present Journal which reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active.

Annual subscription: domestic $17.00; foreign, $21.25. Single copy, $3.00 domestic; $3.75 foreign.

The Journal was formerly published in three sections: Section A "Physics and Chemistry," Section B "Mathematical Sciences," and Section C "Engineering and Instrumentation." Papers published in these former versions of the Journal are reported in this catalog. Each section's coverage is briefly described below:

A. Physics and Chemistry (July 1966 through December 1976)

Contained papers of interest primarily to scientists working in these fields.

B. Mathematical Sciences (July 1966 through December 1976)

Presented studies and compilations designed mainly for the mathematician and the theoretical physicist.

C. Engineering and Instrumentation (July 1966 through June 1972)

Reported research and development results of interest chiefly to the engineer and to the applied scientist.

1.2.2. DIMENSIONS/NBS

This magazine is published to inform both the technical expert and the interested layman of the latest advances in science and technology, with primary emphasis on the work at NBS. The magazine highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, it reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing. Formerly issued monthly. The tables of contents for each issue of DIMENSIONS/NBS (formerly Technical News Bulletin) for the years 1973 through 1976 are listed in Section 3.5.

1.2.3. JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA (JPCRD)

This Journal is published quarterly by the American Chemical Society and the American Institute of Physics for the National Bureau of Standards. The objective of the Journal is to provide critically evaluated physical and chemical property data, fully documented as to the original sources and the criteria used for evaluation. Critical reviews of measurement techniques, whose aim is to assess the accuracy of available data in a given technical area, are also included. The principal source for the Journal is the National Standard Reference Data System (NSRDS). The Journal is not intended as a publication outlet for original experimental measurements such as are normally reported in the primary research literature, nor for review articles of a descriptive or primarily theoretical nature. (See also Section 1.3. National Standard Reference Data Series.)

1.3. NONPERIODICALS

Several categories of nonperiodical publica-

tions, described as follows, are listed in this catalog:

MONOGRAPHS—major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

HANDBOOKS—recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

MISCELLANEOUS PUBLICATIONS. The name of this series was changed to Special Publications in 1970.

SPECIAL PUBLICATIONS—include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Special subject-matter subseries include Semiconductor Measurement Technology (SP400–), Standard Reference Materials (SP260–), and Precision Measurement and Calibration (SP300–).

APPLIED MATHEMATICS SERIES—mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

NATIONAL STANDARD REFERENCE DATA SERIES—provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS, under authority of National Standard Data Act (Public Law 90-396). This series supplements the JPCRD, see also Section 3.4.

BUILDING SCIENCE SERIES—disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

TECHNICAL NOTES—studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Special subject-matter subseries include Optical Radiation Measurements (TN594–) and Self Calibrations Manual for Optical Radiation (TN910–).

COMMERCIAL STANDARDS AND SIMPLIFIED PRACTICE RECOMMENDATIONS. See Voluntary Product Standards below.

VOLUNTARY PRODUCT STANDARDS—developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. The National Bureau of Standards administers the Voluntary Product Standards program as a supplement to the activities of the private sector standardizing organizations.

FEDERAL INFORMATION PROCESSING STANDARDS PUBLICATIONS (FIPS PUBS)—publications in this series collectively constitute the Federal Information Processing Standards Register. Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

Public distribution of FIPS PUBS is by purchase from the National Technical Information Service, Springfield, VA 22161.

CONSUMER INFORMATION SERIES—practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowl-

edge for shopping in today's technological marketplace.

1.4. NBS INTERAGENCY REPORTS

A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Service (Springfield, VA 22161) in paper copy or microfiche form. (See pages XVIII to XLIII.)

1.5. GRANTEE/CONTRACTOR REPORTS AND PATENTS

Grantee/contractor reports are prepared by non-NBS persons or organizations working under grant or contract from the National Bureau of Standards. Those contract reports not incorporated into the formal NBS publication series are available directly from the National Technical Information Service (NTIS), Springfield, VA 22161, in paper copy or microfiche form unless otherwise stated. When ordering a report from NTIS you must order it by the "COM, PB, AD, or N" number as indicated.

Patents are obtained on NBS inventions of high commercial potential, in order to establish Government ownership of the patent rights. The patents are then made available for the grant of nonexclusive licenses to all qualified applicants. A limited exclusive license may be granted under a particular patent, however, if it appears that some period of exclusivity is necessary as an incentive for the investment of risk capital. For information on licensing any of the NBS held patents, write to the Office of the Legal Adviser, National Bureau of Standards, Washington, DC 20234. Copies of patents may be obtained from the U.S. Patent and Trademark Office, Washington, DC 20231 for 50 cents each.

1.6. NBS BIBLIOGRAPHIC SUBSCRIPTION SERVICES

The Cryogenic Data Center of the National Bureau of Standards, Boulder, CO has developed specialized bibliographic issuances designed to provide interested audiences with information on latest developments in certain specialized fields. These issuances, together with subscription information, are listed below:

CRYOGENIC DATA CENTER CURRENT AWARENESS SERVICE (Publications and Reports of Interest in Cryogenics). A literature survey issued weekly. Annual subscription: Domestic, $25.00; Foreign, $30.00.

LIQUEFIED NATURAL GAS. A literature survey issued quarterly. Annual subscription: $20.00.

SUPERCONDUCTING DEVICES AND MATERIALS. A literature survey issued quarterly. Annual subscription: $30.00.

Send subscription orders and remittances for the preceding bibliographic services to the National Bureau of Standards, Cryogenic Data Center (736.00), Boulder, CO 80303.

1.7. PAPERS PUBLISHED BY OTHERS

Many significant contributions by NBS authors are published in other journals. Up-to-date listings of these articles are carried regularly in the Journal of Research and the annual publications catalog (NBS SP305), along with abstracts, key words, and author/subject indexes. Except for the author index, the complete citations for years 1966–1976 have been reprinted in this two-volume catalog.

2. PURCHASE PROCEDURES AND DOCUMENT AVAILABILITY

2.1. PURCHASE PROCEDURES

Many recent publications of the Bureau are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, at the prices listed in this publication. However prices are subject to change without notice. You may also order through the U.S. Department of Commerce Field Office nearest you. Microfiche copies of all recent NBS publications, and paper copies of many non-periodicals, may be ordered through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Note that three of the non-periodical

series are available only from NTIS; these are FIPS PUBS., NBS Interagency Reports (NBSIR's), and Grantee/Contractor Reports (GCR's). This section includes current price lists of available publications, plus instructions on how to acquire reprints of articles by NBS authors, and how to get out-of-print material.

How To Make Remittances. Remittances for publications for which individual sales or subscription prices are shown should be mailed to Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, by postal money order, express money order, or check. Postage stamps will not be accepted. Publications cannot be mailed before remittances are received. *Foreign remittances should be made either by international money order, draft on an American bank or UNESCO coupons.*

The letter symbol, publication number, full title of the publication, SD catalog or SD stock number MUST be given when ordering. The Superintendent of Documents allows a discount of 25 percent on orders of 100 or more copies of one publication.

Persons who make frequent purchases from the Superintendent of Documents may find a deposit account convenient. Deposits of $50 or more are accepted against which orders may be placed without making individual remittances or first obtaining quotations. Order blanks are furnished for this purpose. After the order has been processed, the order itself is returned, showing the publications supplied, explanations regarding those not sent, the amount of charge, and the balance on deposit.

No charge is made for postage on documents sent to points in the United States and its possessions. In computing foreign postage, the charge is approximately one-fourth of the current selling price of the publication. The charge is to cover the special handling required to comply with the customs and international mailing regulations.

How To Make Remittances to NTIS. Orders for publications purchased from the National Technical Information Service (NTIS) must be accompanied by postal money order, express money order, or check made out to the NTIS and covering total cost of the publications order. All inquiries or orders should be addressed to: National Technical Information Service, Springfield, VA 22161.

2.2. ANNOUNCEMENT OF NBS PUBLICATIONS

The National Bureau of Standards and the agencies mentioned below regularly issue the following official announcements dealing with NBS publications.

DIMENSIONS/NBS. Issued monthly by the National Bureau of Standards. In addition to publishing technical news of the Bureau, this periodical announces selected new publications in an NBS series. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Annual subscription, $11.00; $13.75 foreign. Single copies, $1.10 domestic; $1.40 foreign each.

NBS JOURNAL OF RESEARCH. The Journal carries a listing of all NBS publications as issued. See Section 2.6 for subscription information.

Monthly Catalog of United States Government Publications. Issued monthly by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Annual subscription, with consolidated annual index, $45.00; $56.00 foreign.

Selected List of U.S. Government Publications. Issued monthly by the Superintendent of Documents. Each list is arranged by subject, with annotations, prices, and order form. May be obtained free from the U.S. Government Printing Office, Superintendent of Documents, Mail List Section, Stop SSOM, Washington, DC 20402.

Business Service Check List. Bi-weekly announcement of publications of the Department of Commerce. Lists titles and prices of National Bureau of Standards publications, as well as those of other offices of the Department of Commerce. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Annual subscription, $9.00; $11.25 foreign.

NBS Publications Newsletter. This newsletter is issued approximately six times a year.

It presents full citations, including abstracts and availability information, for NBS papers announced during the report period. Its primary audience includes librarians, documentalists and science information specialists. However, other NBS audiences also find it useful as a guide to new NBS publications.

Contact: Editor, NBS Publications Newsletter, Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234.

2.3. CATALOGS OF NBS PUBLICATIONS

The following constitute a complete list of the titles of the Bureau's publications through December 31, 1977. The catalogs are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, unless otherwise stated, or may be consulted in a library which maintains sets of National Bureau of Standards publications. Note that all citations in NBS SP305 and its Supplements 1 through 8 are accumulated into this two-volume catalog.

Circular 460: Publications of the National Bureau of Standards 1901 to June 30, 1947. 375 pages including subject and author indexes. Brief abstracts are included for the period January 1, 1941 to June 30, 1947 ..... *

Supplement to Circular 460: Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957. 373 pages, including subject and author indexes ..... *

Miscellaneous Publication 240: Publications of the National Bureau of Standards, July 1, 1957 to June 30, 1960. First NBS Catalog to include Titles of Papers Published in Outside Journals 1950 to 1959. 391 pages, including subject and author indexes ..... *

Supplement to Miscellaneous Publication 240: Publications of the National Bureau of Standards published by NBS, July 1960 through June 1966; published by others, 1960 through 1965. 740 pages, including subject and author indexes *

Special Publication 305: Publications of the National Bureau of Standards, published by NBS, July 1966 through December 1967; published by others, 1966–1967. 223 pages, a citation of titles and abstracts, with key words and author indexes ..... *

Supplement 1 to Special Publication 305: Publications of the National Bureau of Standards, 1968 through 1969. 497 pages, a citation of titles and abstracts, with key words and author indexes ..... *

Supplement 2 to Special Publication 305: Publications of the National Bureau of Standards, 1970. 378 pages, a citation of titles and abstracts, with key words and author indexes ..... *

Supplement 3 to Special Publication 305: Publications of the National Bureau of Standards, 1971. 342 pages, a citation of titles and abstracts, with key words and author indexes ..... *

Supplement 4 to Special Publication 305: Publications of the National Bureau of Standards, 1972. 449 pages, a citation of titles and abstracts, with key words and author indexes $4.20

Supplement 5 to Special Publication 305: Publications of the National Bureau of Standards, 1973. 349 pages, a citation of titles and abstracts, with key words and author indexes $4.15

Supplement 6 to Special Publication 305: Publications of the National Bureau of Standards, 1974. 523 pages, a citation of titles and abstracts, with key words and author indexes $6.80

Supplement 7 to Special Publication 305: Publications of the National Bureau of Standards, 1975. 595 pages, a citation of titles and abstracts, with key words and author indexes $7.55

Supplement 8 to Special Publication 305: Publications of the National Bureau of Standards, 1976. 728 pages, a citation of titles and abstracts, with key words and author indexes $8.25

Supplement 9 to Special Publication 305: Publications of the National Bureau of Standards, 1977. 601 pages, a citation of titles and abstracts, with key words and author indexes $8.00

* Available by purchase from the National Technical Information Service, Springfield, VA 22161.

2.4. FUNCTIONS OF DEPOSITORY LIBRARIES IN THE UNITED STATES

The Superintendent of Documents, United States Government Printing Office, is authorized by law to furnish Government publications to designated depository libraries.

Under provisions of Title 44 of the United States Code, certain libraries are designated depositories for Government publications. Through them, Federal Government documents are made available to residents of every State, District of Columbia, Guam, Puerto Rico, and the Virgin Islands. Distribution to the libraries is made by the Office of the Superintendent of Documents.

It is sometimes impossible to obtain desired publications by purchase from the Superintendent of Documents. Stocks may have been exhausted or the document may be permanently out of print. In these instances the depositories render an invaluable service by keeping such publications permanently available. Every Government publication cannot be consulted at all depository libraries. Designated Regional Depositories are required to receive

and retain one copy of all Government publications made available to depository libraries either in printed or microfacsimile form. All other libraries are allowed to select the classes of publications best suited to the interest of their particular clientele.

These libraries are now receiving selected publication series of the National Bureau of Standards for general reference use. Whether a given library has a copy of a particular publication can be determined by inquiring at the library.

2.5. FUNCTIONS OF U.S. DEPARTMENT OF COMMERCE DISTRICT OFFICES

Department of Commerce District Offices provide ready access, at the local level, to the services of the Department of Commerce as well as to its reports, publications, statistical statements, and surveys. Each District Office serves as an official sales agent of the Superintendent of Documents, U.S. Government Printing Office, making available for purchase locally a wide range of Government publications. The reference library maintained by each District Office contains many Government and private publications, periodicals, directories, reports, and other reference materials.

2.6. AVAILABILITY OF NBS PUBLICATIONS

A. PERIODICAL SUBSCRIPTION RATES

Periodical	Domestic [1]	Foreign [2]
Journal of Research of the National Bureau of Standards: Effective July 1977 issued bimonthly as single section. Separate Sections A and B discontinued with the June 1977 issues. Paper covers....	$17.00	$21.25
Bound volume (1 volume per year), blue buckram	[3]	[3]
DIMENSIONS/NBS, issued 10 times per year	$11.00	$13.75

NOTE—Send order, with remittance, to Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[1] United States and its possssions.

[2] Foreign price incudes the cost of the publication and postage.

[3] Prices of the bound volumes vary. The Superintendent of Documents will furnish prices on request.

B. SUPERSEDED NBS REFERENCE PUBLICATIONS

Those NBS publications not listed in the Price Lists are out of print and are not available from the Superintendent of Documents. Many can be consulted at libraries. Also, in many cases, photoduplicated copies can be purchased from the Library of Congress. For full information concerning this service, write to the Photoduplication Service, Library of Congress, Washington, DC 20540.

Certain NBS publications are out of print because they have been replaced, or partially replaced, by material issued by other organizations. In this connection NBS is able to offer the following information:

Circular 410, National Standard Petroleum Oil Tables. Information in this Circular has been incorporated in the ASTM–IP Petroleum Measurement Tables issued as D1250 by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. Available at $12.75, 20% off to ASTM members. Tables 5 and 7 of the ASTM–IP Tables may also be purchased from the ASTM in separate reprint form at $2.25 and $2.00 per copy respectively. *Circular 438, Static Electricity.* The National Fire Protection Association, 60 Batterymarch Street, Boston, MA 02110, has issued a publication by the same title, available from them as NFPA Publication 77, at $3.00.

Circular 499, Nuclear Data. Replaced by Atomic and Nuclear Data Tables, published by Academic Press, 111 Fifth Avenue, New York, NY 10003. Available by subscription for $108.00 per year.

Circular 564, Tables of Thermal Properties of Gases. A reprinted edition is available from University Microfilms, Inc., Ann Arbor, MI 48106. Order as OP 12,192 for $56.80. Microfiche of this Circular is available from Cryogenic Data Center, National Bureau of Standards, Boulder, CO 80302.

Circular 576, Automotive Antifreezes. For information on this subject consult American National Standards Institute, 1430 Broadway, New York, NY 10018.

Circular 577 and Supplement, Energy Loss and Range of Electrons and Positrons. These have been superseded by NASA Special Publication

3012, available from the National Technical Information Service, Springfield, VA 22161, at $6.75 hardcopy and $3.00 microfiche number N65–12506.

Miscellaneous Publication 179, American Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures. The American National Standards Institute, 1430 Broadway, New York, NY 10018, has issued a publication on this subject. Available from them as A58.1–1969–1972, at $7.50.

Miscellaneous Publication 187, Directory of Commercial and College Laboratories. A new Directory of Testing Laboratories issued as 333D is published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, at $3.75.

Miscellaneous Publication 211, American Standards Building Code Requirements for Masonry. The American National Standards Institute, 1430 Broadway, New York, NY 10018, has issued a publication on this subject. Available from them as A41.1–1953–R1970, at $4.50.

NBS Handbook 28, Part 1, 2, and 3, Screw Thread Standards. Responsibility for screw thread standards for Federal Government has been transferred to General Services Administration (GSA). Standards will be promulgated as Federal Standard 28 by GSA. Technical Questions should be addressed to Mr. John McGlone, Directorate of Engineering and Standardization, Defense Logistics Agency (DISC), 700 Robbins Ave., Philadelphia, PA 19111, telephone (215) 697–4349. Questions regarding administration of the program should be addressed to Mr. Grant Beattie, Standards Control and Support Division, General Services Administration (Federal Supply Service), attn: FMHS, Washington, DC 20406, telephone (703) 557–0506.

Handbook 30, National Electrical Safety Code (also H81 and its Supplements and H110–1). All NBS publications on this subject have been superseded by National Electrical Safety Code, 1977 Edition, issued by the American National Standards Institute, 1430 Broadway, New York, NY 10018. Available from them as ANSI C2, at $6.50.

Handbook 46, Code for Protection Against Lightning. A United States of America Standards Institute Code for Protection Against Lightning (NFPA–78–1969) is available from the American National Standards Institute, 1430 Broadway, New York, NY 10018, at $4.25, as C5.1–1969–1975.

Handbook 48, Control and Removal of Radioactive Contamination in Laboratories. Reprints of this Handbook can be purchased as NCRP Report at $3.00 from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 49, Recommendations for Waste Disposal of Phosphorus–32 and Iodine–131 for Medical Users. Reprints of this Handbook can be purchased as NCRP Report 9 at $3.00 from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 53, Recommendations for the Disposal of Carbon–14 Wastes. Reprints of this Handbook can be purchased as NCRP Report 12 at $3.00 from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 55, Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts. February 26, 1954 has been combined with NBS Handbook 97. Available as NCRP Report 51, Radiation Protection Design Guidelines for 0.1–100 MeV Particle Accelerator Facilities from NCRP Publications, Post Office Box 30175, Washington, DC 20014 at $6.00.

Handbook 58, Radioactive Waste Disposal in the Ocean. Reprints of this Handbook can be purchased as NCRP Report 16 at $3.00 from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 59, Permissible Dose from External Sources of Ionizing Radiations. Reprints of this Handbook can be purchased as NCRP Report 39 at $5.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 63, Protection Against Neutron Radiation up to 30 MeV. Reprints of this Hand-

book can be purchased as NCRP Report 38 at $6.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 65, Safe Handling of Bodies Containing Radioactive Isotopes. Reprints of this Handbook can be purchased as NCRP Report 37 at $4.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 69, Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure. Reprints of this Handbook can be purchased at $3.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 71, Specifications for Dry Cells and Batteries. Available as C18.1–1972 from the American National Standards Institute, 1430 Broadway, New York, NY 10018, at $6.25.

Handbook 73, Protection Against Radiations from Sealed Gamma Sources (Supersedes H54). Reprints of this Handbook can be purchased as NCRP Report 40 at $5.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 74, Building Code Requirements for Reinforced Masonry. The American National Standards Institute, 1430 Broadway, New York, NY 10018 has issued a publication on this subject. Available from them as A41.2–1960 (R1970), at $3.25.

Handbook 75, Measurement of Absorbed Dose of Neutrons and of Mixtures of Neutrons and Gamma Rays. Reprints of this Handbook can be purchased as NCRP Report 25 at $3.00 per copy from NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 76, Medical X-ray Protection Up to Three Million Volts. Now available as NCRP 33. Purchase from NCRP Publications, Post Office Box 30175, Washington, DC 20014 at $4.00.

Handbook 80, A Manual of Radioactivity Procedures. Reprints of this Handbook will be available as NCRP Report 58 (in press). For more information write to NCRP Publications, Post Office Box 30175, Washington, DC 20014.

Handbook 81 and Its Supplements, Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines (also H30 and H110–1). All NBS publications on this subject have been superseded by National Electrical Safety Code, 1977 Edition, issued by the American National Standards Institute, 1430 Broadway, New York, NY 10018. Available from them as ANSI C2, at $6.50.

Handbook 84, Radiation Quantities and Units. Reprints of this Handbook can be purchased as ICRU Report 19 at $5.00 per copy from ICRU Publications, Post Office Box 30165, Washington, DC 20014.

Handbook 89, Methods of Evaluating Radiological Equipment and Materials. Reprints of this Handbook can be purchased as ICRU Report 10F at $2.50 per copy from ICRU Publications, Post Office Box 30165, Washington, DC 20014.

Handbook 96, Inspection of Processed Photographic Record Films for Aging Blemishes. Reprints of this Handbook can be purchased as PH 1.28–1973 at $4.00 per copy from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

Handbook 97, Shielding for High-Energy Electron Accelerator Installations. July 1, 1964 has been combined with NBS Handbook 55. Available as NCRP Report 51, Radiation Protection Design Guidelines for 0.1–100 MeV Particle Accelerator Facilities from NCRP Publications, Post Office Box 30175, Washington, DC 20014 at $6.00.

Handbook 102, ASTM Metric Practice Guide. Available as Z 210.1–1976 from the American National Standards Institute, 1430 Broadway, New York, NY 10018 at $4.00.

Handbook 110–1, National Electrical Safety Code. Part 1. Rules for Installation and Maintenance of Electric Supply and Communication Lines (also H30 and H81 and its Supplements). All NBS publications on this subject have been

superseded by National Electrical Safety Code, 1977 Edition, issued by the American National Standards Institute, 1430 Broadway, New York, NY 10018. Available from them as ANSI C2, at $6.50.

Technical Note 938, Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction, has been superseded by ASTM E 621–78, Standard Practice of the Use of Metric (SI) Units in Building Design and Construction. It is available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. Price $5.00.

C. STATUS OF PUBLICATIONS CITED IN THIS DOCUMENT

The following list provides the current status of NBS-issued publications cited in this 11-year compilation, including those that have been superseded and those that are still in print at the Government Printing Office (GPO) or the National Technical Information Service (NTIS). NBS publications still available from the Superintendent of Documents, GPO, carry prices effective as of the date of this publication; but these prices are subject to change without notice. Publications shown as available from NTIS are represented by the NTIS price schedule in effect at the time of purchase. NTIS prices as of this date are given below. Again, prices are subject to change.

Publications not listed are out of print; the abstracts have been included in this catalog for information purposes. Your nearest regional depository library may still have copies of these items. (See Section 2.4.)

NTIS PRICE SCHEDULE

Customers in Canada, U.S., and Mexico please use this price schedule; other addressees write for Folder PR-360-4.

A01	$3.00	E01	$3.25	T01	$110.00
A02	4.00	E02	4.75	T02	125.00
A03	4.50	E03	6.25	T03	175.00
A04	5.25	E04	7.50	T04	250.00
A05	6.00	E05	9.00	T05	300.00
A06	6.50	E06	10.50	T06	350.00
A07	7.25	E07	12.50	T07	400.00
A08	8.00	E08	15.00	T08	450.00
A09	9.00	E09	17.50	T09	500.00
A10	9.25	E10	20.00	T10	550.00
A11	9.50	E11	22.50	T11	600.00
A12	10.75	E12	25.00	T12	650.00
A13	11.00	E13	28.00	T13	675.00
A14	11.75	E14	31.00	T14	750.00
A15	12.00	E15	34.00	T15	800.00
A16	12.50	E16	37.00	T16	850.00
A17	13.00	E17	40.00	T17	900.00
A18	13.25	E18	45.00	T18	950.00
A19	14.00	E19	50.00	T19	1,000.00
A20	14.50	E20	60.00	T99	*
A21	15.00	E99	*		
A22	15.25				
A23	15.50	N01	28.00		
A24	16.25	N02	50.00		
A25	16.50				
A99	*				

*Contact NTIS for price quote

No.	Price
2 (PB187-752)	*
3 Vol. 1 (COM71-01000-1)	*
3 Vol. 2 (COM71-01000-2)	*
4 (PB-174-987)	*
7 (COM73-10503)	*
8 (PB186-237)	*
10 (COM75-10235)	*
13 (PB172-156)	*
15 (PB192-874)	*
20 (PB195-221)	*
23 (PB183-992)	*
25 Sec. 1 (PB178-429)	*
25 Sec. 2 (PB178-430)	*
25 Sec. 3 (PB178-431)	*
25 Sec. 4	*
25 Sec. 5	*
25 Sec. 6	*
25 Sec. 7	*
25 Sec. 8 (PB194-872)	*
25 Sec. 9 (COM72-50002)	*
25 Sec. 10 (COM72-51079	*
25 Sec. 11 (COM74-50183)	*
25 Sec. 12 (SN003-003-01376-5)	1.50
25 Sec. 13 (SN003-003-01629-2)	**1.80**
27 & Suppls. See SP373 (COM72-51036)	*
30 (PB193-908)	*
31 (COM75-10045)	*
34 Vol. 1 (COM71-00631)	*
34 Vol. 2	*
36 (COM75-10175)	*
39 (COM74-10933)	*
40 (COM71-00693)	*
41 (PB191-728)	*
42 (COM72-10377)	*
43 Vol. 1 (COM73-10636	*
43 Vol. 2 (COM73-10637)	*
45 (PB186-433)	*
46 (PB176-590)	*
47 (COM71-00691)	*
48 (PB246-865)	*
49 (COM72-10380)	*
52 (COM73-10500)	*
54 (PB265-333)	*
56 (COM75-10244)	*
58 (PB193-909)	*
60 (COM75-10053)	*
63 (COM74-10737)	*
66 (COM75-10245)	*
67 (PB186-426)	*
68 (COM71-00692)	*
70 Vol. 1 (PB168-072)	*
70 Vol. 2 (PB189-714)	*
70 Vol. 3 (COM74-10794)	*
70 Vol 4 (COM74-10795)	*
70 Vol. 5 (COM74-10796)	*
72 (PB186-427)	*
73 (PB186-432)	*
74 (PB195-213)	*
75	*
76 (COM73-10502)	*
77 (PB180-646)	*
80 (PB257-342)	*
82 (PB189-659)	*
83 (COM75-10246)	*
84 (COM72-10513)	*
85 (COM72-10379)	*
86 (COM75-10046)	*
88 (SN003-003-00354-9)	1.05
89 (AD700-466)	*
91 (PB266-262)	*
92	*
93 (COM73-10008)	*
94 (N65-32001)	*
96	*
98	*
99	*
100	*
101	*
102	*
103	*
104	*
105	*
106	*
107	*
109 (AD681-912)	*
111	*
112	*
113 Vol. 1 (PB191-276)	*
113 Vol. 2 (SN003-003-00304-2)	1.65
113 Vol. 3 (PB192-746)	*
116	*
117 (SN003-003-00751-0)	.5
118 (PB194-751)	*
119 (COM71-50201)	*
120 (SN003-003-00749-8)	.8
121 (COM75-10169)	*
124 (COM74-11728	*
125 (SN003-003-01177-1)	4.5
125 Sup. 1 (SN003-003-01391-9)	1.0
126 (SN003-003-01052-9)	2.1
127 (COM72-50359)	*
128 (COM72-50903)	*
129 (COM73-50098)	*
130 (SN003-003-01120-7)	1.1
131 (SN003-003-01076-6)	10.7
132 (SN003-003-01082-1)	15.8
133 (COM74-50309)	*
134 (COM73-50582)	*
135 (SN003-003-01157-6)	.8
136 (SN003-003-01160-6)	.5
137 (COM73-50960)	*
138 (COM74-50459)	*
139 (SN003-003-01317-0)	1.3
140 (SN003-003-01202-5)	9.2
141 (SN003-003-01289-1)	5.5
142 (SN003-003-01290-4)	5.4
143 (SN003-003-01373-1)	1.1
144 (SN003-003-01416-8)	5.0
145 Pt. 1 (SN003-003-01337-4)	8.5
145 Pt. 2 (SN003-003-01338-2)	6.8
146 (COM75-50997)	*
147 (SN003-003-01412-5)	2.1
147 Sup. 1 (SN003-003-01754-0)	**1.1**

MONOGRAPHS (Continued)

No.	Price	No.	Price	No.	Price
48 (SN003-003-01370-6)	1.15	153 (SN003-003-01651-9)	1.35		
49 (SN003-003-01390-1)	1.35	154 (SN003-003-01612-8	1.70		
50 (SN003-003-02187-3)	1.40	157 (SN003-003-01681-1)	4.55		
51 (SN003-003-01621-7)	4.50				
52 (SN003-003-01552-1)	.85				

*Available from The National Technical Information Service; use "PB", "AD", "COM", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

MISCELLANEOUS PUBLICATIONS

No.	Price	No.	Price	No.	Price
179	*	260-11	**	286	***
187	*	260-12	**	287	**
211 (COM73-10871)	**	260-13	**	291	**
240	**	260-14	**	292	**
240 Suppl	**	262-1 (PB261-051)	**	294	**
256 (PB285-882)	**				
260-1 (COM74-11061)	**	262-2 (AD647-371)	**	This series name was changed to Special Publications beginning with SP295	
260-2 (COM74-11063)	**	265 (COM74-10927)	**		
260-3 (COM74-11060)	**	266 (PB168-063)	**		
260-4 (COM74-11059)	**	269 (PB258-618)	**		
260-5 (PB168-068)	**	273 (COM75-11102)	**		
260-6 (COM74-11068)	**	274	**		
260-7 (COM74-11067)	**	275 (SN003-003-01266-1)	8.50		
260-8 (COM74-11066)	**	281	**		
260-9 (COM74-11065)	**	284	**		
260-10 (COM74-11064)	**				

*See page XVIII for additional information.
**Available from The National Technical Information Service; use "AD", "PB", "COM", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.
***Superseded by NBS LC1071, free upon request from the Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234.

No.	Price
250, 1978 Ed. (SN003-003-01916-0)	3.00
260 (SN003-003-01445-1)	1.50
260-16 (COM74-11062)	*
260-18	*
260-19 (PB190-071)	*
260-21 (COM74-11359)	*
260-22 (COM74-11357)	*
260-23 (COM71-00157)	*
260-24 (COM72-50058)	*
260-25 (COM74-11356)	*
260-26 (SN003-003-00786-2)	.85
260-27 (COM74-11358)	*
260-28 (COM71-50365)	*
260-29 (COM71-50282)	*
260-30 (COM71-50283)	*
260-30 (COM71-50563)	*
260-32 (SN003-003-01213-1	.55
260-33 (COM72-50526)	*
260-34 (COM72-50371)	*
260-35 (COM72-50368)	*
260-36 (COM72-50527)	*
260-37 (COM72-50092)	*
260-38 (COM72-50528)	*
260-39 (COM72-50529)	*
260-40 (COM72-50776)	*
260-41 (COM72-50775)	*
260-42 (COM72-50944)	*
260-43 (COM73-50760)	*
260-44 (COM73-50037)	*
260-45 (COM73-50226)	*
260-46 (SN003-003-01385-4)	1.00
260-47 (COM74-50176)	*
260-48 (SN003-003-01278-5)	.60
260-49 (SN003-003-01344-7)	.75
260-50 (SN003-003-01425-7)	1.00
260-51 (SN003-003-01481-8)	1.90
260-52 (SN003-003-01464-8)	1.05
260-53 (SN003-003-01551-2)	1.05
295	*
296	*
299	*
300 Vol. 1 (SN003-003-00072-8)	9.00
300 Vol. 2	*
300 Vol. 3 (SN003-003-00074-4)	8.05
300 Vol. 4 (SN003-003-00778-1)	7.65
300 Vol. 5 (SN003-003-00916-4)	8.65
300 Vol. 6 (SN003-003-00696-3)	7.10
300 Vol. 7 (SN003-003-00887-7)	9.65
300 Vol. 8 (SN003-003-00923-7)	8.75
300 Vol. 9 (SN003-003-00917-2)	7.65
300 Vol. 10 (SN003-003-01179-7)	11.80
301	*
302	*
303	*
304 (SN003-003-01072-3)	.65
304A (SN003-003-01713-2)	.50
305	*
305 Sup. 1 (PB259-274)	*
305 Sup. 2 (COM71-50354)	*
305 Sup. 3 (COM72-50690)	*
305 Sup. 4 (SN003-003-01081-2)	4.20
305 Sup. 5 (SN003-003-01240-8)	4.15
305 Sup. 6 (SN003-003-01361-7)	6.80
305 Sup. 7 (SN003-003-01647-1)	7.55
306	*
306-2	*
306-3 (PB264-245)	*
306-4 (COM73-10870)	*
307	*
309 Vol. 2	*
310	*
312 (Vol. 1&2 (COM73-11439)	*
313	*
314 (SN003-003-00091-4)	6.45
317 Vol. 1 (COM71-50268-01)	*
317 Vol. 2 (COM71-50268-02)	*
319 (COM71-00066)	*
320 (AD701-614)	*
320 Sup. 1 (AD730-356)	*
320 Sup. 2 (COM74-50034)	*
321 (PB194-963)	*
323 (COM72-50351)	*
324 (COM71-50070)	*
326 (COM71-50189)	*
327 (PB193-564)	*
329 (COM71-50172)	*
329 Sup. 1 (COM73-50679)	*
329 Sup. 2 (SN003-003-01362-5)	9.35
330 1977 Ed. (SN003-003-01784-1)	1.70
331	*
332 (PB194-959)	*
333 (PB194-585)	*
334 (COM74-11482)	*
335 (COM75-10051)	*
336 (SN003-003-00688-2)	9.70
337 (COM71-00182)	*
338 (COM74-10736)	*
339 (COM71-50080)	*
343 (COM71-50398)	*
344 See SP398	.25
345 (SN003-003-00884-2)	2.70
345-1 (SN003-003-00731-5)	1.70
345-2 (SN003-003-00824-9)	3.20
345-3 (SN003-003-00859-1)	1.75

*Available from The National Technical Information Service, use "AD", "PB", "COM", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

No.	Price
45-4 (SN003-003-00825-7)	3.20
45-5 (SN003-003-00898-2)	2.15
45-6 (SN003-003-00858-3)	2.30
45-7 (SN003-003-00864-8)	1.75
45-8 (SN003-003-00895-8)	2.10
45-9 (COM71-50305)	*
45-10 (SN003-003-00879-6)	3.05
45-11 (SN003-003-00835-4)	2.70
45-12 (SN003-003-00865-6)	2.00
46 (COM71-50147)	*
47 (COM71-50202)	*
48 (SN003-003-00893-1)	7.45
49 (COM72-50807)	*
50 (COM71-50276)	*
51 (SN003-003-01027-8)	6.45
52 (COM75-10291)	*
53 (COM71-50364)	*
54 (COM72-50808)	*
55 (COM71-50385)	*
56 (SN003-003-00934-2)	2.05
57 (SN003-003-00928-8)	5.40
59 (COM72-50057)	*
61 Vol. 1 (COM72-10309)	*
61 Vol. 2 (COM72-50850)	*
62 (SN003-003-01000-6)	1.15
63 (SN003-003-00962-8)	1.45
64 (COM72-50746)	*
65 (SN003-003-01068-5)	.50
66 (SN003-003-01044-8)	2.80
366-1 (COM74-50063)	*
366-2 (SN003-003-01544-0)	1.35
368 Rev. 1976 (SN003-003-01665-9)	.35 ea 4.65 (per 100 cps.)
369 (SN003-003-01124-8)	1.85
370 (SN003-003-01057-0)	.55
371 (COM73-50245)	*
371-1 (SN003-003-01422-2)	1.45
372 (SN003-003-01059-6)	2.35
373 (COM72-51036)	*
374 (SN003-003-01061-8)	5.20
375 (COM73-50839)	*
376 (SN003-003-01080-4)	.60
377 (SN003-003-01107-0)	.85
378 (COM73-50585)	*
380 (SN003-003-01109-6)	2.10
381 (COM73-50932)	*
382 (SN003-003-01176-2)	3.30
383 (SN003-003-01171-1)	2.10
384 Rev. 1976 (SN003-003-01670-5)	2.45
385 (COM74-50307)	*
386 (SN003-003-01593-8)	1.90
387	*
388 (COM74-50543)	*
389 Superseded by LC1070	**
390 (COM74-50352)	*
391 (SN003-003-01260-2)	2.50
392 (SN003-003-01272-6)	1.30
393 (COM74-50350)	*
394 (COM74-50523)	*
395 (SN003-003-01300-5)	4.25
396-1 (SN003-003-01274-2)	1.25
396-2 (SN003-003-01457-5)	1.10
396-3 (PB250-844)	*
396-4 (SN003-003-01572-5)	1.55
398 (SN003-003-01331-5)	.35
399-1 (SN003-003-01339-1)	2.35
399-2 (SN003-003-01333-1)	2.85
399-3 (SN003-003-01334-0)	2.90
400-1 (COM74-50305)	*
400-2 (SN003-003-01226-2)	1.50
400-3 (SN003-003-01236-0)	.60
400-4 (SN003-003-01354-4	1.70
400-5 (SN003-003-01372-2)	1.10
400-6 (SN003-003-01313-7)	.60
400-7 (SN003-003-01635-7)	.75
400-8 (SN003-003-01374-9)	1.30
400-9 (SN003-003-01357-9)	1.00
400-10 (SN003-003-01358-7)	3.55
400-11 (SN003-003-01428-1)	1.00
400-12 (AD-A011121)	*
400-13 SN003-003-01382-0)	.75
400-15 (SN003-003-01566-1)	1.25
400-17 (SN003-003-01480-0)	1.40
400-18 (SN003-003-01577-6)	1.25
400-19 (SN003-003-01606-3)	2.10
400-20 (SN003-003-01473-7)	1.00
400-21 (SN003-003-01565-2)	1.30

*Available from The National Technical Information Service, use "AD", "PB", "COM", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

**Superseded by NBS LC1071, free upon request from the Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234.

No	Price
400-22 (SN003-003-01623-3)	1.45
400-23 (SN003-003-01604-7)	3.70
400-25 (SN003-003-01678-1)	1.45
400-26 (SN003-003-01600-4)	.55
400-27 (SN003-003-01569-5)	1.20
400-28 (SN003-003-01628-4)	1.25
400-34 (SN003-003-01707-8)	1.45
401 (COM74-50931)	*
403 (SN003-003-01638-1)	3.30
404 (SN003-003-01319-6)	1.45
405 (SN003-003-01346-3)	1.05
406 (SN003-003-01393-5)	2.45
407 (SN003-003-01379-0)	3.75
408 (SN003-003-01389-7)	12.60
409 (SN003-003-01359-5)	3.90
410 1977 Ed. (SN003-003-01736-1)	2.00
411 (SN003-003-01356-1)	3.10
412 (SN003-003-01341-2)	2.65
413 1976 Ed. (SN003-003-01601-2)	1.35
414 (ADA012377)	*
415 (SN003-003-01363-3)	1.75
417 (SN003-003-01395-1)	6.75
418 (SN003-003-01398-6)	1.00
419 (SN003-003-01410-9)	2.80
420 (SN003-003-01408-7)	3.00
421 (SN003-003-01418-4)	1.65
422 1 & 2 (SN003-003-01458-3) set	20.00
423 (SN003-003-01451-6)	6.10
424 (SN003-003-01599-7)	2.90
425 (SN003-003-01461-3)	19.45
426 (SN003-003-01465-6)	3.30
427 (SN003-003-01472-9	3.00
428 (SN003-003-01541-5)	28.50
429 (SN003-003-01463-0)	1.95
430 (SN003-003-01542-3)	.35
431 (SN003-003-01608-0)	11.00
432 (SN003-003-01587-3)	.60
433 (SN003-003-01639-0)	3.50
434 (SN003-003-01624-1)	.55
435 (SN003-003-01603-9)	5.60
436 (SN003-003-01556-3)	4.25
437 (SN003-003-01557-1)	1.05
438 (SN003-003-01581-4)	2.40
439 (SN003-003-01575-0)	.95
441 (SN003-003-01568-7)	2.30
442 (SN003-003-01614-4)	3.30
443 (SN003-003-01633-1)	4.15
444 (SN003-003-01588-1)	5.80
445-1 (SN003-003-01632-2)	1.20
446 (SN003-003-01641-1)	2.05
447 (SN003-003-01654-3)	1.00
448 (SN003-003-01663-2)	1.90
449 (SN003-003-01677-2)	2.00
451 (SN003-003-01662-4)	3.00
452 (SN003-003-01664-1)	2.65
453 (SN003-003-01700-1)	3.55
454 (SN003-003-01666-7)	1.65
455 (SN003-003-01699-3)	4.45
456 (PB262-111)	*
457 (SN003-003-01685-3)	1.80
459 (SN003-003-01686-1)	3.40
460 (SN003-003-01737-0)	2.35
462 (SN003-003-01729-9)	4.60

*Available from The National Technical Information Service, use "AD", "PB", or "COM" number when ordering. Available in Microfiche for $3.00; consult NTIS for paper copy price.

HANDBOOKS

No.	Price
28 1969 (Pt.1)	*
28 1957 (Pt.2)	*
28 1957 (Pt.3)	*
44 4th Ed. (SN003-003-00894-0)	7.90
46	*
48	*
49	*
51 (SN003-003-00115-5)	.60
53	*
55	*
57 (PB248-218)	*
58	*
59	*
63	*
64 (COM73-10872)	**
65	*
69	*
71	*
72 (SN003-003-00123-6)	1.30
73	*
74	*
75	*
76	*
80	*
81 #	*
81 Suppl. 2	*
84	*
85 (SN003-003-00131-7)	2.20
86 (SN003-003-00132-5)	1.30
87 (SN003-003-00133-3)	2.10
88 (SN003-003-00134-1)	1.05
89	*
90 (PB188-654)	**
91 (SN003-003-00135-0)	11.00
92 (SN003-003-00136-8)	2.10
94 (COM73-10635)	**
96	*
97	*
98 (COM72-10619)	**
99	**
100	**
101	**
102	*
105-1 (COM72-50707)	*
105-2 (COM71-50065)	*
107 (PB191-898)	**
109 (COM72-50183)	**
110-1	*
111 (COM72-50698)	**
112 (COM73-50836)	**
113 (SN003-003-01274-6)	2.15
114 (SN003-003-01377-3)	.90
115 (SN003-003-01323-4)	2.90
115 Sup. 1 (SN003-003-01582-2)	2.25
116 (SN003-003-01456-7)	1.10
117 (SN003-003-01563-6)	.75
118 (SN003-003-01567-9)	2.70
119 (SN003-003-01646-2)	5.10
120 (SN003-003-01667-5)	.70

#81 amends in part: Part 2, Definitions and the Grounding Rules of these Handbooks.

*See page XVIII for additional information.

**Available from The National Technical Information Service, use "PB", "COM" or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

NATIONAL STANDARD REFERENCE DATA SERIES

No.	Price
1 (SN003-003-00627-1)	.55
2	*
3 Sec. 1	*
3 Sec. 2	*
3 Sec. 3 (COM72-50056)	*
3 Sec. 4 (COM71-50346)	*
3 Sec. 5 (SN003-003-01444-3)	1.80
3 Sec. 6 (SN003-003-00998-9)	1.15
3 Sec. 7 (SN003-003-01558-0)	.85
4 (SN003-003-00646-7)	6.45
5	*
8 (PB189-698)	*
9	*
10	*
12	*
13 (SN003-003-00622-0)	3.00
14	*
15	*
16	*
18 (SN003-003-00628-9)	1.15
19 (SN003-003-00629-7)	.65
20	*
21 (PB191-956)	*
22 (Vol. 2) (AD696-884)	*
23	*
24	*
25	*
26	**
27 (SN003-003-00637-8)	1.80
28	*
29	*
31 (PB189-028)	*
32 (SN003-003-00729-3)	1.15
33 (PB192-183)	*
34 (SN003-003-00770-6)	1.65
35 Vol. 1 (SN003-003-00949-1)	9.25
35 Vol. 2 (SN003-003-00935-1)	7.95
35 Vol. 3 (SN003-003-00950-4)	8.30
36 (COM71-50203)	*
37 (SN003-003-00872-9)	15.60
38 (COM71-50351)	*
39 (SN003-003-00845-1)	5.10
40 (COM72-50439)	*
41 (COM72-50849)	*
42 (COM72-50886)	*
43 (SN003-003-01083-9)	1.05
43 Suppl. (SN003-003-01429-0)	1.10
44 (COM74-50175)	*
45 (SN003-003-01165-7)	.75
46 (COM73-50623)	*
47 (SN003-003-01125-8)	2.25
48 (SN003-003-01166-5)	.80
49 (SN003-003-01190-8)	1.70
50 (AD771-200)	*
51 (SN003-003-01414-1)	1.2(
52 (SN003-003-01262-9)	1.15
53 (SN003-003-01426-5)	1.15
54 (SN003-003-01406-1)	.85
55 (SN003-003-01431-1)	.85
56 (SN003-003-01396—0)	.85
57 (SN003-003-01609-8)	.55
58 (SN003-003-01627-6)	.70

*Available from The National Technical Information Service, use "AD", "PB", "COM", or NBS publication identification if no specific NTIS number is assigned Available in Microfiche for $3.00; consult NTIS for paper copy price.
**Superseded by the Journal of Physical and Chemical Reference Data, Vol. 6, Supp. 1; available from the American Chemical Society, 1155 16th St., N. W., Washington, DC 20036.

BUILDING SCIENCE SERIES

No.	Price
0 (COM71-00046)	*
1 (PB189-713)	*
2 Pt. 1 (COM72-10542)	*
3	*
4	*
5 Pt. 2	*
6	*
7	*
8 (COM73-10487)	*
9 (PB193-907)	*
10	*
11	*
12	*
13	*
14	*
15	*
16	*
17	*
18 (PB193-736)	*
19	*
20 (PB189-639)	*
21 (PB189-459)	*
22 (PB189-456)	*
23	*
24	*
25 (PB188-789)	*
26	*
27 (PB191-304)	*
28 (PB193-924)	*
29 (PB190-603)	*
30 (COM71-00141)	*
31 (PB193-601)	*
32 (COM71-50078	*
33 (COM71-00159)	*
34 (COM75-10286)	*
35 (COM71-50591)	*
36 (SN003-003-00850-8)	1.55
37 (SN003-003-00857-5)	1.25
38 (COM71-50345)	*
39 (COM72-50068)	*
40 (SN003-003-00940-7)	3.95
41 (COM72-50533)	*
42 (COM72-50675)	*
43 (COM75-10173)	*
44 (SN003-003-01071-5)	.65
45 (COM73-50725)	*
46 (COM73-50188)	*
47 (COM73-50975)	*
48 (SN003-003-01212-2)	4.85
49 (COM74-50353)	*
50 (SN003-003-01282-3)	.55
51 (SN003-003-01267-0)	.90
52 (COM74-50537)	*
53 (SN003-003-01284-0)	.85
54 (SN003-003-01307-2)	1.25
55 (COM74-51188	*
56 (SN003-003-01335-8)	2.35
57 (SN003-003-01364-1)	1.20
58 (SN003-003-01349-8)	2.00
59 (SN003-003-01392-7)	1.30
60 (SN003-003-01352-8)	1.05
61 (COM75-10473)	*
62 (SN003-003-01738-8)	1.90
63 (SN003-003-01407-9)	.70
64 (SN003-003-01360-9)	1.35
65 (SN003-003-01394-3)	1.00
66 (SN003-003-01417-6)	2.10
67 (SN003-003-01468-1)	1.20
68 (SN003-003-01419-2)	1.25
69 (SN003-003-01622-5)	4.60
70 (SN003-003-01437-1)	1.55
71 (SN003-003-01459-1)	2.25
72 (SN003-003-01474-5)	1.80
73 (SN003-003-01479-6)	1.25
74 (SN003-003-01477-0)	1.55
75	*
76 (SN003-003-01644-6)	1.45
77 (SN003-003-01539-3)	2.35
78 (SN003-003-01537-7)	1.25
79 (SN003-003-01546-6)	1.15
80 (SN003-003-02183-1)	1.15
81 (SN003-003-01591-1)	.45
82 (SN003-003-02185-7)	.50
83 (SN003-003-01592-0	.55
85 (SN003-003-01619-5)	2.25
86 (SN003-003-01637-3)	1.05
87 (SN003-003-01642-0)	4.40
88 (SN003-003-01693-4)	.65
89 (SN003-003-01706-0)	.75
90 (PB257-581)	*
91 (SN003-003-01690-0)	1.40
92 (SN003-003-01692-6)	.70

*Available from the National Technical Information Service; use "PB", "COM" or NBS Publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

VOLUNTARY PRODUCT STANDARDS

No.	Price	No.	Price	No.	Price
1-74 (SN003-003-01387-1)	.85	48-71 (SN003-003-00925-3)	.35	60-73 (SN003-003-01248-3)	.40
15-69 (SN003-003-00188-1)	.40	50-71 (SN003-003-00877-0)	.35	61-74 (SN003-003-01421-4)	.45
20-70 (SN003-003-00192-9)	.40	51-71 (SN003-003-00963-6)	.35	62-74 (SN003-003-01375-7)	.55
38-70 (SN003-003-00842-7)	.45	52-71 (SN003-003-00990-3)	.35	63-75 (SN003-003-01415-0)	.50
39-70 (SN003-003-00840-1)	.65	57-73 (SN003-003-01182-7)	.40	64-75 (SN003-003-01583-1)	.35
42-70 (SN003-003-00901-6)	.65	58-73 (SN003-003-01295-5)	.40	65-75 (SN003-003-01585-7)	.35
46-71 (SN003-003-00936-9)	.35	59-73 (SN003-003-01255-6)	.45		

FEDERAL INFORMATION PROCESSING STANDARDS SERIES

No.	Price	No.	Price	No.	Price
0	3.50	17-1	4.00	34	3.50
1	3.50	18-1	4.00	35	4.00
2	3.50	19	3.50	36	3.50
3-1	3.50	20	3.50	37	3.50
4	3.50	21-1	13.50	38	4.50
5-1	3.50	22-1	4.00	39	3.50
6-2	4.00	23	3.50	40	4.50
7	3.50	24	4.00	41	3.50
8-4	3.50	25	3.50	42-1	3.50
9	3.50	26	3.50	43	4.50
10-2	4.00	27	3.50	44	3.50
11-1	4.00	28	3.50	45	4.00
12-2	7.50	29	3.50		
13	3.50	30	3.50		
14	3.50	31	5.00		
15	3.50	32	5.00		
16-1	4.00	33	4.00		

Available only from the National Teachnical Information Service.

APPLIED MATHEMATICS SERIES

No.	Price
1 See AMS25	*
2 (PB194-385)	*
3 (PB251-959)	*
4 (PB251-962)	*
5 (COM73-10501)	*
6 (PB251-862)	*
7 (PB251-863)	*
8 (PB251-864)	*
9 (COM73-10498)	*
10 (PB251-960)	*
11 (AD702-411)	*
12 (PB184-887)	*
13 (PB251-865)	*
14 (SN003-003-00270-4)	11.70
15 (PB251-866)	*
16 (PB251-867)	*
17 (PB251-868)	*
18 (PB175-819)	*
19 (PB175-815)	*
20 (PB251-870)	*
21 (PB178-392)	*
22 (PB192-337)	*
23 (PB175-967)	*
24 (PB175-816)	*
25	*
26 (PB178-415)	*
27 (AD694-116)	*
28 (AD695-952)	*
29 (AD695-953)	*
30 (PB175-817)	*
31 (COM74-11112)	*
32 (COM73-10499)	*
33 (PB175-818)	*
34 (SN003-003-00272-1)	4.70
35 (PB251-103)	*
36 (PB251-871)	*
37 (PB251-872)	*
38 (PB251-900)	*
39 (PB251-901)	*
40 (PB186-428)	*
41 (PB176-521)	*
42 (PB175-819)	*
43 (PB176-127)	*
44 (AD698-954)	*
45 (COM74-10639)	*
46 (PB186-429)	*
47 (PB251-902)	*
48 (PB176-119)	*
49 (PB251-903)	*
50 (PB176-520)	*
51 (PB248-467)	*
52 (PB251-904)	*
53 (PB186-430)	*
54 (COM73-11111)	*
55 (SN003-003-00279-8	12.65
56 (PB190-608)	*
57 (PB266-263)	*
58 (AD700-470)	*
59 (SN003-003-00282-8)	6.80
60 (SN003-003-00283-6)	1.45
61 (PB188-790)	*
62 (SN003-003-00993-8)	1.20
63 (SN003-003-00988-1)	3.45

*Available from The National Technical Information Service; use "PB", "AD", "COM", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

CONSUMER INFORMATION SERIES

No.	Price
1 (SN003-003-00680-7)	.90
3 (SN003-003-00682-3)	.60
4 (SN003-003-00920-2)	1.10
5 (SN003-003-00941-5)	.70
6 (SN003-003-01536-9)	1.70
7 (SN003-003-01688-8)	.35
8 (SN003-003-01446-0)	.70

No.	Price	No.	Price	No.	Price
1 (PB151-360)	*	18-19 (PB195-218)	*	40-9 (PB189-933)	*
2 (PB151-361)	*	18-20 (PB168-044)	*	40-10 (PB189-934)	*
2-2 (PB151-361-2)	*	18-21 (PB195-219)	*	40-11 (PB189-935)	*
3 (PB151-362)	*	18-22 (N661-3994)	*	40-12 (PB189-936)	*
4 (PB151-363)	*	18-23 (COM74-10437)	*	40-13 (PB151-399-13)	*
5 (PB151-364)	*	18-24 (COM74-10438)	*	41 (PB151-400)	*
6 (PB151-365)	*	18-25 (COM74-10473)	*	42 (PB151-401)	*
7 (PB151-366)	*	18-26 (COM74-10439)	*	43 (PB151-402)	*
8 (PB151-367)	*	19 (PB151-378)	*	44 (PB151-403)	*
9 (PB151-368)	*	20 (PB151-379)	*	45 (PB151-404)	*
10 (PB151-369)	*	21 (PB151-380)	*	46 (PB151-405)	*
11 (PB151-370)	*	22 (PB151-382)	*	47 (PB151-406)	*
12 (PB151-371)	*	23 (PB151-382)	*	48 (PB151-407)	*
13 (PB151-372)	*	24 (PB151-383)	*	49 (PB151-408)	*
14 (PB151-373)	*	25 (PB151-384)	*	50 (PB151-409)	*
15 (PB151-374)	*	26 (PB151-385)	*	51 (PB161-552)	*
16 (PB151-375)	*	27 (PB151-386)	*	52 (PB161-553)	*
18 (PB151-377)	*	28 (PB151-388)	*	53 (PB161-554)	*
18-2 (PB151-377-2)	*	29 (PB151-388)	*	54 (PB161-555)	*
18-3 (PB151-377-3)	*	30 (PB151-389)	*	55 (PB161-556)	*
18-4 (PB151-377-4)	*	31 (PB151-390)	*	56 (PB161-557)	*
18-5 (PB151-377-5)	*	33 (PB151-392)	*	57 (PB161-558)	*
18-6 (PB151-377-6)	*	34 (PB151-393)	*	58 (PB161-559)	*
18-7 (PB151-377-7)	*	35 (PB151-394)	*	59 (PB161-560)	*
18-8 (PB151-377-8)	*	37 (PB151-396)	*	60 (PB161-561)	*
18-9 (PB151-377-9)	*	38 (PB151-397)	*	61 (PB161-562)	*
18-10 (PB151-377-10)	*	39 (PB151-398)	*	62 (PB161-563)	*
18-11 (PB151-377-11)	*	40-1 (PB151-399-1)	*	63 (PB161-564)	*
18-12 (PB151-377-12)	*	40-2 (PB151-399-2)	*	64 (PB161-565)	*
18-13 (PB151-377-13)	*	40-3 (PB151-399-3)	*	66 (PB161-567)	*
18-14 (PB195-273)	*	40-4 (PB151-399-4)	*	67 (PB161-568)	*
18-15 (PB195-215)	*	40-5 (PB151-399-5)	*	68 (PB161-569)	*
18-16 (PB195-216)	*	40-6 (PB151-399-6)	*	69 (PB161-570)	*
18-17 (PB195-217)	*	40-7 (PB151-399-7)	*	70 (PB161-571)	*
18-18 (PB168-058)	*	40-8 (PB189-932)	*	71 (PB161-572)	*

*Available from the National Technical Information Service; use "PB", "AD", "N", "COM", or NBS publication number when ordering. Available in Microfiche for $3.00; consult NTIS for paper copy price.

No.	Price
72 (PB161-573)	*
73 (PB161-574)	*
74 (PB161-575)	*
75 (PB161-576)	*
76 (PB161-577)	*
77 (PB161-578)	*
78 (PB161-579)	*
79 (PB161-580)	*
80 (PB161-581)	*
81 (PB161-582)	*
82 (PB161-583)	*
83 (PB161-584)	*
84 (PB161-585)	*
85 (PB161-586)	*
86 (PB161-587)	*
87 (PB161-588)	*
88 (PB161-589)	*
89 (PB161-590)	*
90 (PB161-591)	*
91 (PB161-592)	*
92 (PB161-593)	*
93 (PB161-594)	*
94 (PB161-595)	*
95 (PB151-596)	*
96 (PB161-597)	*
97 (PB161-598)	*
98 (PB186-280)	*
99 (PB186-431)	*
100 (COM74-10393)	*
100-A	*
101-1 (AD687-820)	*
101-2 (AD687-821)	*
102 (PB161-603)	*
106 (PB161-607)	*
107 (PB161-608)	*
108 (PB161-609)	*
109 (PB161-610)	*
110 (PB161-611)	*
111 (PB161-612)	*
112 (PB161-613)	*
113 (PB161-614)	*
114 (PB161-615)	*
115 (PB161-616)	*
116 (PB161-617)	*
117 (PB161-618)	*
118 (PB161-619)	*
119 (PB161-620)	*
120 (PB161-621)	*
120A (PB190-611)	*
121 (PB161-622)	*
122 (PB161-623)	*
123 (PB161-624)	*
124 (PB161-625)	*
125 (PB161-626)	*
128 (PB161-629)	*
129 (PB161-630)	*
129A	*
130 (PB161-631)	*
131 (PB161-632)	*
132 (PB161-633)	*
133 (PB161-634)	*
134 (PB161-635)	*
135 (PB161-636)	*
136 (PB161-637)	*
137 (PB161-638)	*
138 (PB161-639)	*
139 (PB161-640)	*
140 (PB161-641)	*
141 (PB161-729)	*
142 (PB161-643)	*
143 (PB161-644)	*
146 (PB161-647)	*
147 (PB161-648)	*
148 (PB161-649)	*
151 (PB191-730)	*
154 (PB172-217)	*
154A (PB182-435)	*
160	*
163 (COM71-01002)	*
164 (N-6314864)	*
165 (AD401-044)	*
166 (PB181-454)	*
171	*
172 (PB193-915)	*
173 (COM75-10523)	*
174 (COM72-10376)	*
177 (COM72-10514)	*
178 (PB190-917)	*
179 (PB190-610)	*
180 (COM75-10083)	*
182 (COM75-10283)	*
183 (COM75-10052)	*
187 (PB188-807)	*
191 (PB182-538)	*
194 See NSRDS1	.55
195 (COM73-10418)	*
196 (COM73-10483)	*
197 (AD419-866)	*
199 (AD683-408)	*
200 (N64-14272)	*
201 (PB182-539)	*
202	*
204 (PB184-118)	*
205 (COM73-10634)	*
206-1 (COM73-10684)	*
206-2 (COM73-10685)	*
206-3 (COM73-10686)	*
206-4 (COM73-10687)	*
206-5 (COM73-10688)	*
207 (COM73-10689)	*
209 (PB168-043)	*
210 (PB189-930)	*
211	*
214 (PB189-931)	*
215 (PB188-808)	*
217 (PB189-103)	*
218 (PB188-809)	*
219 (PB186-279)	*
220 (COM74-11077)	*
221 (COM71-00690)	*
223 (PB168-051)	*
224 (PB184-119)	*
225 (AD614-056)	*
226 (PB168-042)	*
227 (PB184-473)	*
228 (PB191-731)	*
229 (PB188-805)	*
231 (COM72-10587)	*
233 (COM75-10054)	*
234 (COM73-10485)	*
235 (COM73-10481)	*
236 (AD437-308)	*
237 (COM75-10166)	*
245 (PB184-177)	*
249 (PB168-046)	*
252 (AD612-812)	*
253 (PB184-176)	*
255 (AD614-257)	*
260 (PB168-041)	*
262-A (COM73-10486)	*
263 (COM75-10486)	*
266 (PB195-214)	*
267 (AD628-586)	*

*Available from the National Technical Information Service, use "PB", "AD", "COM", "N", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

No.	Price
268	*
270-1 See TN270-3	3.25
270-2 See TN270-3	3.25
270-3 (SN003-003-00406-5)	3.25
270-4 (SN003-003-00407-3)	2.10
270-5 (COM71-50171)	*
270-6 (SN003-003-00932-6)	1.90
270-7 (COM73-50435)	*
273 (PB248-534)	*
275 (COM73-10484)	*
277	*
278	*
279 (COM75-10375)	*
280 (COM72-10590)	*
285 (AD633-354)	*
287 (PB182-436)	*
288	*
291	*
292 (COM75-10335)	*
293 (AD642-236)	*
294 (PB176-289)	*
295	*
297 (PB188-657)	*
298 (PB186-238)	*
300 (PB168-048)	*
303 (AD611-400)	*
304 (AD615-936)	*
307 (PB168-040)	*
309 (N-65-24999)	*
310 (AD615-937)	*
318 (COM75-10374)	*
319	*
321 (COM75-10238)	*
322 (COM75-10236)	*
323 (COM75-10237)	*
324 (AD654-887)	*
331	*
332	*
334 (PB173-291)	*
341	*
343	*
345	*
346 (PB194-282)	*
347	*
349	*
355	*
360 (PB190-125)	*
361 (COM73-50052)	*
361 (SN003-003-01321-8) (Metric Version)	1.25
362 (COM74-10482)	*
363	*
364	*
365	*
365-1 (COM71-00048)	*
366	*
367	*
368	*
370 (AD688-697)	*
372	*
373	*
374	*
375	*
377	*
378	*
379 (SN003-003-00834-6)	.65
381	*
382	*
383	*
384 (COM75-10174)	*
385 (PB190-548)	*
386 (PB191-638)	*
387 (COM74-50059)	*
388 (COM71-50077)	*
389	*
390 (PB191-639)	*
391	*
392 (COM74-50057)	*
393 (COM75-10043)	*
397 (COM71-50060)	*
398 (SN003-003-00814-1)	.40
399 (COM71-50294)	*
400	*
403	*
406	*
409	*
410	*
411	*
412	*
414 (PB176-109)	*
416	*
417	*
419 (PB179-432)	*
420	*
421	*
423	*
425	*
426	*
428	*
431	*
432	*
434	*
435	*
436	*
437	*
438 (AD665-245)	*
439	*
440	*
444	*
445	*
461	*
464	*
465	*
467 (COM72-50871)	*
469	*
470	*
472 (AD681-330)	*
473	*
474 (AD681-351)	*
475 (AD683-808)	*
476	*
477	*
478 (PB190-609)	*
479	*
480	*
483	*
484 (AD692-231)	*
485	*
486	*
487	*
488 (AD692-232)	*
490	*
491	*
495 (AD695-820)	*
496 (PB284-674)	*

*Available from the National Technical Information Service, use "PB", "AD", "COM", "N", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

o.	Price
97 (AD695-821)	*
98 (SN003-003-00590-8)	.65
98-1 (SN003-003-00774-9)	.60
98-2 (SN003-003-00686-6)	.70
00 (PB191-352)	*
03	*
10	*
11	*
13 (AD702-871)	*
15 (SN003-003-00606-8)	.65
17	*
19 (PB190-760)	*
20 (AD702-833)	*
22 (PB191-024)	*
23 (PB191-057)	*
24 (PB191-277)	*
25	1.10
27 (AD710-906)	*
28 (PB191-305)	*
29 (PB192-153)	*
30 (COM71-00047)	*
32 (SN003-003-00776-5)	.75
33 (PB192-875)	*
34 (PB192-877)	*
35 (PB193-794)	*
36 (PB192-953)	*
43 (COM71-00081)	*
44 (PB194-960)	*
47 (COM71-00082)	*
50 (COM71-00068)	*
51 (COM71-50076)	*
52 (SN003-003-00918-1)	3.25
54 (PB194-750)	*
55 (AD718-534)	*
57 (COM74-10405)	*
58 (COM71-50072)	*
60 (AD719-976)	*
62 (COM71-00128)	*
63 (COM71-50341)	*
66 (COM71-50062)	*
68 (AD728-642)	*
569 (COM74-10436)	*
570 (COM71-50075)	*
572 (COM71-50150)	*
573 (COM71-50227)	*
575 (COM75-10280)	*
577 (COM71-50264)	*
578 (COM75-10185)	*
579 (COM75-10184)	*
584 (COM71-50635)	*
585 (COM72-50066)	*
589 (COM72-50061)	*
590 (COM71-50292)	*
591 (COM75-10168)	*
592 (SN003-003-00892-3)	1.15
593 (COM72-50031)	*
594-1 (COM72-50674)	*
594-2 (COM72-51003)	*
594-3 (COM75-10183)	*
594-4 (COM73-50224)	*
594-5 (SN003-003-00159-7)	.55
594-6 (SN003-003-01253-0)	.95
594-7 (SN003-003-01244-1)	.75
594-8 (COM74-50536)	*
594-9 (SN003-003-01342-1	1.10
594-10 (SN003-003-01453-2)	.85
594-11 (SN003-003-01675-6)	1.15
594-12 (SN003-003-01676-4)	.75
594-13 (SN003-003-01709-4)	**1.40**
595 (COM71-50362)	*
596 (SN003-003-00904-1)	1.05
597 (COM75-10176)	*
598 (AD732-553)	*
599 (COM71-50399)	*
600 (COM71-50297)	*
602 (SN003-003-00880-0)	.55
604 (SN003-003-00861-3)	.65
605 (COM71-50332)	*
606 (COM71-50325)	*
607 (AD734-035)	*
609 (AD730-357)	*
610 (COM72-50059)	*
612 (COM72-50205)	*
613 (COM72-50020)	*
614 (COM72-50523)	*
615 (COM72-50524)	*
616 2nd Rev. (SN003-003-01798-1)	1.30
618 (COM72-50695)	*
619 (COM72-50955)	*
620 (COM73-50584)	*
621 (SN003-003-01055-3)	1.10
622 (COM72-51039)	*
623 (COM72-51040)	*
624 (COM72-51041)	*
625 (COM72-51081)	*
626 (COM73-50038)	*
627 (SN003-003-01108-8)	1.00
628 (COM73-50263)	*
629 (COM73-50100)	*
631 (COM75-10334)	*
632 (COM73-50238)	*
633 (COM73-50239)	*
634 (COM73-50339)	*
635 (COM75-10177)	*
637 (COM75-10082)	*
638 (COM73-50727)	*
640 (COM73-50805)	*
641 (COM75-10281)	*
642 (COM73-50973)	*
643 (COM73-50885)	*
644 (COM73-50972)	*
645 (COM74-50133)	*
646 (COM74-50842)	*
648 (SN003-003-01246-7)	1.25
649 (COM74-50308)	*

*Available from the National Technical Information Service, use "PB", "AD", "COM", "N", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

No.	Price
650 (COM74-50430)	*
651 (SN003-003-01280-7)	.50
652 (SN003-003-01299-8)	.50
653 (COM74-50637)	*
654 (COM74-50698)	*
655 (COM74-51542)	*
657 (COM75-50069)	*
658 (COM75-50161)	*
659 (SN003-003-01442-7)	.85
660 (SN003-003-01383-8)	1.00
661 (SN003-003-01350-1)	.80
662 (SN003-003-01413-3)	.70
663 (SN003-003-01405-2)	1.10
664 (COM75-10289)	*
665 (SN003-003-01403-6)	1.00
666 (COM75-10288)	*
667 (SN003-003-01560-1)	1.85
668 (SN003-003-01449-4)	1.05
669 (COM75-10918)	*
670 (SN003-003-01586-2)	1.60
672 (SN003-003-01550-4)	2.40
673 (PB246-934)	*
674 (SN003-003-01559-8)	1.50
675 (SN003-003-01596-2)	1.30
677 (SN003-003-01597-1)	1.20
680 (SN003-003-01616-1)	.50
681 (SN003-003-01652-7)	1.05
682 (SN003-003-01653-5)	.80
683 (SN003-003-01657-8)	1.00
684 (SN003-003-01732-9)	3.85
685 (SN003-003-01789-2)	**.65**
686 (PB260-666)	*
687 (SN003-003-01714-1)	.75
688 (SN003-003-01715-9)	.65
689 (PB263-104)	*
690 (PB262-551)	*
691 (PB263-103)	*
692 (SN003-003-01734-5)	**.55**
693 (SN003-003-01710-8)	**1.20**
695 (SN003-003-01781-7)	**2.80**
696 Rev. 1977 (SN003-003-01850-3)	**1.50**
697 (SN003-003-01862-7)	**2.20**
698 (SN003-003-01864-3)	**1.30**
699 (SN003-003-01865-1)	**2.75**
700 (COM73-50015)	*
702 (AD734-427)	*
703 (COM71-50607)	*
706 (COM72-50892)	*
707 (COM72-50054)	*
708 (COM72-50062)	*
710-1 (COM72-50276)	*
710-2 (COM72-50346)	*
710-3 (COM72-50520)	*
710-4 (COM72-50521)	*
710-5 (COM72-50694)	*
710-6 (SN003-003-01087-1)	1.00
710-7 (COM73-50483)	*
711 (COM72-50064)	*
713 (COM72-50204)	*
714 (SN003-003-00974-1)	1.50
716 (COM72-50361)	*
717 (AD740-674)	*
718 (COM73-50206)	*
720 (SN003-003-00989-0)	.6
721 (COM72-50467)	*
723 (COM72-50535)	*
724 See TN983	
725 (SN003-003-01003-1	.
726 (AD748-788)	*
727 (COM72-50538)	*
728 (COM72-50666)	*
729 (COM72-50667)	*
731 (SN003-003-01023-5)	.9
732 (SN003-003-01029-4)	.7
733 (COM72-50812)	*
734 (COM72-50732)	*
735 (COM72-50873)	*
736 (COM72-50924)	*
737 (COM75-10170)	*
738 (COM72-50810)	*
747 (SN003-003-01065-1)	1.2
748 (COM73-50209)	*
749 (COM73-50103)	*
750 (COM72-51080)	*
751 (SN003-003-01093-6)	.8
752 (COM73-50624)	*
753 (SN003-003-01097-9)	1.1
754 (COM73-50225)	*
755 (SN003-003-01094-4)	.7
756 (COM73-50257)	*
757 (SN003-003-01092-8)	.4
758 (SN003-003-01115-1)	2.1
759 (SN003-003-01102-9)	.6
760 (SN003-003-01112-6)	.9
761 (SN003-003-01132-1)	1.1

*Available from the National Technical Information Service, use "PB", "AD", "COM", "N", or NI publication identification if no specific NTIS number is assigned. Available in Microfiche for $3.00; consult NTIS for paper copy price.

No.	Price
53 (SN003-003-01114-2)	.65
54 (SN003-003-01131-2)	.65
55 (SN003-003-01135-5)	.60
56 (COM73-50374)	*
57 (AD758-981)	*
58 (COM73-50379)	*
59 (COM73-50677)	*
70 (SN003-003-01136-3)	1.40
71 (SN003-003-01137-1)	.95
72 (SN003-003-01140-1)	1.25
73 (COM73-50534)	*
74 (COM73-50535)	*
75 (SN003-003-01141-0)	.50
76 (AD760-676)	*
77 (COM73-50792)	*
78 (COM73-50523)	*
79 (COM73-50571)	*
80 (SN003-003-01158-4)	.55
81 (COM73-50536)	*
82 (SN003-003-01286-6)	.90
85 (COM73-50682)	*
86 (SN003-003-01194-1)	.50
87 (SN003-003-01161-4)	.90
88 (COM73-50683)	*
89 (SN003-003-01163-1)	2.35
89-1 (SN003-003-01439-7)	.80
90 (COM73-50678)	*
91 (COM73-50665)	*
92 (SN003-003-01183-5)	.80
93 (COM73-50831)	*
94 (COM73-50927)	*
96 (COM73-50876)	*
797 (SN003-003-01192-4)	.50
798 (COM73-50930)	*
799 (COM74-50135)	*
800 (COM74-50141)	*
801 (SN003-003-01292-1)	.60
802 (SN003-003-01217-3)	.60
803 (COM75-10279)	*
804 (SN003-003-01229-7)	2.00
805 (SN003-003-01231-9)	1.20
806 (COM73-50928)	*
807 (COM73-50971)	*
808 (COM74-50085)	*
809 (COM74-50174)	*
810 (SN003-003-01211-4)	.50
811 (SN003-003-01245-9)	1.00
812 (SN003-003-01247-5)	.65
814 (SN003-003-01235-1)	1.10
815 (SN003-003-01232-7)	.60
816 (COM74-50181)	*
817 (SN003-003-01265-3)	.60
818 (SN003-003-01238-6)	.80
819 (COM74-50279)	*
820 (COM74-50140)	*
821 (SN003-003-01257-2)	.60
822 (COM74-50340)	*
823 (SN003-003-01264-5)	.60
824 (SN003-003-01258-1)	.65
825 See TN983	
826 (COM74-50346)	*
827 (COM74-50457)	*
828 (SN003-003-01287-4)	2.05
829 (SN003-003-01301-3)	1.10
830 (COM74-50532)	*
831 (SN003-003-01291-2)	.95
832 (SN003-003-01327-7)	.70
833 (SN003-003-01302-1)	1.20
834 (SN003-003-01294-7)	.55
835 (SN003-003-01353-6)	1.95
836 (COM74-50567)	*
837 (COM74-50636)	*
838 (COM74-50841)	*
839 (SN003-003-01303-0)	1.85
840 (SN003-003-01315-3)	.55
841 (SN003-003-01312-9)	.60
842 (SN003-003-01310-2)	1.25
843 (COM74-50839)	*
844 (SN003-003-01316-1)	.70
845 (COM74-50926)	*
847 (SN003-003-01340-4)	.80
848 (COM74-50943)	*
849 (COM74-50998)	*
850 (SN003-003-01366-8)	.85
851 (COM74-51065)	*
852 (COM74-51085)	*
853 (SN003-003-01330-7)	.85
854 (SN003-003-01381-1)	2.00
855 (SN003-003-01367-6)	1.05
856 (SN003-003-01371-4)	.65
857 (SN003-003-01423-1)	1.05
858 (SN003-003-01433-8)	3.75

*Available from the National Technical Information Service, use "PB", "AD", "COM", "N", or NBS publication identification if no specific NTIS number is assigned. Available in Microfiche for $.00; consult NTIS for paper copy price.

No.	Price
859 (SN003-03-01543-1)	4.15
860 (SN003-003-01401-0)	2.05
861 (SN003-003-01380-3)	.80
862 (SN003-003-01402-8	.80
863 (SN003-003-01404-4)	1.15
864 (SN003-003-01400-1)	1.20
865 (SN003-003-01411-7)	1.35
866 (SN003-003-01441-9)	1.85
867 (SN003-003-01427-3)	1.25
868 (SN003-003-01430-3)	1.50
869 (SN003-003-01424-9)	.80
870 (SN003-003-01434-6)	1.05
871 (SN003-003-01435-4)	.140
872 (SN003-003-01436-2)	2.10
873 (SN003-003-01555-5)	.75
874 (SN003-003-01438-9)	1.00
875 (SN003-003-01448-6)	.65
876 (COM75-11113)	*
877 (SN003-003-01455-9)	.80
878 (SN003-003-01440-1)	.65
879 (SN003-003-01432-0)	1.10
880 (SN003-003-01447-8)	.85
881 (SN003-003-01469-9)	1.10
882 (SN003-003-01462-1)	.85
883 (SN003-003-01475-3)	1.45
884 (SN003-003-01471-1)	.45
885 (SN003-003-01476-1)	1.45
886 (SN003-003-01470-2)	.65
887 (SN003-003-01545-8	1.45
888 (SN003-003-01482-6	1.65
889 (SN003-003-01574-1)	1.80
890 (SN003-003-01548-2)	1.10
891 (SN003-003-02186-5)	1.10
892 (SN003-003-01549-1)	1.70
893 (SN003-003-01561-0)	1.30
894 (SN003-003-01570-9)	1.45
895 (SN003-003-01564-4)	2.30
896 (SN003-003-01562-8)	2.15
897 (SN003-003-01589-0)	1.15
898 (SN003-003-01584-9)	.55
899 (SN003-003-01579-2)	4.00
900 (SN003-003-01611-0)	.75
901 (SN003-003-01607-1)	1.15
902 (SN003-003-01598-9)	2.70
903 (SN003-003-01578-4)	.85
904 (SN003-003-01617-9)	.75
905 (SN003-003-01610-1)	1.10
906 (SN003-003-01630-6)	1.35
908 (SN003-003-01643-8)	1.55
909 (SN003-003-01615-2)	1.05
910-1 (SN003-003-01590-3)	2.1
910-3 (SN003-003-01785-0)	**2.1**
912 (SN003-003-01613-6)	2.0
913 (SN003-003-01645-4)	1.0
914 (SN003-003-01636-5)	.8
915 (SN003-003-01631-4)	.7
916 (SN003-003-01626-8)	2.8
917 (SN003-003-01640-3)	.8
918 (SN003-003-01661-6)	1.1
919 (SN003-003-01658-6)	1.2
920 (SN003-003-01648-9)	1.1
921 (SN003-003-01660-8)	2.2
922 (SN003-003-01668-3)	1.7
923 (SN003-003-01679-9)	.7
924 (SN003-003-01671-3)	1.0
925 (SN003-003-01680-2)	1.7
927 (SN003-003-01683-7)	1.
928 (SN003-003-01711-6	1.1
929 (SN003-003-01694-2)	.8
930 (SN003-003-01672-1)	.5
931 (SN003-003-01689-6)	1.8
932 (SN003-003-01703-5)	1.

*Available from the National Technical Information Service; use "AD", or "COM" number wh ordering. Available in Microfiche for $3.00; consult NTIS for paper copy price.

These reports are available by purchase from the National Technical Information Service, Springfield, VA 22161. Those items in boldface denote the publications cited in this supplement. The prices are those in effect as of the date this publication went to press. When ordering, use the "AD", "PB", "N" or "COM" number. The prices quoted are for paper copy domestic, add $2.25 additional for foreign mailing. Microfiche are available for $2.25 per set. Prices are subject to change without notice.

No.	Price
73-101 (COM73-10867)	A05
73-102 (COM73-10856)	A04
73-105 (COM73-10858)	A03
73-110 (COM73-11191)	A07
73-112 (COM74-10702-03)	A04
73-113 (COM74-10702-01)	A13
73-114 (COM74-10702-02)	A13
73-116 (COM73-10859)	A04
73-119 (AD757789)	A04
73-121 (COM73-10860)	A06
73-125 (COM73-11189)	A04
73-126 (COM73-10854)	A06
73-127 (COM73-10857)	A05
73-128 (AD760150)	A04
73-129 (COM73-10853)	A05
73-131 (COM73-10863)	A04
73-132 (PB222300)	A07
73-135 (COM73-10840)	A03
73-138 (COM73-10868)	A03
73-140 (COM73-10842)	A02
73-141 (COM73-10841)	A03
73-144 (PB220-849)	A07
73-145 (COM75-10541)	A03
73-146 (COM73-10989)	A04
73-148 (COM73-10855)	A05
73-151 (COM73-10866)	A02
73-152 (AD914258)	A07
73-154 (COM73-10865)	A02
73-156 (COM73-11286)	A04
73-157 (COM74-10394)	A03
73-159 (COM73-11174)	A02
73-161 (PB225310)	A04
73-163 (COM74-10542)	A06
73-164 (COM73-10834)	A03
73-165 (COM73-10837)	A02
73-166 (COM73-10835)	A02
73-167 (COM73-10836)	A02
73-168 (COM73-10838)	A03
73-169 (COM73-10839)	A02
73-170 (COM73-10843)	A03
73-172 (COM73-11175)	A05
73-173 (COM73-10844)	A03
73-175 (COM74-10395)	A04
73-177 (COM75-10336)	A03
73-180 (COM74-10130)	A03
73-182 (COM73-11284)	A05
73-183 (COM73-11177)	A04
73-184 (COM73-11110)	A05
73-185 (COM73-11287)	A03
73-187 (PB221-188)	A04
73-188 (PB221-183)	A05
73-189 (COM73-11173)	A03
73-190 (COM73-10831)	A02
73-191 (PB221-695)	A02
73-192 (COM73-10832)	A02
73-197 (COM74-10468)	A04
73-198 (COM74-11289)	A02
73-199 (COM74-10129)	A06
73-200 (COM74-10478)	A03
73-201 (COM73-11221)	A05
73-202 (COM74-10479)	A03
73-203 (See NBSIR 74-430 COM74-10724)	A06
73-206 (COM73-11262)	A06
73-207 (AD769-266)	A07
73-208 (COM74-10127)	A03
73-209 (COM74-10469)	A11
73-210 (COM74-11767)	A10
73-211 (COM74-10950)	A08
73-212 (COM74-11009)	A07
73-213 (COM74-11771)	A07
73-214 (COM74-11239)	A06
73-215 (COM74-11010)	A06
73-216 (COM74-11011)	A07
73-217 (COM74-10470)	A03
73-218 (COM75-10144)	A03
73-220 (PB222-437)	A02
73-221 (COM73-11113)	A05
73-223 (COM73-11220)	A05
73-228 (PB222-425)	A02
73-231 (PB224-645)	A03
73-233 (COM74-11770)	A04
73-234 (COM74-10128)	A03
73-240 (COM74-10986)	A03
73-242 (PB224-654)	A03

No.	Price
73-244 (AD-A003-900)	A04
73-246 (COM74-10989)	A02
73-248 (COM74-10474)	A05
73-251 (PB224-688)	A03
73-252 (AD775-082)	A12
73-254 (COM74-10987)	A02
73-256 (COM75-11443)	A02
73-257 (COM75-11444)	A02
73-258 (COM75-11445)	A02
73-259 (COM75-11446)	A02
73-260 (COM75-11440)	A02
73-261 (COM75-11441)	A02
73-262 (COM75-10370)	A04
73-263 (PB225-284)	A04
73-264 (PB243-541)	A02
73-265 (COM73-11453)	A04
73-266 (PB225-286)	A03
73-267 (COM73-11955)	A04
73-268 (AD768-303)	A03
73-275 (COM74-10126)	A04
73-277 (PB225-278)	A04
73-280 (AD782-094)	A06
73-281 (AD782-028)	A06
73-287 (COM73-11928)	A02
73-288 (COM73-11861)	A04
73-289 (COM74-10475)	A03
73-290 (COM74-10974)	A02
73-294 (AD787-327)	A04
73-295 (COM74-10471)	A02
73-297 (AD772-066)	A02
73-299 (PB243-543)	A03
73-301 (COM73-10762)	A03
73-302 (COM73-10869)	A05
73-303 (AD759-374)	A04
73-304 (COM74-10281)	A05
73-308 (COM73-10761)	A03
73-309 (COM73-11981)	A05
73-316 (COM73-11954)	A05
73-318 (N73-27390)	A09
73-320 (COM73-11971)	A02
73-322 (COM73-11464)	A03
73-326 (COM73-11465)	A02
73-329 (COM74-10608)	A05
73-330 (COM74-10609)	A04
73-331 (COM74-10238)	A05
73-335 (COM74-11051)	A05
73-338 (COM73-11660)	A03
73-339 (COM73-11985)	A13
73-341 (COM74-10885)	A03
73-342 (COM73-11978)	A13
73-343 (COM75-10282)	A05

No.	Price
73-344 (COM74-10749)	A0
73-345 (COM74-10239)	A0
73-346 (COM74-10240)	A0
73-347 (COM74-10674)	A0
73-348 (COM74-10241)	A0
73-349 (COM74-11374)	A0
73-351 (COM74-10784)	A0
73-402 (COM74-10472)	A0
73-403 (COM74-10016)	A0
73-404 (PB230-952)	A0
73-405 (COM74-10131)	A0
73-406 (COM74-11352)	A0
73-407 (COM74-11078)	A0
73-412 (COM74-10512)	A0
73-413 (COM74-10750)	A0
73-414 (COM74-10866)	A0
73-415 (COM75-11448)	A0
73-416 (COM74-10511)	A0
73-417 (COM74-10477)	A0
73-418 (COM74-11783)	A0
73-420 (COM74-11092)	A0
73-421 (COM74-11224)	A0
73-422 (COM74-11240)	A0
73-423 (COM74-11722)	A0
73-424 (COM74-10867)	A0
74-355 (N74-30195)	A0
74-357 (COM74-10551)	A0
74-359 (AD780-596)	A2
74-361 (COM74-11222)	A0
74-363 (COM74-11053)	A0
74-364 (COM74-11208)	A0
74-365 (COM74-11375)	A0
74-366 (COM74-11076)	A0
74-369 (COM74-11688)	A0
74-371 (COM74-11567)	A0
74-372 (ADA006-037)	A0
74-375 (COM74-11657)	A0
74-377 (COM74-11449)	A0
74-378 (COM74-11450)	A0
74-379 (PB247-658)	A0
74-380 (COM74-11686)	A0
74-381 (COM75-10522)	A0
74-382 (AD783-433)	A1
74-387 (COM74-11643	A0
74-388 (COM74-11687)	A0
74-389 (COM74-11717)	A0
74-390 (COM74-11718)	A0
74-391 (COM74-10258)	A0
74-393 (COM75-10768)	A1
74-394 (COM75-10126)	A0
74-395 (COM75-10161)	A0

No.	Price
4-396 (COM74-11766)	A03
4-398 (COM75-10130)	A15
4-426 (COM74-11074)	A06
4-430 (COM74-10724)	A06
4-432 (COM74-10751)	A04
4-434 (COM74-11079)	A02
4-438 (COM74-10980)	A03
4-439 (COM74-10985)	A02
4-442 (AD787-743)	A03
4-443 (COM74-11003)	A02
4-444 (COM74-10548)	A03
4-449 (COM75-10049)	A03
4-452 (PB204-486)	A06
4-454 (COM74-10988)	A02
4-455 (COM74-10865)	A03
4-456 (COM74-11793)	A02
4-457 (COM74-11792)	A05
4-458 (AD776-337)	A02
4-461 (PB246-623)	A03
4-464 (COM74-10785)	A05
4-465 (COM75-10417)	A04
4-466 (COM74-10700)	A21
4-467 (COM74-11754)	A04
4-470 (PB232-629)	A05
4-471 (COM74-10981)	A02
4-473 (COM74-11719)	A04
4-474 (AD778-340)	A03
4-477 (COM74-11784)	A03
4-479 (PB239-420)	A07
4-481 (COM74-11794)	A04
4-482 (COM75-10147)	A10
4-485 (AD780-704)	A02
4-486 (AD780-705)	A04
4-487 (COM74-10886)	A23
4-488 (COM75-10088)	A06
4-495 (COM74-11575)	A05
4-496 (COM74-11576)	A05
4-497 (COM74-11269)	A02
4-499 (COM74-11378)	A03
4-501 (COM75-10131)	A02
4-506 (COM74-11632)	A05
4-507 (AD/A0001343)	A03
4-509 (COM74-11377)	A02
4-510 (AD782-793)	A03
4-511 (COM74-11448)	A02

No.	Price
74-514 (COM75-10102)	A04
74-515 (COM74-11498)	A09
74-516 (COM74-11384)	A04
74-518 (PB239-633)	A05
74-519 (PB238-284)	A03
74-520 (COM74-11480)	A07
74-521 (COM75-10187)	A04
74-522 (COM75-10080)	A02
74-523 (COM75-11126)	A02
74-524 (COM74-11568)	A03
74-525 (AD782-564)	A02
74-526 (COM75-10087)	A04
74-527 (COM74-11720)	A04
74-529 (COM74-11495)	A04
74-530 (COM75-10041)	A03
74-533 (PB238-573)	A06
74-535 (COM74-11659)	A05
74-537 (COM74-11577)	A02
74-539 (COM74-11574)	A05
74-541 (COM75-10618)	A03
74-542 (COM75-10081)	A03
74-543 (COM74-11772)	A07
74-544 (COM74-11525)	A03
74-545 (COM74-11656)	A04
74-550 (COM74-11721)	A05
74-551 (COM74-11658)	A06
74-552 (COM74-11644)	A05
74-553 (COM75-10058)	A04
74-554 (COM74-10703)	A03
74-555 (COM74-10704)	A03
74-556 (COM74-10703)	A05
74-557 (COM75-11439)	A03
74-561 (COM75-10413)	A03
74-564 (COM74-11726)	A04
74-567 (COM74-11631)	A13
74-568 (COM74-11578)	A04
74-572 (COM74-11791)	A04
74-577-1 (COM74-11723)	A09
74-577-2 (COM74-11724)	A14
74-578 (COM74-11765)	A02
74-580 (PB248-465)	A02
74-581 (COM75-10127)	A03
74-582 (COM74-11645)	A03
74-583 (AD/A003-900)	A05
74-586 (COM75-10525)	A02
74-588 (COM75-10040)	A03
74-590 (COM75-11434)	A02

No.	Price
74-591 (COM75-10101)	A02
74-595 (COM75-10057)	A02
74-596 (COM75-10209)	A03
74-597 (COM75-11069)	A03
74-600 (AD/A008-935)	A09
74-602 (COM75-10048	A03
74-605 (COM75-10464)	A03
74-606 (COM75-10340)	A05
74-608 (COM75-10056)	A02
74-610 (COM75-10073)	A03
74-612 (COM75-10414)	A02
74-613 (COM75-10059)	A03
74-614 (COM75-11013)	A03
74-618 (COM75-11014)	A02
74-619 (COM75-10047)	A02
74-620 (PB246-622)	A02
74-621 (COM75-10422)	A03
74-623 (COM75-10210)	A05
74-624 (COM75-10412)	A03
74-625 (PB243-547)	A03
74-626 (COM75-10411)	A02
74-627 (COM75-10134)	A02
74-628 (COM75-10514)	A02
74-629 (COM75-11281)	A03
74-631 (COM75-10208)	A02
74-632 (PB246-554)	A05
74-633 (COM75-10691)	A04
74-634 (COM75-10685)	A03
74-635 (COM75-10276)	A04
75-637 (COM75-10055)	A02
75-639 (AD/A005-410)	A02
75-641 (COM75-11209)	A05
75-647 (COM75-10418)	A03
75-649 (PB241-237)	A02
75-651 (COM75-11211)	A05
75-652 (COM75-11399)	A05
75-653 (PB248-097)	A03
75-654 (COM75-10367)	A02
75-658 (AD/A007-445)	A03
75-659 (AD/A008-538)	A03
75-660 (COM75-10669)	A03
75-661 (COM75-10763)	A03
75-662 (COM75-10420)	A02
75-664 (AD/A007-447)	A03
75-665 (COM75-10421)	A03
75-666 (COM75-11381)	A03
75-667 (PB241-267)	A03
75-672 (COM75-10338)	A03
75-673 (COM75-10921)	A03
75-675 (COM75-10686)	A03
75-677 (COM75-10516)	A04
75-678 (PB248-687)	A04
75-679 (COM75-10419)	A03
75-680 (COM75-10423)	A06
75-682 (COM75-10524)	A02
75-685 (COM75-10690)	A05
75-687 (COM75-11137)	A07
75-688 (COM75-11222)	A06
75-689 (COM75-11190)	A04
75-690 (COM75-11207)	A05
75-691 (COM75-11015)	A05
75-692 (PB250-385)	A06
75-693 (COM75-11194)	A02
75-696 (COM75-10527)	A05
75-697 (COM75-10920)	A04
75-699 (COM75-11016)	A03
75-700 (COM75-11280)	A04
75-701 (COM75-11282)	A02
75-702 (COM75-11433)	A03
75-703 (COM75-11278)	A03
75-705 (COM75-11277)	A03
75-706 (PB248-640)	A02
75-707 (COM75-11017)	A03
75-708 (COM75-10817)	A02
75-710 (COM75-11030)	A02
75-711 (COM75-10689)	A04
75-712 (COM75-11070)	A03
75-713 (COM75-11134)	A04
75-715 (COM75-11208)	A02
75-716 (COM75-11210)	A08
75-718 (COM75-10750)	A03
75-719 (PB251-410)	A03
75-721 (PB246-864)	A03
75-722 (PB248-641)	A03
75-723 (COM75-10753)	A04
75-729 (PB246-858)	A03
75-730 (AD/A018451)	A03
75-731 (COM75-11071)	A03
75-732 (COM75-11022)	A02
75-733 (COM75-11139)	A02
75-734 (COM75-11212)	A03
75-735 (PB256-295)	A07
75-736 (COM75-11018)	A02
75-737 (COM75-11472)	A03
75-738 (COM75-11279)	A03
75-739 (COM75-11189)	A02
75-740 (COM75-11127)	A03
75-741 (COM75-11136)	A03
75-742 (PB248-744)	A04

NBS INTERAGENCY REPORTS (Continued)

No.	Price
75-744 (COM75-11072)	A02
75-745 (PB347-657)	A03
75-746 (COM75-11432)	A04
75-747 (COM75-11131)	A03
75-748 (COM75-11031)	A05
75-750 (PB249-934)	A03
75-751 (AD-A017-626)	A03
75-755 (PB248-642)	A03
75-757 (PB248-914)	A03
75-760 (AD/A016-843)	A10
75-761 (COM75-11377)	A06
75-763 (COM75-11276)	A10
75-766 (COM75-11376)	A04
75-767 (PB246-879)	A03
75-768 (PB247-943)	A03
75-769 (PB246-978)	A11
75-770 (COM75-11370)	A03
75-772 (PB246-861)	A04
75-774 (COM75-11364)	A04
75-775 (PB248-864)	A04
75-778 (PB246-435)	A04
75-779 (PB249-935)	A06
75-781 (AD/A015630)	A02
75-782 (PB248-643)	A03
75-784 (PB246-862)	A04
75-785 (PB246-345)	A03
75-786 (PB251-411)	A04
75-787 (AD/A016-844)	A04
75-788 (PB250-843)	A03
75-790 (PB250-848)	A16
75-791 (PB253-229)	A04
75-793 (PB247-538)	A04
75-794 (PB247-203)	A03
75-795 (PB246-866)	A04
75-796 (PB247-656)	A02
75-797 (COM75-11465)	A02
75-801 (PB252-044)	A08
75-804 (COM75-10395)	A03
75-805 (PB252-971)	A03
75-806 (COM75-10368)	A04
75-807 (COM75-10396)	A05
75-809 (COM75-10989)	A03
75-810 (COM75-10919)	A06
75-812 (AD/A012889)	A03
75-814 (COM75-11132)	A04
75-816 (AD/A001250)	A04
75-818 (PB245439)	A03
75-819 (PB258554)	A06
75-820 (PB246436)	A04
75-822 (PB246933)	A03
75-823 (PB246658)	A05
75-825 (PB258-913)	A04
75-827 (PB247-938)	A02
75-828 (PB249-041)	A09
75-829 (PB248-855)	A03
76-844 (PB264-300)	A04
75-900 (PB250-859)	A03
75-901 (PB246-860)	A03
75-902 (PB249-539)	A03
75-903 (PB246859)	A03
75-908 (PB247-270)	A02
75-909 (PB246-863)	A02
75-910 (PB248-646)	A06
75-913 (PB248-911)	A03
75-915 (PB249-775)	A02
75-916 (AD/A019648)	A05
75-917 (PB247-655)	A02
75-918 (PB251-412)	A05
75-920 (PB248-913)	A03
75-923 (PB250-767)	A02
75-924 (PB248-686)	A05
75-926 (PB257-467)	A06
75-927 (PB255-809)	A04
75-929 (PB261-498)	A03
75-930 (PB258-250)	A04
75-931 (PB261-030)	A03
75-932 (PB257-425)	A04
75-933 (PB248-983)	A04
75-937 (PB265-614)	A02
75-942 (PB256-644)	A04
75-943 (PB258-914)	A05
75-944 (PB258-372)	A03
75-947 (PB258-323)	A04
75-950 (PB250-664)	A03
75-951 (PB249-094)	A03
75-952 (PB248-910)	A03
75-953 (PB256-219)	A03
75-954 (PB253-242)	A03
75-955 (PB248-685)	A08
75-956 (PB247-654)	A02
75-957 (PB250-769)	A02
75-958 (PB248-743)	A02
75-960 (PB249-774)	A04
75-961 (PB257-466)	A11

No.	Price
75-962 (PB247-639)	A02
75-966 (PB250-768)	A02
75-967 (PB251-413)	A02
75-968 (PB250-845)	A03
75-971 (PB249-776)	A03
75-972 (PB259-630)	A05
75-973 (PB249-255)	A04
75-974 (PB249-777)	A06
75-975 (PB253-113)	A03
75-976 (PB248-986)	A03
75-977 (PB251-220)	A03
76-833 (PB250-846)	A03
76-834 (PB250-666)	A03
76-836 (PB254-459)	A03
76-837 (PB261-709)	A07
76-839 (PB252-013)	A08
76-840 (PB258-324)	A03
76-841 (PB256-319)	A03
76-842 (PB258-331)	A02
76-846 (PB258-327)	A03
76-848 (PB261-996)	A14
76-979 (PB248-992)	A02
76-980 (PB250-849)	A10
76-982 (PB248-699)	A15
76-983 (PB251-213)	A03
76-984 (PB262-020)	A07
76-985 (PB250-755)	A04
76-986 (PB250-858)	A04
76-987 (PB250-857)	A03
76-988 (PB254-469)	A05
76-990 (PB251-769)	A02
76-991 (AD/A021255)	A02
76-992 (AD/A021295)	A04
76-993 (PB253-227)	A03
76-996 (PB251-998)	A03
76-997 (PB254-298)	A05
76-998 (PB253-228)	A03
76-1000 (PB251-219)	A04
76-1002 (PB257-469)	A04
76-1003 (PB251-211)	A02
76-1007 (PB252-021)	A04
76-1008 (PB251-218)	A03
76-1010 (PB250-654)	A03
76-1011 (PB259-641)	A03
76-1012 (PB257-197)	A04
76-1013 (PB256-130)	A03
76-1014 (PB251-414)	A02
76-1015 (PB249-530)	A13
76-1016 (PB254-177)	A04
76-1017 (PB251-917)	A03
76-1018 (PB257-779)	A04
76-1019 (PB251-944)	A02
76-1020 (PB258-256)	A03
76-1021 (PB257-101)	A04
76-1022 (PB259-628)	A02
76-1023 (PB256-191)	A02
76-1024 (PB255-876)	A04
76-1025 (PB251-753)	A05
76-1027 (PB253-243)	A03
76-1028 (PB251-415)	A02
76-1029 (PB261-199)	A03
76-1031 (PB253-932)	A02
76-1034 (PB254-460)	A05
76-1037 (PB253-933)	A03
76-1038 (PB251-918)	A02
76-1039 (PB254-047)	A03
76-1040 (PB254-178)	A02
76-1041 (PB257-086)	A04
76-1043 (PB254-347)	A06
76-1046 (PB256-476)	A06
76-1049 (PB256-600)	A04
76-1050 (PB253-111)	A04
76-1052 (PB258-118)	A05
76-1054 (PB253-110)	A06
76-1056 (PB254-179)	A03
76-1058 (PB262-097)	A07
76-1059 (PB257-086)	A08
76-1060 (PB253-934)	A03
76-1061 (PB256-328)	A04
76-1063 (PB257-102)	A03
76-1064 (PB257-102)	A04
76-1066 (PB254-473)	A02
76-1067 (PB257-195)	A03
76-1069 (PB256-296)	A03
76-1070 (PB260-913)	A07
76-1072 (PB255-446)	A04
76-1074 (PB261-497)	A03
76-1076 (PB254-180)	A03

No.	Price
76-1081 (PB256-329)	A05
76-1082 (PB258-235)	A08
76-1083 (PB255-803)	A06
76-1084 (PB257-180)	A03
76-1087 (PB257-202)	A03
76-1089 (PB254-475)	A10
76-1090 (PB255-505)	A03
76-1091 (PB257-768)	A03
76-1093 (PB256-318)	A02
76-1095 (PB255-808)	A05
76-1096 (PB257-076)	A04
76-1097 (PB257-141)	A03
76-1098 (PB259-523)	A03
76-1099 (PB258-612)	A06
76-1100 (PB258-371)	A04
76-1102 (PB257-729)	A08
76-1107 (PB258-322)	A04
76-1109 (PB257-194)	A04
76-1110 (PB257-073)	A03
76-1112 (PB259-636)	A03
76-1115 (PB257-196)	A02
76-1120 (PB257-837)	A02
76-1124 (PB261-846)	A05
76-1126 (PB260-878)	A04
76-1130 (PB257-347)	A09
76-1131 (PB259-242)	A03
76-1132 (PB260-363)	A05
76-1133 (PB261-228)	A08
76-1136 (PB261-965)	A04
76-1137 (PB257-770)	A05
76-1138 (PB259-522)	A04
76-1140 (PB259-626)	A19
76-1141 (AD/A031530)	A03
76-1142 (PB263-099)	A02
76-1143 (PB257-769)	A03
76-1144 (PB259-243)	A02
76-1147 (PB259-637)	A03
76-1153 (PB259-638)	A02
76-1154 (PB260-400) Vol. 1	A09
76-1154 (PB260-401) Vol. 2	A07
76-1159 (PB261-994)	A03
76-1162 (PB260-879)	A04
76-1172 (PB261-217)	A03
76-1176 (PB261-995)	A03
76-1178 (PB262-114)	A06

No.		Price
73-1	(PB192-365)	A03
73-2	(PB194-614)	A05
73-3	(COM71-00605)	A10
73-4	(COM73-10323)	A04
73-5	(COM73-10951)	A08
73-6	(COM73-10959)	A04
73-7	(COM73-10958)	A04
73-8	(COM73-10954)	A10
73-9	(COM73-10953)	A03
73-10	(COM73-10952)	A08
73-11	(PB242-597)	A12
73-12	(COM73-10955)	A06
73-13	(COM73-10957)	A05
73-14	(COM73-10950)	A04
73-15	(PB242-582)	A15
73-16	(COM73-11265)	A04
73-17	(COM74-10932)	A07
73-18	(COM73-11783)	A03
73-19	(COM74-10481)	A04
73-21	(COM74-10722)	A07
74-22	(COM74-10934)	A16
74-23	(COM74-10929)	A02
74-24	(COM74-10983)	A05
74-25	(COM74-11075)	A07
74-26	(COM74-11633)	A06
74-27	(COM75-10143)	A06
74-28	(PB176-912)	A12
74-29	(PB176-913)	A04
74-30	(COM74-11732)	A03
74-31	(COM74-11733)	A02
74-32	(COM75-10039)	A04
75-33	(COM75-10133)	A11
75-34	(COM75-10128)	A04
73-35	(COM75-10341)	A05
75-36	(PB261-144)	A16
75-37	(PB261-145)	A06
75-38	(PB261-021)	A05
75-40	(COM75-10696)	A03
75-42	(COM75-10805)	A24
75-43	(AD-16782)	A06
75-44	(COM75-10991)	A10
75-45	(PB257-835)	A02
75-46	(PB247-235)	A09
75-47	(PB247-236)	A17
75-48	(PB248-781)	A09
75-50	(PB247-939)	A07
75-51	(PB247-483)	A15
76-54	(PB251-682)	A05
76-55	(PB250-571)	A04
76-56	(PB250-572)	A04
76-57	(PB250-573)	A06
76-58	(PB256-291)	A07
76-59	(PB256-639)	A10
76-60	(PB253-588)	A05
76-61	(PB253-553)	A05
76-63	(PB256-440)	A06
76-64	(PB255-445)	A05
76-69	(PB254-276)	A06
76-70	(PB254-748)	A04
76-71	(PB254-751)	A04
76-72	(PB256-190)	A06
76-73	(PB257-424)	A08
76-74	(PB256-771)	A03
76-75	(PB261-201)	A03
76-76	(PB261-200)	A06
76-79	(PB259-127)	A03

No.	Price
3-01 (COM73-11373)	A12
3-02 (COM73-11375)	A08
3-03 (COM73-11374)	A06
3-04 (COM74-10256)	A02
3-05 (COM74-10257)	A04
3-06 (COM74-10258)	A03
3-07 (COM74-10939) Vol. 1	A05
3-07 (COM74-10940) Vol. 2	A14
5-01 (COM75-11369)	A07
6-03 (PB251-266)	A04
6-04 (PB251-683)	A15
6-05 (PB253-108)	A03
6-06 (PB253-918)	A09
6-08 (PB254-078)	A03
6-09 (PB252-488)	A03
6-10 (PB253-260)	A03
6-11 (PB253-115)	A06
6-12 (PB254-996)	A19
6-13 (PB253-475)	A03
6-14 (PB253-476)	A03
6-15 (PB253-477)	A03
76-16 (PB256-129)	A11
76-17 (PB254-233)	A10
76-18 (PB256-642)	A03
76-19 (PB256-643)	A03
76-22 (PB257-884)	A20
76-23 (PB258-991)	A03
76-24 (PB258-093)	A11

3. TITLES AND ABSTRACTS OF NBS PUBLICATIONS

3.1. PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 70A, JULY–DECEMBER 1966

July-August 1966

Elastic constants of synthetic single crystal corundum, W. E. Tefft, *J. Res. NBS* **70A**4-403, pp. 277-280 (July-Aug. 1966).

Key words: Aluminum oxide; corundum; elastic constants; shear modulus; Young's modulus.

The elastic constants of synthetic single crystal corundum (aluminum oxide) were calculated from 0 to 900 °K from data obtained by a resonance technique from 80 to 900 °K.

Phase equilibria as related to crystal structure in the system niobium pentoxide-tungsten trioxide, R. S. Roth and J. L. Waring, *J. Res. NBS* **70A**4-404, pp. 281-303 (July-Aug. 1966).

Key words: Crystal structure; niobium pentoxide; phase equilibria; system; tungsten trioxide.

The phase equilibrium diagram for the binary system niobium pentoxide-tungsten trioxide has been constructed from results of x-ray diffraction studies on both single crystals and powders and from fusion characteristics. Twelve stable compounds have been found in the system. The exact composition of eight of these compounds has been established by single crystal analyses at the Nb_2O_5:WO_3 ratios of 6:1, 13:4, 7:3, 8:5, 9:8, 1:1, 4:9, and 2:7. The approximate compositions of the remaining four other phases are 30:1, 6:11, 1:11, and 1:15. The 6:1, "6:11", 4:9, and 2:7 phases melt congruently at 1476, 1378, 1380, and 1357 °C, respectively. The "30:1", 7:3, 8:5, 9:8, "1:11", and "1:15" phases melt incongruently at 1470, 1440, 1385, 1375, 1356, and 1358 °C, respectively; and the 13:4 and 1:1 phases decompose before melting at 1435 and 1115 °C, respectively. The 8:5, 9:8, "6:11", 2:7, "1:11", and "1:15" compounds are shown on the phase diagram as having minimum temperatures of stability. One metastable phase having a narrow range of composition near the 3:8 ratio was also encountered. Although Nb_2O_5 apparently exhibits no solid solution, WO_3 was found to accept a maximum of three mole percent niobia in solid solution enabling all the reported polymorphs of WO_3 to be obtained at room temperature.

Properties of aqueous mixtures of pure salts. Thermodynamics of the ternary system: Water-calcium chloride-magnesium chloride at 25 °C, R. A. Robinson and V. E. Bower, *J. Res. NBS* **70A**4-405, pp. 305-311 (July-Aug. 1966).

Key words: Isopiestic measurements; vapor pressure; calcium chloride; mixed solutions; activity coefficients.

Isopiestic vapor pressure measurements have been made on the system water-calcium chloride-magnesium chloride at 25 °C. Activity coefficients have been evaluated for each salt in the presence of the other in systems of constant total ionic strength. The excess free energy of mixing has been calculated and compared with the values for analogous systems.

Properties of aqueous mixtures of pure salts. Thermodynamics of the ternary system: Water-sodium chloride-calcium chloride at 25 °C, R. A. Robinson and V. E. Bower, *J. Res. NBS* **70A**4-406, pp. 313-318 (July-Aug. 1966).

Key words: Calcium chloride; isopiestic measurements; mixed salt solutions; sodium chloride; vapor pressure of aqueous solutions.

Isopiestic vapor pressure measurements have been made to determine some thermodynamic properties of the system: water-sodium chloride-calcium chloride at 25 °C. Equations are derived for the activity coefficient of each salt in the presence of the other when the total ionic strength is kept constant. The limiting conditions in very dilute solutions are considered and "trace" activity coefficients calculated. A comparison with previous work is made. The excess free energy of mixing is calculated.

Use of the consistency check in the vector verification method, A. D. Mighell and R. A. Jacobson, *J. Res. NBS* **70A**4-407, pp. 319-321 (July-Aug. 1966).

Key words: Crystal; structure; Patterson; vector; symmetry; consistency; frequency; superposition.

The consistency check is a type of frequency check in which full use is made of the space group symmetry. It is designed for application to a symmetry map, to a tentative atom map, to the results of superpositions, or to any pseudoelectron-density map. Like the frequency check, its purpose is to aid in the analysis of one of the above maps by assigning a relative weight (relative weight equals the number of other peaks that the given peak is consistent with) to the peaks in these maps. To determine the relative weight, each peak in the map is compared with each of the others to see if it is consistent. Two peaks are considered consistent with each other, if and only if, the set of unique vectors between the two is present in the Patterson map. The method is equivalent to doing a full set of symmetry superpositions at each peak in a symmetry map or a tentative atom map; counting the number of points in the resulting map; and outputting this number at the initial peak position. No assumptions other than that for space group symmetry are required to apply the consistency check to a symmetry map. The resulting map, which has been calculated in a routine fashion directly from the Patterson map, may then be conveniently used as the starting point for the structure analysis of an unknown compound.

Self-reversal in the spectral lines of uranium, D. D. Laun, *J. Res. NBS* **70A**4-408, pp. 323-324 (July-Aug. 1966).

Key words: Uranium, spectrum; spectrum, uranium; self-reversal; uranium spectrum.

In 1946, spectrum analysis indicated that the outer-electron configuration of normal uranium atoms was $5f^36d^17s^2$, with an energy level designated $^5L^\circ_6$ representing the normal state. Now that conclusion is experimentally verified by the observation of self-reversed lines in uranium spectra emitted by a high-current pulsed arc between metallic electrodes. Fifty-four reversed lines were observed; thirty-eight involve the normal state and sixteen are distributed among four low metastable states of the same configuration.

Oscillator strengths for ultraviolet lines of Fe I, C. H. Corliss and B. Warner, *J. Res. NBS* **70A**4-409, pp. 325-371 (July-Aug. 1966).

Key words: Atomic spectra; iron; oscillator strengths; transition probability; ultraviolet lines of Fe I.

Relative intensities and oscillator strengths for 2000 ultraviolet lines of Fe I from several investigations between 2080 and 4150 Å have been critically discussed and adjusted to a uniform absolute scale. New values for many lines not measured heretofore are reported.

September-October 1966

Orientation of calcium molybdate ($CaMoO_4$) and other single crystals having the scheelite structure, E. N. Farabaugh, H. S. Peiser, and J. B. Wachtman, Jr., *J. Res. NBS* **70A**5-410, pp. 379-384 (Sept.-Oct. 1966).

Key words: Calcium molybdate; crystal orientation; crystallographic groups; interplanar angles; physical properties; scheelite structure; single crystal; x-ray back-reflection.

Values of interplanar angles useful in distinguishing the [100] from the [110] direction in $CaMoO_4$ are given to facilitate orientation by analysis of back-reflection Laue patterns. The distinction between the [001] and [001] directions in the scheelite structure is discussed and examples of physical properties dependent upon this distinction are given. The [001] direction is defined in terms of the crystal structure and a procedure for identifying (001) using Laue patterns is described. The same distinction applies to certain nonpolar directions of all crystals belonging to the following nonenantiomorphous point groups: $\bar{1}$, m, 2/m, mmm, $\bar{3}$, 3m, $\bar{3}$m, $\bar{4}$, 4/m, 4/mmm, $\bar{6}$, 6/m, 6/mmm, m3, and m3m.

Crystal structure of $BaGe[Ge_3O_9]$ and its relation to benitoite, C. Robbins, A. Perloff, and S. Block, *J. Res. NBS* **70A**5-411, pp. 385-391 (Sept.-Oct. 1966).

Key words: Barium tetragermanate; structure; benitoite; crystal; x-ray.

$BaGe[Ge_3O_9]$ is trigonal space group P3 with lattice constants $a=11.61$, $c=4.74$ Å, and $Z=3$. The structure was established by three-dimensional Patterson and electron density syntheses. Three-dimensional least-squares refinement resulted in a final R value of 6.8 percent (observed data only).

The previously proposed structural relationship of this compound with benitoite, $BaTiSi_3O_9$, has been confirmed. The structure can be considered as composed of Ge_3O_9 rings, in which the Ge is tetrahedrally coordinated, linked through octahedrally coordinated Ge atoms to form a three-dimensional Ge-O network. All Ge polyhedra are linked by corner sharing. The Ba ions occupy positions in channels of the network.

A rotating cylinder method for measuring normal spectral emittance of ceramic oxide specimens from 1200 to 1600 °K, H. E. Clark and D. G. Moore, *J. Res. NBS* **70A**5-412, pp. 393-415 (Sept.-Oct. 1966).

Key words: Alumina; ceramic oxides; emittance; error sources; magnesia; measurement uncertainties; spectral emittance; thermal radiation; thoria; zirconia.

Equipment was designed and constructed for measuring the spectral emittance of polycrystalline ceramic oxide specimens in the wavelength region 1 to 15 μ and at temperatures of 1200, 1400, and 1600 °K. Specimens consisted of small hollow cylinders that were rotated at 100 rpm in a furnace cavity equipped with a water-cooled viewing port. Emittances were determined by comparing the radiance of the specimen to that of a blackbody at the same temperature.

A series of six measurements (two measurements each on three specimens) was made on commercially pure specimens of alumina, thoria, magnesia, and zirconia. All four materials showed similar behavior in that the emittances were low in the shorter wavelength regions and high at the longer wavelengths. The temperature coefficients of spectral emittance were positive for all four materials, but varied with the material; those for thoria were appreciably higher than the other three. In all cases coefficients were greater at short wavelengths than at long.

Error sources were investigated, and the measurement uncertainties associated with each source were evaluated. It was concluded that at 1200 °K the true values of emittance at 2 μ for the particular specimens measured might be as much as 0.032 lower or 0.012 higher than the reported values. The data were in good agreement with reflectance measurements of the same material and with recently reported absorption coefficients.

Electron absorption spectrum of cobalt(II)-doped trisphenanthrolinezinc nitrate dihydrate, C.W. Reimann, *J. Res. NBS* **70A**5-413, pp. 417-419 (Sept.-Oct. 1966).

Key words: Trisphenanthroline cobalt(II) nitrate dihydrate; trisphenanthrolinezinc nitrate dihydrate; electron absorption spectrum.

The electron absorption spectrum of cobalt(II)-doped trisphenanthrolinezinc nitrate dihydrate has been observed at room temperature and at 77 °K. Broad bands appear at 10,750 and 22,000 cm^{-1} which are assigned to the $^4T_{1g}(F) \leftarrow\rightarrow {}^4T_{2g}(F)$ and the $^4T_{1g}(F) \leftarrow\rightarrow {}^4T_{1g}(P)$ transitions respectively. A broad weak band occurs near 19,000 cm^{-1} but at 77 °K this band is resolved into a series of narrower bands. These bands are assigned to ^2G transitions. The relationship between the spectrum of cobalt(II) trisphenanthrolinezinc nitrate dihydrate and the solution spectra of cobalt(II) in ammonia and ethylenediamine is discussed.

Procedures for homogeneous anionic polymerization, L. J. Fetters, *J. Res. NBS* **70A**5-414, pp. 421-433 (Sept.-Oct. 1966).

Key words: Homogeneous anionic polymerization; monodisperse, polystyrene, poly-α-methylstyrene; polyisoprene; and polybutadiene.

This report is a review of the procedures and equipment used in the preparation of polymers of predictable molecular weights and narrow molecular weight distributions. The monomers considered in detail are sytrene, α-methylstyrene, isoprene, and butadiene.

The configurations $4d^n+4d^{n-1}$ 5*s* in doubly-ionized atoms of the palladium group, Y. Shadmi, *J. Res. NBS* **70A**5-415, pp. 435-445 (Sept.-Oct. 1966).

Key words: Configurations $4d^n+4d^{n-1}$ 5*s*, energy levels interaction parameters; palladium group; theoretical; third spectra.

Four hundred and eighty-three energy levels belonging to the low even configurations of the third spectra of the palladium group are predicted by the use of interpolation formulas for the interaction parameters.

November-December 1966

Absolute isotopic abundance ratios and atomic weight of magnesium, E. J. Catanzaro, T. J. Murphy, E. L. Garner, and W. R. Shields, *J. Res. NBS* **70A**6-416, pp. 453-458 (Nov.-Dec. 1966).

Key words: Absolute ratios; atomic weight; isotopic abundances; magnesium.

Absolute values have been obtained for the isotopic abundance ratios of magnesium, using surface emission mass spectrometry. Samples of known isotopic composition, prepared from nearly pure separated magnesium isotopes, were used to calibrate the mass spectrometers. The resulting absolute values

are $^{25}Mg/^{24}Mg = 0.12663 \pm 0.00013$ and $^{26}Mg/^{24}Mg = 0.13932 \pm 0.00026$, yielding an atomic weight ($^{12}C = 12$) of 24.30497 ±0.00044. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for effects of known sources of possible systematic error.

Mass spectrometric study of photoionization, V. Water and ammonia, V. H. Dibeler, J. A. Walker, and H. M. Rosenstock, *J. Res. NBS* **70A**6-417, pp. 459-463 (Nov.-Dec. 1966).

Key words: Autoionization; electronic; excited states; H_2O^+; NH_3^+; NH_2^+; OH^+ ions; heats of formation; ionization thresholds; mass spectrometer; photoionization; radicals; Rydberg levels; vacuum monochromators.

Photoionization efficiency curves are obtained for the molecule and fragment ions of H_2O and NH_3 in the wavelength region extending from onset of ionization to 600 A. Threshold values of 12.593eV and 10.162eV are observed for the H_2O^+ and NH_3^+ ions, respectively. Vibrationally excited states of the molecule ions and autoionization of Rydberg levels are observed. A determination of the bond angle of the H_2O^+ ion from the Franck-Condon factors of the bending overtones results in a value of 112 degrees. Threshold values of the fragment ions permit calculations of heats of formation of the OH^+ and NH_2^+ ions and result in the ionization energies, I(OH)=12.94eV and I(NH_2)=11.22eV.

Interpretation of the third spectrum of gold (Au III), L. Iglesias, *J. Res. NBS* **70A**6-418, pp. 465-466 (Nov.-Dec. 1966).

Key words: Corrections to analysis of Au III; gold; spectrum of Au III; third spectrum.

A revision of the analysis of the Au III spectrum is presented. Of 9 energy levels considered doubtful on the basis of a recent theoretical treatment, 6 are found to be real and 3 have been rejected as incorrect. Three new energy levels have also been found in agreement with theoretical predictions.

A formal solution for slit corrections in small-angle x-ray scattering, J. Mazur and A. M. Wims, *J. Res. NBS* **70A**6-419, pp. 467-471 (Nov.-Dec. 1966).

Key words: Distribution of intensity; integral equation; scattering cross section; slit correction; small-angle x-ray scattering.

Slit shaped apertures are usually used in small-angle x-ray scattering measurements in order to obtain easily measured intensities of scattered radiation. As a result, the scattering intensity at a given angle determined by the camera, the center of the sample, and the central incident x-ray beam is not simply related to the scattering from the sample only at that angle. The experimentally determined intensities $\mathbf{I}(x)$ are related to the true scattering intensities by the following integral equation:

$$\tilde{I}(x) = \int_{-\infty}^{\infty} I[(x^2 + t^2)^{1/2}] W(t) dt.$$

This integral equation has been previously solved only for certain simplified functional forms for $W(t)$ and $\mathbf{I}(x)$. In this paper, a formal procedure is developed for calculating $I(x)$ from the observed angular measurements, which does not necessitate making any a priori assumption about the form of $W(t)$ and $\mathbf{I}(x)$.

High-temperature reactions of hexafluorobenzene, J. M. Antonucci and L. A. Wall, *J. Res. NBS* **70A**6-420, pp. 473-480 (Nov.-Dec. 1966).

Key words: Direct replacement; high temperature; mechanisms; nonionic or ionic coreactants; nuclear fluorine; pentafluorohalobenzenes.

The direct replacement of aromatic fluorine in hexafluorobenzene has hitherto been possible only by the use of nucleophilic reagents. In this investigation, the replacement of nuclear fluorine by nonnucleophilic, or weakly nucleophilic, reagents was achieved by reaction at relatively high temperatures, 300 to 850 °C. For example, the reaction of hexafluorobenzene with such reagents as bromine, chlorine, and tetrafluoroethylene gave as major products bromopentafluorobenezene, chloropentafluorobenzene, and octafluorotoluene. In addition, pentafluorohalobenzenes can also be produced by passage of hexafluorobenzene over the appropriate alkali or alkaline earth-metal halides at elevated temperatures.

The mechanism of the pyrolytic reactions of hexafluorobenzene and the nonionic coreactants are considered to involve free-radical intermediates. The reaction of hexafluorobenzene with the ionic coreactants may proceed by an ionic mechanism similar to that advanced for the usual, relatively low temperature, nucleophilic substitution reactions of aromatic systems. However, a more complicated free radical-ionic process cannot be ruled out for these reactions.

The melting temperatures of the *n*-paraffins and the convergence temperature for polyethylene, M. G. Broadhurst, *J. Res. NBS* **70A**6-421, pp. 481-486 (Nov.-Dec. 1966).

Key words: Convergence temperature; melting temperatures; methyl surfaces; *n*-paraffins; polyethylene; thermodynamic properties.

The extrapolation of the melting points, T_m, of the *n*-paraffins to large chain lengths ($n \rightarrow \infty$) is reexamined in order to resolve the differences in the proposed values of the convergence temperature $T_0 = \lim_{n \rightarrow \infty} T_m$. Experimental liquid entropies can be made consistent with a term, $R \ln n$, proposed by Flory and Vrij. This term effectively replaces the well-known expression $T_m = T_0(n+a)/(n+b)$ with an expression $T_m = T_0(n+a)/(n+\ln n+b)$; thus, slowing the convergence rate and increasing T_0 from 141.1 °C to 144.7 °C. Independent estimates of the parameters in the melting relationship were obtained from thermodynamic data and the least squares estimate of T_0=144.7 °C (calculated from 33 melting points with a standard deviation of T_m=0.3 °C) could not be altered by more than ±0.5 °C by any reasonable variation of the parameters. A simplified melting expression is obtained for polyethylene which includes both the chain end and fold surface energies, and it is shown that chain end effects partly account for the discrepancy between the 144.7 °C convergence temperature and experimental melting temperatures (~139 °C) of extended chain polyethylene crystals.

General treatment of the thermogravimetry of polymers, J. H. Flynn and L. A. Wall, *J. Res. NBS* **70A**6-422, pp. 487-523 (Nov.-Dec. 1966).

Key words: Degradation; nonisothermal kinetics; polymers; pyrolysis; thermal decomposition; thermogravimetry; thermolysis; stability of polymers.

Theoretical equations are developed for typical decompositions of polymers including those in which the volatilization does not follow a simple "reaction order" and those made up of a composite of several reactions of differing energies of activation. The effects of order, activation energy, heating rate and temperature dependence upon the calculated thermograms is illustrated. The literature on thermogravimetric kinetics is critically reviewed and coalesced into a logical and coherent development stressing the interrelation of methods and employing a consistent system of notation. As a result, a number of improved methods and new methods for the analysis of kinetic data applicable to the complex systems mentioned above are developed. It is concluded that methods involving a variable rate of heating or involving several thermogravimetric traces at

different rates of heating are capable of establishing the uniqueness of kinetic parameters. A new method of determining initial parameters from rate-conversion data is developed. A novel concept is employed of programming reaction variables (in this case, the heating rate) in a manner which greatly simplifies the mathematics of the kinetic system and which shows promise of a wide range of applicability in the area of rate processes.

Viscoelastic behavior under large deformations, L. J. Zapas, *J. Res. NBS* **70A**6-423, pp. 525-532 (Nov.-Dec. 1966).

Key words: BKZ theory; constant rate of strain; creep; elastic fluid; nonlinear behavior; polyisobutylene; recovery; stress; relaxation.

The BKZ elastic fluid theory is used to correlate experimental results obtained in biaxial strain and steady simple shear. With a heuristic potential function involving three material properties, excellent agreement is obtained between theory and experiment. In the special case where one of the material properties is dominant, the behavior in steady simple shear is calculated from dynamic measurements in the infinitesimal range and is compared with actual data.

Statistical aspects of second and third law heats, W. S. Horton, *J. Res. NBS* **70A**6-424, pp. 533-539, (Nov.-Dec. 1966).

Key words: Bias of least squares estimators; coefficient of variation; correlated estimators; enthalpy adjustments; heat of vaporization; high temperature chemistry; overestimation of standard deviation; second law heat; slope estimators; third law heat; vapor pressure.

The effects of random errors and of nonconstant heat of vaporization upon the estimation of the second and third law heats of vaporization are examined. The most important conclusion is that the often noticed marked improvement in precision of the third law heat over that for the second law heat is real and is a natural consequence of the difference between the two estimators. The effects of systematic errors upon the two heats are not investigated here. Other results of interest, but of less importance because of the small magnitude of the effects, include: (1) the two heats are negatively correlated, (2) the second law heat is generally biased, (3) the third law heat is not the minimum variance unbiased estimator of the heat of vaporization, and (4) the standard deviation obtained from least squares fitting consistently overestimates the true standard deviation, but by a negligible amount. Any reversible process for which the equilibrium constant is treated by a similar procedure is governed by the same considerations. The results apply approximately at any temperature although the stimulus for these considerations comes from high temperature chemistry.

Density-temperature formulae for coexisting liquid and vapor and for freezing liquid parahydrogen, R. D. Goodwin, *J. Res. NBS* **70A**6-425, pp. 541-544 (Nov.-Dec. 1966).

Key words: Coexistence densities; freezing liquid densities; hydrogen; melting-line liquid densities; orthobaric densities; parahydrogen; vapor-liquid equilibrium.

A single formula is given for coexistence temperature as a continuous function of the vapor-liquid densities. With six coefficients and seven adjusted exponents, it may conveniently replace the several formulae formerly used in separate regions of the data. Freezing liquid densities are described by a simple power law in temperature, replacing more complicated formulae. Computed results are tabulated and compared with the derived data.

Solubility of $CaHPO_4 \cdot 2H_2O$ and formation of ion pairs in the system $Ca(OH)_2$-H_3PO_4-H_2O at 37.5 °C, E. C. Moreno, T. M. Gregory and W. E. Brown, *J. Res. NBS* **70A**6-426, pp. 545-552 (Nov.-Dec. 1966).

Key words: Solubility of calcium monohydrogen phosphate dihydrate at 37.5 °C; calcium-phosphate ion-pairs; solubility of dicalcium phosphate dihydrate; solubility of dibasic calcium phosphate dihydrate.

The solubility isotherm for $CaHPO_4 \cdot 2H_2O$ (DCPD) in the three-component system $Ca(OH)_2$-H_3PO_4-H_2O was determined in the *p*H range 3.5 to 6.8 by leaching a thermostated column of DCPD with dilute phosphoric acid solutions. In confirmatory experiments, equilibrium was approached both from super- and under-saturation by shaking DCPD with appropriate solutions. The calculated ionic activity product $(Ca^{++}) \times (HPO_4^{=})$, appeared to be a parabolic function of *p*H with a minimum near *p*H 5.0. The *p*H dependence of the ionic product could be accounted for by considering the ion pairs $[CaHPO_4]^\circ$ and $[CaH_2PO_4]^+$ as semi-empirical parameters. Under the condition of saturation with respect to DCPD, the activity of the pair $[CaHPO_4]^\circ$ must be a constant. The activity of the species $[CaH_2PO_4]^+$ was shown to vary directly with hydrogen ion activity. The activities of the two ion pairs were adjusted to give a set of *p*H-independent ionic activity products with a mean of $2.19 \pm 0.11 \times 10^{-7}$. The stability constants for $[CaHPO_4]^\circ$ and $[CaH_2PO_4]^+$ are $5.88 \pm 0.031 \times 10^2$ and 7.49 ± 0.039, respectively. Experiments were conducted to study the hydrolysis of DCPD to more basic calcium phosphates and the kinetics of these transformations is discussed. The significance of the ion pairs in human serum is considered.

Dissociation of some substituted phenols in 50-percent aqueous methanol as solvent, R. A. Robinson and R. G. Bates, *J. Res. NBS* **70A**6-427, pp. 553-556 (Nov.-Dec. 1966).

Key words: Dissociation constant; methanol-water mixtures; solvent effects; substituted phenols.

The dissociation constants of the following substituted phenols in 50 wt percent methanol have been measured at 25 °C: *o*-nitrophenol, *p*-nitrophenol, 4-methyl-2-nitrophenol, 2, 6-dichlorophenol, pentachlorophenol. The respective values found, expressed as *pK* values, are 7.91_7, 7.69_2, 8.28_4, 7.68_0, and 5.27_8. The dissociation constants of 4-methyl-2-nitrophenol and pentachlorophenol, again expressed as *pK* values, have been measured in water as solvent at 25 °C and found to be 7.59_7 and 4.82_0, respectively.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 71A, JANUARY-DECEMBER 1967

January-February 1967

Electric fields produced in cubic crystals by point defects, A. D. Franklin and D. J. Sparks, *J. Res. NBS* **71A**1-428, pp. 1-2 (Jan.-Feb. 1967).

Key words: Electric fields; ionic crystals; lattice sums; point defects; polarization; NaCl; CsCl; CaF_2; ZnS.

Charged point defects in crystals polarize the surrounding ions. These induced dipoles contribute to the electric field in the crystal. In this paper, lattice sums for the calculation of this contribution are given for the NaCl, CsCl, CaF_2, and ZnS structures. Various positions for the defect are chosen, and the field evaluated near lattice sites in the vicinity of the defect, with radial (with respect to the defect) displacements of ±20 percent of the cation-anion distance allowed away from each lattice site. The lattice sums are expressed in power series, including terms up to cubic in the displacements, and the coefficients tabulated.

Heat capacity and thermodynamic properties of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, from 15 to 390 °K, G. T. Furukawa and W. G. Saba, *J. Res. NBS* **71A**1-429, pp.3-8 (Jan.-Feb. 1967).

Key words: Beryllium 1:3-aluminate; enthalpy; entropy; Gibbs energy; heat capacity; low temperature calorimetry; thermodynamic properties.

The heat capacity of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, was determined from 15 to 380 °K and the thermodynamic properties calculated from 0 to 390 °K. The entropy at 298.15 °K was found to be 175.55 J deg^{-1} mol^{-1} (41.96 cal deg^{-1} mol^{-1}).

Dissociation constant of *m*-nitrophenol in 50 wt percent methanol-water solvent from 25 to 40 °C and related medium effects, B. J. Steel, R. A. Robinson, and R. G. Bates, *J. Res. NBS* **71A**1-430, pp. 9-12 (Jan.-Feb. 1967).

Key words: Dissociation; electrolytes; methanol; *m*-nitrophenol; nonaqueous solvents; phenols; thermodynamics.

The dissociation constant of *m*-nitrophenol in 50 wt percent methanol-water as solvent has been determined at 25, 30, 35, and 40 °C. A spectrophotometric method was used, together with acidity functions for buffer solutions in 50 percent methanol derived from previous emf measurements. Values of the enthalpy and entropy changes on dissociation of the phenol have been calculated. A comparison with corresponding values for the dissociation of *m*-nitrophenol in aqueous solution affords a measure of the medium effects. The medium effect for *m*-nitrophenol lies intermediate between that for *o*-nitrophenol and that for *p*-nitrophenol.

On the calculation of moments of molecular weight distribution from sedimentation equilibrium data, I. H. Billick, M. Schultz, and G. H. Weiss, *J. Res. NBS* **71A**1-431, pp. 13-17 (Jan.-Feb. 1967).

Key words: Molecular weight average; molecular weight distributions; moments; polydispersity; polynomial representation; sedimentation equilibrium.

In this paper we discuss a technique for calculating moments of polydisperse materials in terms of concentration readings along the cell. The proposed method minimizes dependence on data from the end points where they may be unreliable. An analysis is given of the errors involved in the use of the proposed method when the underlying molecular weight distribution is the Schulz distribution or the lognormal.

The far infrared spectrum of vulcanized natural rubber, J. E. Stewart and F. J. Linnig, *J. Res. NBS* **71A**1-432, pp. 19-23 (Jan.-Feb. 1967).

Key words: Accelerators; far infrared; natural rubber; sulfur; tetramethylthiuram disulfide; vulcanization; zinc dibutyldithiocarbamate; zinc dimethyldithiocarbamate.

Earlier studies of the infrared spectra of rubber and some vulcanizates of rubber have been extended into the 650 to 33 cm^{-1} far infrared region. Some of the absorption bands originating in the crystalline portion of unvulcanized rubber have been studied by using polarized radiation and samples oriented by stretching. Vulcanization of rubber with sulfur alone produces a general weakening of all absorption bands and no new absorptions. Vulcanization with sulfur and an accelerator also results in a reduction in intensity of the rubber absorptions, but is accompanied by the appearance of new bands. When the accelerator is tetramethylthiuram disulfide (TMTD) the new bands are probably indicative of a thiocarbamate structure. When zinc dibutyldithiocarbamate is used as an accelerator a band probably due to zinc sulfide occurs. Vulcanization with TMTD alone produces only slight changes in the far infrared spectrum. However, when TMTD is used in the presence of zinc oxide a reaction occurs in which zinc dimethyldithiocarbamate (ZnDMDC) is formed. After vulcanization for a short period of time strong TMTD bands remain, but after long vulcanization the TMTD bands are replaced by ZnDMDC bands.

Irradiation of dextran and its aqueous solutions with cobalt-60 gamma rays, J. H. Flynn, L. A. Wall, and W. L. Morrow, *J. Res. NBS* **71A**1-433, pp. 25-31 (Jan.-Feb. 1967).

Key words: Aqueous solution; cross-linking; dextran; dextran triacetate; gamma irradiation; polymer degradation; postirradiative decay.

Cross-linking predominates over chain scission during the irradiation of concentrated aqueous dextran solutions by cobalt-60 gamma rays in the absence of oxygen. An extensive and long-lived postirradiative viscosity decay, which has not been previously reported, is attributed to the agency of hydrogen peroxide formed during the radiolysis of water. Solid dextran primarily degrades upon γ-irradiation while dextran triacetate is borderline between dominant scission and cross-linking. Both exhibit a postirradiative viscosity decrease when irradiated in the presence of water vapor. Electron spin resonance spectra of dextran in the solid state and in aqueous solution are presented and compared. Spin resonance spectral and chemical evidence concerning the mechanism of cross-linking and postirradiative decay reactions is presented. There is conflicting evidence for the presence of oxyradicals. Speculations are made concerning possible mechanisms of oxyradical formation and their role in the production of ether and peroxy linkages.

Synthesis of poly-*p*-oxyperfluorobenzylene and related polymers. A novel synthesis of the monomer 2,3,5,6-tetrafluoro-4-trifluoromethylphenol, J. M. Antonucci and L. A. Wall, *J. Res. NBS* 71A1-434, pp. 33-41 (Jan.-Feb. 1967).

Key words: 1-*t*-butoxy-2,3,5,6-tetrafluoro-4-trifluoromethylbenzene; perfluoro-*p*-quinonemethide; polymerization; poly-*p*-oxyperfluorobenzylene; pyrolysis; 2,3,5,6-tetrafluoro-4-trifluoromethylphenol.

The synthesis and polymerization of 2,3,5,6-tetrafluoro-4-trifluoromethylphenol (heptafluoro-*p*-cresol) is described. The polymer, poly-*p*-oxyperfluorobenzylene (polyperfluoro-*p*-benzylene oxide), is probably formed through the perfluoro-*p*-quinonemethide intermediate obtained by the intramolecular loss of either hydrogen fluoride or a metal fluoride. The polymer has a structure analogous to that reported for the polymer derived from *p*-trifluoromethylphenol under similar conditions.

In the course of the synthesis of the monomer, heptafluoro-*p*-cresol, a novel synthetic method was discovered. The synthesis consists in the prior preparation of 1-*t*-butoxy-2,3,5,6-tetrafluoro-4-trifluoromethylbenzene and its subsequent thermal decomposition into the isobutylene and the desired cresol. Similarly, *N*-*t*-butyl-2,3,5,6-tetrafluoro-4-trifluoromethylaniline undergoes a similar liquid phase pyrolysis into isobutylene and 2,3,5,6,-tetrafluoro-4-trifluoromethylaniline. However, during the course of this pyrolysis, practically all of the aniline undergoes polymerization with concomitant loss of hydrogen fluoride. The polymer is formed by the same mechanism operative in the thermal polymerization of *p*-heptafluorocresol except that additional quantities of hydrogen fluoride can be eliminated from the $-NHCF_2-$ segments of the polymer chain thereby introducing -N=CF- units into the polymer backbone.

Other *t*-butyl derivatives were synthesized and their thermal decomposition studied. Several possible mechanisms for the decomposition of these *t*-butyl compounds are considered.

Preparation, purity, and homogeneity of NBS standard samples 705 and 706, polystyrene, D. McIntyre, *J. Res. NBS* 71A1-435, pp. 43-47 (Jan.-Feb. 1967).

Key words: Ash content; elemental analysis; homogeneity; lithium content; molecular weights; polymer; preparation; purity; sampling; standard sample; volatile content.

The state-of-art in the measurement of the molecular weights of macromolecules is discussed. The preparation of polystyrene standard samples 705 and 706 is described. The results and the description of the carbon-hydrogen microanalysis, the ash determination, the lithium analysis, and the volatiles determination are given. The sampling methods for determining the homogeneity of 705 and 706 are presented. Some evidence of heterogeneity appeared to be present, particularly for lot 705, but the experiment did not provide conclusive evidence of heterogeneity of the material.

Large-scale, preparative paper chromatography, H. L. Frush, *J. Res. NBS* 71A1-436, pp. 49-52 (Jan.-Feb. 1967).

Key words: Chromatography on seed-test paper; large-scale paper chromatography; radioactive carbohydrates; use of heavy papers in preparative chromatography.

Simplified techniques are described for the use of heavy papers in large-scale, preparative chromatography. A new technique is illustrated for nondestructively locating bands of compounds on wet chromatograms. Capacities and behavior characteristics of Whatman seed-test paper and Whatman No. 17 paper are illustrated.

Infrared absorption spectra of some aldofuranoid, aldopyranoid, and acyclic 1-acylamido derivatives of sugars, R. S. Tipson, A. S. Cerezo, V. Deulofeu, and A. Cohen, *J. Res. NBS* 71A1-437, pp. 53-79 (Jan.-Feb. 1967).

Key words: Absorption spectra; acyclic sugars; 1-acylamido sugars; aldofuranoid sugars; aldopyranoid sugars; infrared spectra.

The infrared absorption spectra of two glycofuranosylacetamides and their perbenzoates, and of eleven glycopyranosylacylamides and eight esters thereof, are presented and discussed. For comparison, the spectra of thirteen 1,1-bis(acylamido)-1-deoxyalditols and eight esters thereof are also given and discussed.

The useful correlations between structure and infrared absorption made by Barker and co-workers for certain carbohydrates, and by Nanasi and co-workers for some *N*-arylglycosylamines, cannot be extended to the 1-acylamido compounds we have studied. Certain of Verstraeten's correlations may have some diagnostic value.

March-April 1967

Relative enthalpy of beryllium 1:1-aluminate, $BeO{\cdot}Al_2O_3$, from 273 to 1173 °K. Thermodynamic properties from 273 to 2150 °K, D. A. Ditmars and T. B. Douglas, *J. Res. NBS* 71A2-438, pp. 89-95 (Mar.-Apr. 1967).

Key words: Beryllium aluminate; chrysoberyl; drop calorimetry; enthalpy measurements; high-temperature calorimetry; mixed oxides; specific heat; thermodynamic properties.

The relative enthalpy of the beryllium aluminate $BeO{\cdot}Al_2O_3$ was measured by "drop" calorimetry from 273 to 1173 °K. The thermodynamic properties were calculated up to 2150 °K (approximately the melting point). For this calculation, the data were extrapolated above 1173 °K and the entropy at 273 °K, previously determined at the NBS, was used.

Relative enthalpy of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, from 273 to 1173 °K. Thermodynamic properties from 273 to 2150 °K, D. A. Ditmars and T. B. Douglas, *J. Res. NBS* 71A2-439, pp. 97-103 (Mar.-Apr. 1967).

Key words: Beryllium aluminate (1:3); drop calorimetry; enthalpy measurements; high-temperature calorimetry; mixed oxides; specific heat; thermodynamic properties.

The relative enthalpy of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, was measured from 273 to 1173 °K. Thermodynamic properties were calculated up to 2150 °K (near the melting point) by extrapolating the present measurements and making them consistent with existing low-temperature data.

The heats of combustion of polytetrafluoroethylene (Teflon) and graphite in elemental fluorine, E. S. Domalski and G. T. Armstrong, *J. Res. NBS* 71A2-440, pp. 105-118 (Mar.-Apr. 1967).

Key words: Aluminum fluoride; carbon tetrafluoride; fluorine; fluorine bomb calorimetry; graphite; heat of combustion; heat of formation; hydrogen fluoride aqueous; Teflon.

Bomb calorimetric measurements are reported for the combustion in fluorine of polytetrafluoroethylene (Teflon) and graphite-polytetrafluoroethylene mixtures. Mass spectrometric examination of the product gases showed CF_4 to be the only major product with $C_2F_6(g)$ present in only very small amounts. The completeness of combustion of the graphite was determined by chemical analysis of combustion residues and found to range from 97 to better than 99 percent. From the combustion data, the heats of formation $\Delta H\,°_{f298}[CF_4(g)]$ and $\Delta H\,°_{f298}[C_2F_4$ (solid

polymer)] were determined to be -222.87 ± 0.38 kcal mol^{-1} and -197.82 ± 0.39 kcal (gfw $C_2F_4)^{-1}$, respectively. The uncertainties are estimates of the overall experimental errors.

A previously reported value for the heat of formation of AlF_3(c) is adjusted to be consistent with the present work. An evaluation of other data on CF_4 is presented. The heat of formation of CF_4(g) is combined with other work to derive the heats of formation of HF solutions at three specific concentrations.

Phase relations in the systems TiO_2-IrO_2 and SnO_2-IrO_2 in air, C. L. McDaniel and S. J. Schneider, *J. Res. NBS* 71A2-441, pp. 119-123 (Mar.-Apr. 1967).

Key words: Dissociation; phase relations; SnO_2-IrO_2 system; solid solution; TiO_2-IrO_2 system.

The pseudobinary systems TiO_2-IrO_2 and SnO_2-IrO_2 were studied by x-ray diffraction after treatment at various temperatures in air. Their equilibrium phase diagrams were similar, with no intermediate phases detected in either system. Maximum solid solution of TiO_2 occurs with the addition of about 5 mole percent IrO_2 at 1040 °C. Solid solution of TiO_2 in IrO_2 extends to a maximum of about 12 mole percent TiO_2 at 1040 °C, the dissociation temperature. Limited solid solubility of SnO_2 in IrO_2 exists up to 3 mole percent SnO_2 at the dissociation temperature, 1025 °C. Solid solution in SnO_2 was not detected at temperatures up to 1400 °C.

Sample purity and the N.Q.R. of Cl^{35} in $KClO_3$ at 0 °C, D. B. Utton, *J. Res. NBS* 71A2-442, pp. 125-126 (Mar.-Apr. 1967).

Key words: Measurements at 0 °C; nuclear quadrupole resonance thermometry; potassium chlorate.

It is shown that careful preparation is necessary to achieve a consistent value for the Cl^{35} nuclear quadrupole resonance frequency in $KClO_3$ samples at 273.16 °K (the triple point of water). This is illustrated by measurements on a number of samples. It is suggested that the N. Q. R. frequency of Cl^{35} in $KClO_3$ at 273.16 °K and atmospheric pressure is 28,213,372±2Hz. This value is compared with measurements made by previous workers which show a considerable spread.

Techniques for the growth of large single crystals of potassium of high purity, H. J. Foster and P. H. E. Meijer, *J. Res. NBS* 71A2-443, pp. 127-132 (Mar.-Apr. 1967).

Key words: Crystal growth; fermi surface; orientation; potassium; spark cutting; zone refining.

The preparation of large, high purity, single crystals of potassium is described. First, high initial purity is obtained by careful zone refining. Then, a modification of the Bridgman technique is applied which leads to crystals with resistivity ratios up to 6800 at 4.2 °K. The modification consisted of a heat shield as described in the test. We concluded from the magnetoacoustic experiments that were subsequently done with these samples, that the samples had mean free paths of the order of 10^{-2} cm. Typical crystals were 7/8 in diam and about 8 in long, with growth direction along [110]. A description is given of an easy method of orientation as well as the use of a spark erosion technique to cut and polish the surfaces.

Synthesis of α-L-fucose-1-^{14} *C* (6-deoxy-L-galactose-1-^{14}*C*), H. S. Isbell, H. L. Frush, and N. B. Holt, *J. Res. NBS* 71A2-444, pp. 133-136 (Mar.-Apr. 1967).

Key words: Carbon-14-labeled L-fucose; L-fuconic acid-*1*-^{14}*C*; L-fucose-*1*-^{14}*C*; radioactive carbohydrates; synthesis of radioactive sugars.

α-L-Fucose-*1*-^{14}*C* was synthesized in a radiochemical yield of 30 percent. The synthesis involved degradation of nonradioactive L-fuconic acid to 5-deoxy-L-lyxose and synthesis from this of α-L-fucose-*1*-^{14}*C* by use of ^{14}C-labeled cyanide in the cyanohydrin reaction. The resulting epimeric, ^{14}C-labeled aldonic acids were separated as either the barium or the sodium salts. Both salts of L-fuconic acid crystallize more readily than corresponding salts of the epimeric 6-deoxy-L-talonic acid.

The preparation of barium L-fuconate by the electrolytic oxidation of L-fucose in the presence of barium carbonate and barium bromide is described.

Deuterium isotope effects in α-β pyranose and in pyranose-furanose interconversions, H. S. Isbell and C. W. R. Wade, *J. Res. NBS* 71A2-445, pp. 137-148 (Mar.-Apr. 1967).

Key words: Acid-base catalysis in D_2O; deuterium isotope effects; D-fructose; D-glucose; isotope effects; mechanism of mutarotation; mutarotation; pyranose-furanose interconversions; sugars in solution.

Rates of mutarotation, catalytic coefficients, and isotope effects are reported for the mutarotations of α-D-xylose, α-D-glucose, and β-D-fructose in H_2O and in D_2O at 20 °C. The isotope effects (k_h/k_d) for the mutarotation of β-D-fructose (a pyranose-furanose interconversion) parallel in striking manner the isotope effects for the mutarotation of α-D-glucose (an α-β pyranose anomerization). For each sugar, the isotope effect is lowest for the acid-catalyzed reaction and highest for the water-catalyzed reaction. The parallelism of the values obtained for the isotope effects under various conditions shows that the rate-determining steps in the two reactions are similar. Presumably, in both instances, the overall mutarotation arises from concurrent reactions operating on different species of the sugar and showing substantially different isotope effects. The gradual change in the isotope effect indicates that, under the conditions studied, three reactions take place concurrently.

The following isotope effects were found for the mutarotations at 20 °C: For α-D-glucose, k_{H3O+}/k_{D3O+}=1.39: k_{H2O}/k_{D2O}=3.87; and k_B/k^*_B=1.83. For β-D-fructose, k_{H3O+}/k_{D2O+}=1.39; k_{H2O}/k_{D2O}=3.87; and k_B/k^*_B=1.92. Mechanisms are presented for the several concurrent acid- and base-catalyzed mutarotation reactions.

Calculated transition strengths between the configurations $5d^86s$ and $5d^86p$ in Au III, H. Mendlowitz, *J. Res. NBS*, 71A2-446, pp. 149-156 (Mar.-Apr. 1967).

Key words: Au III; calculated transition strengths; configurations $5d^86s$ and $5d^86p$.

The transition strengths have been calculated for transitions between configurations $5d^86s$ and $5d^86p$ of Au III based upon the wavefunctions given by Shadmi. These strengths have been compared with the estimated intensities given by Iglesias and are found to be in substantial agreement.

Hartree-Fock multiplet strengths for K I, Ca II, and Sc III, A. W. Weiss, *J. Res. NBS*, 71A2-447, pp. 157-162 (Mar.-Apr. 1967).

Key words: Multiplet strength; self-consistent field; term values; wavefunctions.

Analytical approximations to Hartree-Fock wavefunctions have been computed for the 4*s*, 4*p*, and 3*d* states of K I, Ca II, and Sc III. Multiplet strengths for the 4*s*-4*p* and 4*p*-3*d* transitions in these ions are also computed. Examination of the results indicate that relaxation of the core in the field of the series electron accounts for a large portion of the core polarization effect, at least for the 3*d* level. Serious cancellation is found to invalidate the dipole velocity results of the 4*p*-3*d* transition in Ca II.

Oscillator strengths for the helium isoelectronic sequence, A. W. Weiss, *J. Res. NBS*, 71A2-448, pp. 163-168 (Mar.-Apr. 1967).

Key words: Atomic term value; oscillator strengths; wavefunctions.

Variational wavefunctions have been computed for the 1^1S, $2^{1,3}S$, $2^{1,3}P$, $3^{1,3}P$, and $3^{1,3}D$ terms of ions in the helium isoelectronic sequence from He through Ne^{+8}. The trial functions are Hylleraas type expansions, explicitly involving r_{12}, and with expansion lengths of around 50 terms, differing slightly for the different states. Oscillator strengths have been computed for all the allowed transitions by both the dipole length and velocity formulas. Agreement between these forms, comparisons with very accurate data for neutral helium, and the accuracy of the computed energies all point to considerable reliability of the results for the entire sequence, probably around 5 percent, if not better.

Solvent effects on the ultraviolet absorption of polystyrene, V. M. Story, D. McIntyre, and J. H. O'Mara, *J. Res. NBS*, 71A2-449, pp. 169-175 (Mar.-Apr. 1967).

Key words: Carbon tetrachloride; cyclohexane; ethylbenzene; extinction coefficient; polymer; polystyrene; solvent effects; ultraviolet absorption.

NBS Standard Sample Polystyrene 705 is shown to exhibit a small, but significant, hypochromism in the 38,300 cm^{-1} region in several solvents compared to the model compound, ethylbenzene. Beer's law is not obeyed for solutions of the polymer in all solvents. The concentration dependence of the extinction coefficient is related to the scattered light and its dependence on the activity coefficient of the solvent. The specific extinction coefficients for polystyrene 705 in cyclohexane and in carbon tetrachloride are 20.89 and 27.38, respectively.

May-June 1967

Measured relative enthalpy of anhydrous crystalline aluminum trifluoride, AlF_3, from 273 to 1173 °K and derived thermodynamic properties from 273 to 1600 °K, T. B. Douglas and D. A. Ditmars, *J. Res. NBS*, 71A3-450, pp. 185-193 (May-June 1967).

Key words: Aluminum trifluoride; drop calorimetry, enthalpy measurements; high-temperature calorimetry; phase transition; pretransition phenomena; specific heat; thermodynamic properties.

The enthalpy of a high-purity sample of anhydrous crystalline aluminum trifluoride, AlF_3, relative to that at 0 °C (273.15 °K), was precisely measured with an ice calorimeter and a "drop" method at 18 temperatures starting at 50 °C and proceeding in 50-deg steps to 900 °C (1173.15 °K). Thirty additional enthalpy measurements between 450 and 453 °C revealed a gradual transition. A simple general relation for the progress of transition when impurity is in solid solution is derived. The relation fits the observed transition data and indicates a first-order transition temperature of 455 °C (728 °K). X-ray powder patterns on the sample, measured in the Crystallography Section of the NBS, established the existence of a phase transition by showing not only the known hexagonal structure at room temperature (even after violent quenching from above the transition temperature region) but a new, simple-cubic structure at 570 °C (843 °K). The smooth heat-capacity curve formulated from the data merges very smoothly with that representing published precise low-temperature data. The common thermodynamic properties were derived, and are tabulated at and above 273.15 °K, with extrapolation up to 1600 °K.

The heat of formation of boron trifluoride by direct combination of the elements, E. S. Domalski and G. T. Armstrong, *J. Res. NBS*, 71A3-451, pp. 195-202 (May-June 1967).

Key words: Bomb calorimeter; boron; boron trifluoride; fluorine; heat of formation; Teflon.

The energy of combination of crystalline boron in gaseous fluorine was measured in a bomb calorimeter. The experimental data combined with reasonable estimates of all known errors may be expressed by the equation:

$$B(c) + 3/2F_2(g) = BF_3(g), \Delta H°_{f298} = -271.03 \pm 0.51 \text{ kcal mol}^{-1}.$$

This result is compared with other recent work on and related to the heat of formation of boron trifluoride.

An equation of state for fluid parahydrogen from the triple-point to 100 °K at pressures to 350 atmospheres, R. D. Goodwin, *J. Res. NBS* 71A3-452, pp. 203-212 (May-June 1967).

Key words: Equation of state; hydrogen; parahydrogen; *PVT*-relations; thermodynamic properties.

This equation of state may be useful for interpolation and for computations which include thermodynamic properties of parahydrogen. A principal advantage is that it employs only one set of 24 coefficients for all fluid states. The basic form is relatively simple. And adjustment term for the critical region leads to good agreement with published PVT data and specific heats in this especially difficult area. The forms of fitting functions were developed by systematic trial methods using least squares to find the coefficients.

The dissociation constants of some disubstituted anilines and phenols in aqueous solution at 25 °C, R. A. Robinson, *J. Res. NBS*, 71A3-453, pp. 213-218 (May-June 1967).

Key words: Dissociation constant; substituted anilines; substituted phenols.

The dissociation constants of six disubstituted anilines and of five disubstituted phenols in aqueous solution at 25 °C have been measured using the spectrophotometric method. Consideration is given to the extent to which these dissociation constants can be predicted from corresponding values for monosubstituted anilines and phenols. In addition, the question as to whether the *pK* value of a substituted aniline can be predicted from the *pK* value of a phenol with substituents in the same positions is also investigated.

Third virial coefficient for air-water vapor mixtures, R. W. Hyland and E. A. Mason, *J. Res. NBS*, 71A3-454, pp. 219-224 (May-June 1967).

Key words: Chemical association; Lennard-Jones potential parameters; virial coefficients; water vapor-air mixtures.

The third interaction virial coefficient C_{aww} for air-water vapor mixtures is estimated in the temperature range 0 to 100 °C, by means of an approximate method based on molecular association. The results are believed accurate to within a factor of two. The value of C_{aww} can be combined with previous estimates of the other interaction coefficient C_{aaw} and the values of the third virial coefficients of pure air and pure water vapor, to give a quantitative description of the equation of state of air-water vapor mixtures through the complete third virial coefficient. It is shown that the maximum total contribution from both C_{aww} and C_{aaw} to the compressibility factor is only of the order of parts in 10^4 up to 100 °C and 100 atmospheres total pressure. At -50 °C, it can be shown by extrapolation of C_{aww} that the contribution of the C_{aww} term to the compressibility factor is only on the order of parts in 10^{11}.

Recrystallization and melting of partially melted stark rubber, D. E. Roberts, *J. Res. NBS* 71A3-455, pp. 225-229 (May-June 1967).

Key words: Crystal size; crystallized rubber; heating rate; melting range; melting temperature; oriented; partial melting; recrystallization; rubber; slow melting; stark rubber.

Two specimens from a piece of stark rubber which had a melting temperature originally at 41 °C were partially melted at 38 °C and allowed to stand for 11 years, one at about 25 °C, the other at 38 °C. The first showed a continuous slow decrease in specific volume, while the second increased slowly in volume for 5 months and remained constant for about 5 months more before showing the continuous slow decrease. The melting temperature of the first increased to 45 °C and the melting range was broadened. The melting temperature of the second became 52 °C and the range was narrowed. Perfecting or enlarging of crystals and the effect of higher recrystallization temperatures have influenced the melting temperatures. The effect of heating rate is discussed in connection with slow increases in volume, attributed to relaxation of oriented regions, during melting.

Effects of a distribution of volume relaxation times in the annealing of BSC glass, P. B. Macedo and A. Napolitano, *J. Res. NBS*, 71A3-456, pp. 231-238 (May-June 1967).

Key words: Annealing; borosilicate crown glass; glass; index of refraction; relaxation times; two-relaxation time model; volume relaxation.

The influence of a distribution of relaxation times is studied in annealing experiments. A two-relaxation time model is proposed, which permits the calculation of the distribution of relaxation times from the crossover data of Spinner and Napolitano as well as that of Ritland. This model also characterizes the structure of any glass in terms of two parameters. Thus, quenched equilibrium as well as nonequilibrium glass were compared with rate cooled glasses with respect to their behavior upon further annealing as well as their conductivity at low temperatures with excellent agreement.

Borosilicate crown glass was found to have a narrow distribution of relaxation times which is particular to associated liquid monomers rather than polymers. The results can be explained in terms of a topological model for the distribution of relaxation times. The temperature dependence of the viscosity is due to a true activation energy rather than a free volume effect.

July-August 1967

Kinetics of crystallization in multicomponent systems: I. Binary mixtures of *n*-paraffins, J. I. Lauritzen, Jr., E. Passaglia, and E. A. DiMarzio, *J. Res. NBS* 71A4-457, pp. 245-259 (July-Aug. 1967).

Key words: Crystal growth; kinetics; multicomponent systems; *n*-paraffins; pair distributions; phase diagrams.

The kinetics of crystallization of a binary mixture of *n*-paraffins is treated using a theory for the rate of growth of chains in multicomponent systems. The kinetic chain is considered to be a strip of crystalline material composed of molecules of both components that is growing on a substrate of uniform thickness. This substrate is considered to be a close-packed surface step. Using the binary mixture of $C_{24}H_{50}$ and $C_{26}H_{54}$ as an example, the calculations are carried out by an iterative procedure so that the mean thickness of the strip equals that of the substrate. This procedure necessitates modification of the rate constants that would be used without this requirement. The rate of growth of the strips (total flux) is calculated as well as their composition over an appropriate range of temperature and a complete range of liquid compositions. The pair distribution in the strips is also determined. The substrate is assumed to be unkinked in the calculations, whereas the substrate is probably highly kinked in the actual system. For this reason the calculated total flux is probably not representative of the actual crystal growth rate in a binary mixture of $C_{24}H_{50}$ and $C_{26}H_{54}$. It is believed that the calculated compositions are reasonably accurate. For a binary mixture of longer *n*-paraffins (e.g., $C_{50}H_{102}$ $C_{52}H_{106}$) the substrate should have many fewer kinks, and the total flux calculated by this theory will be more closely related to actual crystal growth rate studies. However, no data exist for such systems.

Kinetics of crystallization in multicomponent systems: II. Chain-folded polymer crystals, J. I. Lauritzen, Jr. and E. Passaglia, *J. Res. NBS* 71A4-458, pp. 261-275 (July-Aug. 1967).

Key words: Chain-folded crystals; crystal growth; kinetics; multicomponent systems; surface free-energy.

Using polyethylene as an example, the kinetics of growth of chain-folded polymer crystals is treated using a theory for the kinetics of growth of chains in multicomponent systems. The kinetic chain is considered to be a chain-folded strip growing on the lateral face of a chain-folded lamella, and the various components are the possible lengths l_j the polymer chain may form on folding at the end of the growing strip. Thus, the number of components is in principle infinite, but it is sufficient to take a number of the order of 20-50 for the calculations. By an iteration procedure, the calculations are carried out so that the average thickness of the strip is the same as that of the chain-folded lamella on which it grows. This necessitates modification of the rate constants that would be used without this requirement. The rate of growth, average thickness and its standard deviation, and the pair distribution are calculated as a function of undercooling and other relevant parameters of the system. The results for the rate of growth and thickness are similar to those of simpler theories, provided that the constant end-surface free-energy of those theories is replaced by a temperature dependent "effective" surface free-energy. The standard-deviation of the thickness is larger than commonly believed, values of 8 to 14 Å being typical. Consequently, the crystals as grown may have quite rough fold surfaces, although the equilibrium roughness will be less.

Infrared absorption spectra of 2-oxo-1,3-bis(phenylhydrazono) derivatives and related bis- and tris-phenylhydrazones, A. J. Fatiadi, *J. Res. NBS* 71A4-459, pp. 277-285 (July-Aug. 1967).

Key words: Absorption spectra; infrared spectra; mono-, bis-, and tris-(phenylhydrazones); phenylazo compounds.

The infrared absorption spectra of six 2-oxo-1,3-bis(phenylhydrazones), four tris(phenylhydrazones), and six related mono- and bis-(phenylhydrazono) derivatives are presented. For comparison, partial spectra of ten selected aromatic azo compounds are also given and discussed.

The important features of the absorption bands arising from the N=N (1579 to 1558 cm^{-1} and 1447 to 1408 cm^{-1}), N–H (bending) (1557 to 1515 cm^{-1}), and Ph–N (1163 to 1123 cm^{-1}) groups are presented and discussed.

Dielectric constant of *n*-hexane as a function of temperature, pressure, and density, F. I. Mopsik, *J. Res. NBS* 71A4-460, pp. 287-292 (July-Aug. 1967).

Key words: Clausius-Mossotti; density; dielectric constant; dilatometer; function; high pressure; *n*-hexane; pressure; three-terminal electrode set.

A description is given of apparatus employing a cell that is both a bellows dilatometer and a three-terminal electrode set for measuring simultaneously the density and dielectric properties of

liquids as functions of temperature and pressure. Measurements are possible at temperatures from 120 °K to over 300 °K and pressures from 1 to 2000 atm with an uncertainty of 0.03 percent. The density, dielectric constant, and Clausius-Mossotti function of *n*-hexane have been measured for temperatures from 223 to 298 °K (−50 to 25 °C) and at pressures from 1 to 2000 atm. There is a linear decrease in the Clausius-Mossotti function with density and a decrease with temperature corresponding to an effective dipole moment of 0.085 debye.

Heat capacities and related thermal data for diethyl phthalate crystal, glass, and liquid to 360 °K, S. S. Chang, J. A. Horman, and A. B. Bestul, *J. Res. NBS* 71A4-461, pp. 293-305 (July-Aug. 1967).

Key words: Annealed glass; crystal; diethyl phthalate; glass transformation; heat capacity calorimetry; molecular configurational state, normal and supercooled liquid; quenched glass, residual (configurational) entropy; thermodynamic properties.

Experimentally determined heat capacity values, precise to within 0.1 percent, and related thermal data are reported for quenched and annealed diethyl phthalate glasses from 10 °K to the glass transformation temperature, T_g (around 180 °K), for the liquid from T_g to 360 °K, and for the crystal from 10 °K to the melting temperature (269.9 °K). The mole fraction of liquid-soluble, solid-insoluble impurity in the sample as determined by fractional melting was 0.0012. Common thermodynamic properties calculable from the experimental data are reported. The heat capacities of the two glasses differ by more than the uncertainty of the measurements, and both lie below that of the crystal in the range from 30 to 75 °K. At low temperatures, just above 10 °K, the heat capacities of the glasses rise as much as 8 percent above that of the crystal.

Heats of formation of aluminum diboride and α-aluminum dodecaboride, E. S. Domalski and G. T. Armstrong, *J. Res. NBS* 71A4-462, pp. 307-315 (July-Aug. 1967).

Key words: Aluminum diboride; α-aluminum dodecaboride; aluminum fluoride; bomb calorimeter; boron trifluoride; fluorine; heat of combustion; heat of formation; Teflon.

The energies of combustion of AlB_2 and α-AlB_{12} were measured in a bomb calorimeter using fluorine as the oxidant. Major problems of this investigation were the assessment of the state and distribution of impurities in the samples and the establishment of the stoichiometry of the aluminum boride phase. We obtain -16 ± 3 kcal mol^{-1} and -48 ± 10 kcal mol^{-1} for the heats of formation of AlB_2 and α-AlB_{12}, respectively. The uncertainties cited are the overall experimental errors. Their magnitudes are chiefly due to uncertainties in the impurity correction applied and the uncertainties in the heats of formation of the combustion products.

Effect of environment upon the melting point of Al_2O_3. S. J. Schneider and C. L. McDaniel, *J. Res. NBS* 71A4-463, pp. 317-333 (July-Aug. 1967).

Key words: Al_2O_3; dissociation; environmental effects; melting point; premelting.

The melting point of Al_2O_3 has been determined in vacuum, air, argon, and helium utilizing iridium or tungsten containers. All melting point experiments were conducted in induction furnaces capable of heating small samples under blackbody conditions to 3000 °C in vacuum, 2600 °C in inert atmospheres, and 2400 °C in air. Temperatures were continuously monitored with a recording photoelectric pyrometer which has a sensitivity of ±0.2° at 1063 °C and ±1° at 2000 °C. Melting points were determined on specimens having a purity in excess of 99.9 percent. The data indicated that the melting point of Al_2O_3 determined in vacuum ($\sim 6.5 \times 10^{-5}$ torr) is 2051 °C (IPTS). The overall maximum uncertainty was estimated to be ±6 °C. The measurements themselves were precise within ±1.5 °C. Vacuum treatment had least detrimental effect upon the Al_2O_3 specimens. Each of the gaseous atmospheres including air yielded lower melting points for Al_2O_3, presumably due to a premelting phenomenon.

September-October 1967

Zeeman effect in positronium annihilation at low temperatures, W. C. Sauder and R. D. Deslattes, *J. Res. NBS* 71A5-464, pp. 347-353 (Sept.-Oct. 1967).

Key words: Annihilation radiation; Compton wavelength of the electron; positronium; quenching.

The annihilation of positronium is discussed as a means of obtaining a precise measurement of the Compton wavelength of the electron. In particular the spectral line shape of the annihilation radiation is calculated for positronium thermalized in helium gas cooled to the region of its critical point with an applied magnetic field sufficient to yield a three photon to two photon branching ratio of unity for the $^3S_0$ component. Under such conditions the rapid thermalization of the positronium and the long half-life of two photon decay out of the predominantly triplet state make possible the production of rather narrow spectral distributions. An exact solution of the Zeeman effect in positronium is included. This study suggests that a wavelength determination beyond the one part per million level is attainable within the range of present technology.

Surface-layer relaxation in the dielectric spectrum of CaF_2 doped with GdF_3. A. D. Franklin, S. Marzullo, and J. B. Wachtman, Jr., *J. Res. NBS* 71A5-465, pp. 355-362 (Sept.-Oct. 1967).

Key words: CaF_2; conductivity; crystals; defect pairs; dielectric relaxation; electrode capacitance; surface layers.

CaF_2 crystals doped with 0.1 percent GdF_3 were observed to develop surface layers when annealed above 700 °C in air, during application of Pt paste electrodes. The conductivity in these surface layers was much higher than in the bulk, due presumably to the large numbers of anion vacancies produced by dissolved oxygen. The presence of these high conductivity surface layers produced a relaxation in the dielectric spectrum with (1) an approximately temperature-independent magnitude, $\Delta\kappa$, (2) a relaxation time controlled by the conductivity of the surface layers, and influenced therefore by heat treatment of the specimen, and (3) an activation energy equal to that for conductivity of the surface layers, about 0.9 eV. This relaxation is sufficiently similar to dielectric relaxations observed previously in ionic crystals and ascribed to defect pairs to suggest that great care must be taken in interpreting dielectric measurements in these materials. What is thought to be dipole relaxation may in fact be due to the presence of thin layers accidentally present on the crystal. There is a marked electrode polarization effect in these crystals. The electrode capacitance at not-too-low frequencies depended upon the frequency and both the number and mobility of the charge carriers with 3/2 power laws.

Thermal expansion of rutile from 100 to 700 °K, R. K. Kirby, *J. Res. NBS* 71A5-466, pp. 363-369 (Sept.-Oct. 1967).

Key words: Anisotropic crystal; Gruneisen's constant; interferometer; rutile; thermal expansion.

The thermal expansion of a single crystal of rutile (TiO_2) was determined in directions parallel to its crystallographic axes. A unique macroscopic technique was used wherein a cube-shaped specimen was cut from the anisotropic crystal, each of its six faces polished flat and nearly parallel to the face opposite it, and

the expansion measured along each of its three body axes with an Abbe-Pulfrich interferometer. The relationship between the expansion along the body axes of the specimen and that in the crystallographic directions was determined from a Laue x-ray pattern. The unusual behavior of the thermal expansion that was observed can be explained by assuming an acoustical and optical contribution where the corresponding Gruneisen constants are 2.80 and 0.75 respectively.

Mass spectrometric study of photoionization. VII. Nitrogen dioxide and nitrous oxide, V. H. Dibeler, J. A. Walker, and S. K. Liston, *J. Res. NBS* **71A**5-467, pp. 371-378 (Sept.-Oct. 1967).

Key words: Dissociation; fragment ions; ionization; mass spectrometer; molecule; NO_2; NO_2^+ N_2O^+; photoionization; threshold; ultraviolet; vacuum.

Photoionization efficiency curves are obtained for the molecule and fragment ions of NO_2 and N_2O from ionization threshold to 600 Å. Features of the molecule ion curves are ascribed to autoionization and the Rydberg levels are correlated with reported spectroscopic observations. The minimum onset of ionization for NO_2 occurs at 1272 Å (9.75 eV). The threshold value of 12.34 eV for the NO^+ fragment results in $D(NO-O)$ of 3.09 eV in good agreement with that calculated from thermochemical heats of formation. The O^+ ion is apparently formed with 0.1 eV excess energy. The minimum threshold energy for the N_2O^+ ion is 962 Å (12.89 eV). The N_2^+ fragment ion curve has a threshold at 17.29 eV corresponding to the thermochemical bond energy, $D(N_2-0)=1.67$ eV. However a lower-energy threshold at 15.57 eV is ascribed to ionization of molecular nitrogen from an unknown source. There is no evidence for an ion-pair process. The ground state transition for NO^+ is forbidden by spin conservation rules. The observed threshold is 0.8 eV in excess of the calculated value and suggests a vibrationally excited state of the ion. The N^+ ion is also formed with excess energy.

Ionization constants of substituted benzoic acids in ethanol-water, G. M. Brauer, G. Durany, and H. Argentar, *J. Res. NBS* **71A**5-468, pp. 379-384 (Sept.-Oct. 1967).

Key words: Allyl- and propenylbenzoic acids; change of pK with dielectric constant; Hammett sigma constants; ionization constants; pK values in ethanol-water; sigma constants in ethanol-water; substituted benzoic acids.

The thermodynamic ionization constants of meta and para substituted allyl- and propenylbenzoic acids were determined potentiometrically in aqueous ethanol of varying ethanol concentration. The pK values increase with increasing ethanol content. The relative acid strength does not vary with change in solvent concentration. The $\Delta pK/\Delta$ percent ETOH increases with ethanol content of the medium until a maximum is reached around 40 weight-percent ethanol. A plot of $pK+\log [H_2O]$ versus the reciprocal of the dielectric constant of the solvent gives a nearly linear relationship to about 44 weight-percent ethanol. From pK values found in the literature a similar linear relationship exists for other benzoic acids. With the exception of the p-propenylbenzoic acid the σ-substituent constants of the Hammett equation do not change greatly with ethanol concentration. This behavior may be indicative that the solvation shell surrounding the p-propenyl-acid differs from that of other benzoic acids.

Dissociation constants of some substituted nitrophenols in aqueous solution at 25 °C, R. A. Robinson, *J. Res. NBS* **71A**5-469, pp. 385-389 (Sept.-Oct. 1967).

Key words: Dissociation constant; nitrophenols; substituted phenols.

The dissociation constants of twelve substituted phenols with a nitro group in the o- or p-position have been determined by spectrophotometric measurements in aqueous solution at 25 °C.

November-December 1967
(A Memorial Issue to William Frederick Meggers, July 13, 1888 to November 19, 1966)

The second spectrum of ytterbium (Yb II), W. F. Meggers, (Edited by C. E. Moore), *J. Res. NBS* **71A**6-470, pp. 396-545 (Nov.-Dec. 1967).

Key words: Analysis of Yb II; atomic energy levels of Yb II; classified line of Yb II; spectrum, Yb II; ytterbium, second spectrum; Zeeman effect in Yb II.

The analysis of Yb II provides the most complete interpretation of a complex rare-earth spectrum known to date. The total number of energy levels is 315; 141 even levels and 174 odd levels. Three coupling schemes are represented: LS-coupling for the terms $4f^{14}ns^2S(n=6, 7, 8)$; $4f^{14}nd^2D(n=5,6,7)$ and $4f^{13}6s^2\ ^2F°$: J_lJ_{ll}-coupling for the levels from the configurations $4f^{13}6s6p$ and $4f^{13}5d6p$; and J_lL_{ll}-coupling for those from the $4f^{13}5d6s$ and $4f^{13}5d^2$ configurations.

More than 5000 Yb II lines are listed, of which about 80 percent have been classified, and 95 percent of the total intensity is accounted for. Observed Zeeman patterns for over 1000 lines have yielded g-values for 258 levels. The agreement between observation and theory is excellent as regards both the positions of the energy levels and the g-values. The theoretical work was done in collaboration with Racah and his associates over more than a decade.

A limit, 98150 K, giving an ionization potential of 12.17 eV, has been derived from the three-member ^2S series.

An improved description of technetium spectra (Tc I and Tc II), 2000 to 9000 Å, W. R. Bozman, W. F. Meggers, and C. H. Corliss, *J. Res. NBS* **71A**6-471, pp. 547-565 (Nov.-Dec. 1967).

Key words: Spectra of technetium; technetium, spectra of; wavelengths of technetium.

A new description of technetium spectra has been made that is more complete and provides more accurate data on wavelengths than those reported heretofore. The observations were made in the region 2000 to 9000 Å with arc and spark sources. Larger samples of technetium and spectrographs of higher resolution were used and the number of lines reported (4500) is more than doubled. The intensities are estimated over a range from 1 to 20,000 and the relative strengths in arc and spark permit assignment of the origin of the lines to neutral atoms (3300 lines) or ions (1200 lines).

Lifetimes of energy levels in neutral iron, C. H. Corliss and J. L. Tech, *J. Res. NBS* **71A**6-472, pp. 567-573 (Nov.-Dec. 1967).

Key words: Atomic spectra; energy levels; iron; iron, lifetimes in; lifetimes in Fe I; radiative lifetimes; spectroscopy.

Mean radiative lifetimes for 408 energy levels of neutral iron are calculated from the known transition probabilities of 3288 lines of Fe I.

Transition probabilities in argon I, C. H. Corliss and J. B. Shumaker, Jr., *J. Res. NBS* **71A**6-473, pp. 575-583 (Nov.-Dec. 1967).

Key words: Argon; atomic spectra; transition probabilities.

In order to derive transition probabilities from intensity measurements of Ar I lines made by Dieke and Crosswhite, new

transition probabilities for 26 lines from high levels in Ar I have been measured in a high current constricted arc. With these data, relative level populations of Ar I in Dieke and Crosswhite's microwave discharge are determined and transition probabilities for 240 lines of Ar I in the wavelength range 4100 to 9800 Å are derived. The new values are compared with other published values.

The fifth spectrum of praseodymium, V. Kaufman and J. Sugar, *J. Res. NBS* 71A6-474, pp. 583-585 (Nov.-Dec. 1967).

Key words: Atomic energy levels; isoelectronic sequence; praseodymium; rare earth; sliding spark discharge lamp; spectrum.

Twelve spectral lines of quadruply-ionized praseodymium in the region 840 to 2250 Å are reported. Five terms ($4f^2$F, $5d^2$D, $6s$ ^{2}S, $6p$ ^{2}P, and $7s$ ^{2}S) and the hyperfine splitting of the $6s$ ^{2}S term are given. A calculation of the principal ionization energy ($Pr^{4+} \rightarrow Pr^{5+}$) leads to a value of 57.44 eV with an estimated uncertainty of ±0.05 eV.

Fundamental energy levels of neutral promethium (Pm I), J. Reader and S. P. Davis, *J. Res. NBS* 71A6-475, pp. 587-599 (Nov.-Dec. 1967).

Key words: Atomic spectroscopy; electronic energy levels; neutral atom; promethium; rare earth.

The spectrum of atomic promethium has been observed with a variety of light sources and spectrographs. The Zeeman effect has also been recorded. Analysis of the spectrum shows that the ground configuration of the neutral promethium atom is $4f^5 6s^2$. The relative positions (in cm^{-1}) of the low levels of this configuration are:

$^6H^\circ_{5/2}$	0.00	$^6H^\circ_{13/2}$	3919.03	$^6F^\circ_{5/2}$	5872.84
$^6H^\circ_{7/2}$	803.82	$^6H^\circ_{15/2}$	5089.79	$^6F^\circ_{7/2}$	6562.86
$^6H^\circ_{9/2}$	1748.78	$^6F^\circ_{1/2}$	5249.48	$^6F^\circ_{9/2}$	7497.99
$^6H^\circ_{11/2}$	2797.10	$^6F^\circ_{3/2}$	5460.50	$^6F^\circ_{11/2}$	8609.21

This group represents all levels of $4f^5 6s^2$ expected below 14,000 cm^{-1}. From these results the following values of interaction parameters and their estimated uncertainties have been inferred:

ζ_{4f}=925±20 cm^{-1} $\quad\quad$ E^3=510±20 cm^{-1}

Data on 209 upper levels of even parity and 714 classified lines are given.

PAPERS FROM THE NBS JOURNAL OF RESEARCH, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 72A, JANUARY–DECEMBER 1968

January-February 1968

Reactions of uranium with the platinide elements. I. The uranium-ruthenium system, J. J. Park, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 1-10 (Jan.-Feb. 1968).

Key words: Intermetallic compounds; phase diagram; ruthenium; solubility; uranium.

The phase diagram of the uranium-ruthenium system was constructed from data obtained by thermal analysis, metallographic examination, and x-ray diffraction. The system is characterized by five intermetallic compounds: U_2Ru, formed peritectically near 937 °C; "URu," melting congruently near 1158 °C; U_3Ru_4, formed peritectically near 1163 °C; U_3Ru_5, formed peritectically near 1182 °C; and URu_3, formed peritectically at about 1850 °C. "URu" has a solid-state transition at about 795 °C. One eutectic occurs near 886 °C and 18.5 atomic percent (a/o) ruthenium; and a second at about 1148 °C and 49 a/o ruthenium. The maximum solid solubilities are about 7.5 a/o ruthenium in uranium and near 1.3 a/o uranium in ruthenium. Ruthenium lowers the gamma-uranium transformation to near 691 °C and the beta-transformation to near 625 °C.

Reactions of uranium and the platininde elements. II. The uranium-rhodium system, J. J. Park, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 11-17 (Jan.-Feb. 1968).

Key words: Intermetallic compounds; phase diagram; rhodium; solubility; uranium.

The phase diagram of the uranium-rhodium system was constructed from data obtained by thermal analysis, metallographic examination, and x-ray diffraction. The system is characterized by four intermetallic compounds: U_4Rh_3, formed peritectically near 1155 °C and having a solid state transformation at about 720 °C; U_3Rh_4, formed peritectically near 1450 °C; U_3Rh_5, formed peritectically near 1550 °C; and URh_3, melting congruently at about 1700 °C. One eutectic occurs near 865 °C and 24.5 atomic percent (a/o) rhodium, and a second near 1393 °C and 87 a/o rhodium. The maximum solid solubility of rhodium in uranium is approximately 8 a/o, and of uranium in rhodium is approximately 3 a/o.

Reactions of uranium and the platinide elements. III. The uranium-iridium system, J. J. Park and L. R. Mullen, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 19-25 (Jan.-Feb. 1968).

Key words: Intermetallic compounds; iridium; phase diagram; solubility; uranium.

The phase diagram of the uranium-iridium system was constructed from data obtained by thermal analysis, metallographic examination, and x-ray diffraction. The system is characterized by five intermetallic compounds: U_3Ir, formed peritectically near 945 °C and decomposing eutectoidally near 758 °C; U_3Ir_2, formed peritectically near 1121 °C; UIr, melting congruently at about 1470 °C; UIr_2, formed peritectically above 1850 °C; and UIr_3, having a congruent melting point above 1950 °C. U_3Ir_2 has a solid state transition near 898 °C. One eutectic occurs at 914 °C at about 15 atom percent (a/o) iridium between uranium and U_3Ir; a second occurs between UIr and UIr_2 near 1450 °C; and a third occurs between UIr_3 and iridium at about 1950 °C. The solid solubility of iridium in gamma-uranium is about 5.5 a/o and of uranium in iridium is under 3 a/o. Iridium lowers the gamma-beta uranium transformation to about 681 °C and the beta-alpha transformation to about 565 °C.

Phase relations between palladium oxide and the rare earth sesquioxides in air, C. L. McDaniel and S. J. Schneider, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 27-37 (Jan.-Feb. 1968).

Key words: Dissociation; equilibrium; Ln_2O_3:PdO compounds; Ln_2O_3-PdO systems; phase relations.

The equilibrium phase relations were determined in an air environment between PdO and each of the following: La_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Dy_2O_3, Ho_2O_3, Y_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, and Lu_2O_3. In air PdO dissociates to Pd metal at 800 °C. The dissociation of PdO is apparently a reversible process. The Nd_2O_3-PdO and Sm_2O_3-PdO systems were studied in detail inasmuch as they typified several of the Ln_2O_3-PdO systems. Three compounds, $2Nd_2O_3 \cdot PdO$, metastable $Nd_2O_3 \cdot PdO$, $Nd_2O_3 \cdot 2PdO$ occur in the Nd_2O_3-PdO system. The 2:1, 1:1, and 1:2 compounds, of unknown symmetry, dissociate or decompose at 1135, 860, and 1085 °C, respectively. The 2:1 compound dissociates to the solid phases, Nd_2O_3 and Pd. No further reactions occur between Nd_2O_3 and Pd up to 1300 °C. Three compounds, 2:1, metastable 1:1, and 1:2 occur in the Sm_2O_3-PdO and Eu_2O_3-PdO systems. Two compounds, 2:1 and 1:2 occur in the La_2O_3-PdO system. Other compounds detected were the 1:1 and 1:2 in the Gd_2O_3-PdO system and the metastable 1:1 in the Dy_2O_3-PdO system. Each of these compounds subsequently dissociated upon heating. No apparent reaction occurred between PdO and either Ho_2O_3, Y_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, or Lu_2O_3.

Preparation and purification of some oxidation products of perylene, A. J. Fatiadi, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 39-47 (Jan.-Feb. 1968).

Key words: Absorption spectra; air pollutants; anthraquinone-1,5-dicarboxylic acid; dihydroxyperylenequinones; infrared; perylene; perylenequinones; photo-oxidation products of perylene; polycyclic aromatic hydrocarbons; thin-layer chromatograms; ultraviolet; visible absorption spectra; 4-oxo-4*H*-benz[*de*]anthracene-7,8-dicarboxylic anhydride.

Reliable procedures are given for the purification of perylene, and for the preparation and purification of 3,10-perylenequinone, 1,12-perylenequinone, 2,11-dihydroxy-3,10-perylenequinone, 4,9-dihydroxy-3,10-perylenequinone, 4-oxo-4*H*-benz[*de*]-anthracene-7,8-dicarboxylic anhydride, phenanthrene 1,8,-9,10-tetracarboxylic dianhydride, and anthraquinone-1,5-dicarboxylic acid. Data on the physical properties of 3,9-perylenequinone are also reported.

Electron spin resonance spectra of polymer radicals in aqueous solution, R. E. Florin, F. Sicilio, and L. A. Wall, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 1, 49-73 (Jan.-Feb. 1968).

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

Key words: Abstraction; dextran; dextrin; free radicals; hydroxyl; polyacrylic; polyethylene imine; polyethylene oxide; polymer degradation; polymethacrylic acid; polypropylene oxide; polyvinyl alcohol; starch.

Mixing of aqueous polymer solutions containing Ti^{3+} and H_2O_2 in a rapid flow mixer produced radicals by abstraction, OH + RH → R · + H_2O, which were observed by electron spin resonance. Oscillation of segments was sufficient to narrow the lines to 0.5 — 2.0 g. Polymers and radicals identified with more or less certainty were polyacrylic acid, ~~$CH(CO_2H)\dot{C}HCH(CO_2H)$~~, polymethacrylic acid, ~~$C(CH_3)(CO_2H)\dot{C}HC(CH_3)(CO_2H)$~~, polyvinyl alcohol, ~~$CHOH\dot{C}HCHOH$~~, and one indefinite, polyethylene imine, ~~$CH_2\dot{N}CH_2$~~ or ~~$CH_2\dot{N}OCH_2$~~, polyethylene oxide, ~~$CH_2O\dot{C}HCH_2O$~~. Radicals from polypropylene oxide, dextran, dextrin, soluble starch, and the disaccharide maltose were unidentified; the last three were strikingly similar.

Products of secondary C—C scission were not observed with certainty. It is presumed that such reactions are slow compared to the time-scale of the experiment, 10 msec. However, some evidence exists for a very rapid β—OH loss in carbohydrate radicals and a slow C—O scission in polyethylene oxide radicals. A large number of related small molecule radicals were investigated, and hyperfine splittings and g-values are reported.

A mass spectrometric study of the BeO-BeF_2 system of high temperatures, J. Efimenko, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 1, 75-80 (Jan.-Feb. 1968).

Key words: Beryllium difluoride; beryllium oxide; high temperatures; mass spectrometry; reaction enthalpy; sublimation enthalpy.

Mass spectrometric studies were made at high temperatures of the vapors over BeF_2(s) and BeO(s) individually and of their mixture. The sublimation enthalpy, ΔH_0° = 55.56 ± 0.43 kcal/mol, where 1 kcal equals 4184 J, was obtained for BeF_2 by the use of a log I^+T versus $1/T$ plot. A complex molecule appeared in the BeF_2-BeO system at high temperatures which, on the basis of its m/e position, corresponded to Be_2OF_2. For the reaction, BeO(s)+BeF_2(g)=Be_2OF_2(g), a second law treatment of the data gave an enthalpy value, ΔH_0°=41.56±1.8 kcal/mol. The data, combined with free energy functions, resulted in a mean reaction enthalpy, ΔH_0°=42.6 kcal/mol. The heat of formation for Be_2OF_2(g), ΔH_0°=−288.3 kcal/mol, was computed using the reaction enthalpy based on the second law.

Laser induced Raman spectra of some tungstates and molybdates, R. K. Khanna, W. S. Brower, B. R. Guscott, and E. R. Lippincott, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 1, 81-84 (Jan.-Feb. 1968).

Key words: Molybdates; Raman spectra; tungstates.

The Raman spectra of single crystals of $CaWO_4$, $CaMoO_4$, $PbWO_4$, and $PbMoO_4$ have been recorded using a He-Ne laser (λ = 6328 Å) and an Argon ion laser (λ = 4880 Å) as the exciting radiation sources. The polarization data have enabled us to classify unambiguously the observed fundamentals into the Raman active species of the point group C_{4h} to which these crystals belong. The comparison of the spectra of these crystals in the low frequency region has also enabled us to make a rough classification of the bands into the rotational and the translational lattice vibrations.

Valence-only correlation in LiH and BeH^+, W. A. Sanders and M. Krauss, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 1, 85-90 (Jan.-Feb. 1968).

Key words: BeH^+; correlation energy; dissociation energy; LiH; molecular orbital; potential energy curve.

The pseudonatural orbital procedure has been applied to the calculation of the potential energy curve of LiH and the dissociation energy of BeH^+. Only the two-electron bonding pair is correlated and estimates of σ and π type correlation are obtained. The results for LiH are in good agreement with the most accurate previously published calculations. Comparison with experimental results for LiH indicates that the calculated dissociation energies are accurate to about 0.15 to 0.2 eV.

Thermalization by elastic collisions: positronium in a rare gas moderator, W. C. Sauder, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 1, 91-93 (Jan.-Feb. 1968).

Key words: Elastic collisions; positronium; thermalization.

The energy decay of particles moving through a moderating medium is discussed for the case in which only elastic collisions occur between these incoming particles and the moderator atoms; the random thermal motion of the moderator atoms is taken into account. It is shown that if the cross section is independent of particle velocity the equation for the energy decay emerges in a rather simple form involving the hyperbolic cotangent. Finally, the theoretical development is applied to estimating the thermalization time of positronium in rare gas moderators, and is shown to agree with the limited experimental results presently available.

Density fluctuations in fluids having an internal degree of freedom, R. D. Mountain, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 1, 95-100 (Jan.-Feb. 1968).

Key words: Brillouin scattering; density fluctuations in liquids; Rayleigh scattering; spectral distribution of scattered light; structural relaxation; thermal relaxation; volume viscosity.

The frequency spectrum of density fluctuations is calculated for a fluid whose molecules possess an internal degree of freedom which is weakly coupled to the translational degree of freedom of the fluid. Irreversible thermodynamics is used to obtain an equation of motion for the internal degree of freedom. This equation plus the linearized hydrodynamic equations are solved for the frequency spectrum of density fluctuations. The results are compared with a similar calculation involving a frequency dependent volume viscosity. The results are identical for structural relaxation but there is a difference for thermal relaxation. The origin of the difference is discussed and the magnitude of the difference is examined for CCl_4 and for CS_2.

March-April 1968

Constant pressure flame calorimetry with fluorine. II. The heat of formation of oxygen difluoride, R. C. King and G. T. Armstrong, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 2, 113-131 (Mar.-Apr. 1968).

Key words: Bond energy (O—F); flame calorimetry; flow calorimetry; fluorine; heat of formation; heat of reaction; hydrogen fluoride (aqueous); oxygen; oxygen difluoride; reaction calorimetry; water.

The heats of the following reactions were measured directly in an electrically calibrated flame calorimeter operated at one atm pressure and 303 °K.

$$OF_2(g) + 2H_2(g) + 99H_2O(l) \rightarrow 2[HF \cdot 50H_2O](l)$$

$$F_2(g) + H_2(g) + 100H_2O(l) \rightarrow 2[HF \cdot 50H_2O](l)$$

$$\tfrac{1}{2}O_2(g) + H_2(g) \rightarrow H_2O(l)$$

The reactants and products were analyzed for each of the reactions. From these heats we calculated the corresponding heats of formation, as follows:

$OF_2(g)\Delta H^\circ_{f298.15} = +24.52 \pm 1.59$ kJ mol^{-1} ($+5.86 \pm 0.38$ kcal mol^{-1})

$HF \cdot 50H_2O(l)\Delta H^\circ_{f298.15} = -320.83 \pm 0.38$ kJ mol^{-1} (-76.68 ± 0.09 kcal mol^{-1})

$H_2O(l)\Delta H^\circ_{f298.15} = -285.85 \pm 0.33$ kJ mol^{-1} (-68.32 ± 0.08 kcal mol^{-1})

The uncertainties indicated are the estimates of the overall experimental errors. The value of the average O—F bond energy in OF_2 was calculated to be 191.29 kJ mol^{-1} (45.72 kcal mol^{-1}).

The heat of formation of boron carbide, E. S. Domalski and G. T. Armstrong, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 133-139 (Mar.-Apr. 1968).

Key words: Bomb calorimeter; boron carbide; boron trifluoride; carbon tetrafluoride; heat of combustion; heat of formation; polytetrafluoroethylene.

The standard heat of combustion in fluorine of a boron carbide sample having the composition $B_{4.222}C$ was determined from the heats of combustion of polytetrafluoroethylene and of boron carbide-polytetrafluoroethylene mixtures. The energy of the combustion reaction was measured in an isothermal-jacket bomb calorimeter. From the experimental data, we calculate -17.1 kcal mol^{-1} for the heat of formation of boron carbide. By combining all probable errors, we estimate our overall experimental uncertainty to be 2.7 kcal mol^{-1}. The value for the heat of formation of boron carbide is for the phase represented by the formula $B_{4.222}C$.

Solubility of tris(hydroxymethyl)aminomethane in water-methanol solvent mixtures and medium effects in the dissociation of the protonated base, P. Schindler, R. A. Robinson, and R. G. Bates, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 141-148 (Mar.-Apr. 1968).

Key words: Dissociation constant; medium effect; methanol-water solvents; solubility; tris(hydroxymethyl)aminomethane.

The dissociation constant of the protonated form of tris(hydroxymethyl)aminomethane has been measured at 25 °C in water-methanol solvents containing 30, 50, 70, and 90 wt percent methanol by means of potentiometric titrations. The solubility of tris(hydroxymethyl)aminomethane at 15, 25, and 35 °C in water-methanol solvents containing from 0 to 100 percent methanol has been determined. The results are discussed in terms of free energies of transfer and "medium effects" for hydrochloric acid, tris(hydroxymethyl)aminomethane, and tris(hydroxymethyl)aminomethane hydrochloride.

Calibration of the nickel dimethylglyoxime spectral shift at pressures to 20 kilobars for use in spectroscopic pressure measurement, H. W. Davies, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 149-153 (Mar.-Apr. 1968).

Key words: Absorption spectra; diamond-anvil cell; high pressure measurement; nickel dimethylglyoxime.

A method for incorporating solid nickel dimethylglyoxime in a liquid enclosed by a gasket in the diamond-anvil high pressure cell is described. A calibration curve relating the spectral shift of the nickel dimethylglyoxime visible absorption band to the known freezing pressures of 14 liquids has been obtained. The equation for the calibration line is $\Delta\bar{\nu} = -158.9\ P + 1.82\ P^2$ where P is expressed in kilobars. The 90 percent confidence band about the calibration curve has been computed, and the curve has been used to determine the room-temperature freezing pressures of acetone and methylcyclohexane.

Second virial coefficient of He^4 in the temperature range from 2 to 20 °K, M. E. Boyd, S. Y. Larsen, and H. Plumb, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 155-156 (Mar.-Apr. 1968).

Key words: He^4; low temperature; second virial.

We present preliminary values for the second virial coefficient of He^4 in the temperature range from 2 to 20 °K. They were derived from recent sound velocity measurements in the gas made by Plumb and Cataland using an ultrasonic interferometer.

Diffusion rates in inorganic nuclear materials, A. L. Dragoo, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 157-173 (Mar.-Apr. 1968).

Key words: Chemical interdiffusion; grain-boundary diffusion; intrinsic diffusion; lattice diffusion; self-diffusion; tracer diffusion.

The tracer diffusion coefficient, the self-diffusion coefficient, the intrinsic diffusion coefficient and the interdiffusion coefficient are briefly described. Grain boundary and lattice (volume) diffusion are contrasted. The frequency factors (D_0) and activation energies (Q) are tabulated for diffusion in the borides, carbides, and oxides of Be, Hf, Mo, Nb, Ta, Th, Ti, and Zr and for diffusion of C, N, and O in these metals. The purity of the solvent media, the preparation and properties of the samples, the method, the type of diffusion coefficient measured and the temperature range are also specified.

Effect of oxide additions on the polymorphism of tantalum pentoxide (system Ta_2O_5-TiO_2), J. L. Waring and R. S. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 175-186 (Mar.-Apr. 1968).

Key words: Phase equilibria; polymorphism; tantalum pentoxide; titanium dioxide.

The phase equilibrium relationships of the TiO_2-Ta_2O_5 system were determined in air. An equimolar compound, $TiTa_2O_7$, was found to melt congruently at about 1662 °C and have a monoclinic unit cell $a = 20.297$ Å, $b = 3.804$ Å, $c = 11.831$ Å, $\beta = 120°14'$, apparently isostructural with $TiNb_2O_7$. In addition, two other compounds are postulated to occur at about TiO_2:49Ta_2O_5 and TiO_2:7Ta_2O_5 and to dissociate at about 1230 and 1190 °C, respectively. TiO_2 apparently accepts a maximum of 9 mole percent Ta_2O_5 in solid solution at 1630 °C. Two eutectics occur in the system at 54 mole percent Ta_2O_5 and 1650 °C and 31 mole percent Ta_2O_5 and 1630 °C.

The high temperature form of Ta_2O_5 is apparently triclinic at room temperature with $a = 3.801$ Å, $b = 3.785$ Å, $c = 35.74$ Å, $\alpha = 90°54.4'$, $\beta = 90°11.5'$, and $\gamma = 89°59.9'$. A metastable transition occurs at 320 °C to a monoclinic form which inverts to tetragonal at 920 °C with $a = 3.81$ Å, $c = 36.09$ Å. Several intermediate morphotropic phases are found with up to 9 mole percent TiO_2 in solid solution.

Effect of statistical counting errors on wavelength criteria for x-ray spectra, J. S. Thomsen and F. Y. Yap, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 187-205 (Mar.-Apr. 1968).

Key words: Lattice constants; peak intensity; physical constants; spectral line profiles; statistical error analysis; x-ray line shapes; x-ray spectra; x-ray wavelength criteria.

Various features of the spectral profile of an x-ray line can be measured with an uncertainty which is only a small fraction of the observed line width. With recent improvements in measurement techniques, statistical errors due to the random fluctuations of the intensities in counter recordings may become significant. The present study considers the effect of such errors on several features of the line profile which could be used for definition of

its wavelength. These may be broadly classified into three groups, viz, the peak, the centroid, and the median. In the present analysis the statistical errors associated with these features are compared theoretically, with the assumption of negligible error in angular measurement. Certain systematic errors are also briefly examined. The effects of truncation range, asymmetry, and background intensity are considered, as well as possible optimization of the data-taking procedure.

In general, σ, the standard deviation of the wavelength, is given by $\sigma/W = F/(I_p T)^{1/2}$, where W is the full width at half-maximum intensity, I_p the peak intensity, T the total counting time, and F a dimensionless factor of the order of unity. Thus F may be regarded as a factor of merit for comparing the various cases, a low value of F being desirable. When the form of the line profile is known a priori, it is usually best to make use of this knowledge; e.g., a Lorentzian can be thus fitted with $F \approx 0.8$ for any of the three wavelength features. Using optimized truncation ranges and including the error in locating end points, one obtains approximately this same F for the centroid or median even without prior knowledge of the profile. In the latter case the value of F for the peak usually ranges from about 1.6 to 2.1. However, the peak is less subject to certain systematic errors and is preferable from the viewpoint of simplicity and historical precedent. It is recommended that use of the peak be continued at present; further study of the problem from the viewpoint of atomic energy level interpretation would be desirable.

Thermodynamic properties of ammonia as an ideal gas, L. Haar, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 2, 207-216 (Mar.-Apr. 1968).

Key words: Ammonia; ideal gas; thermodynamic functions.

Thermodynamic functions for ammonia as an ideal gas at one atmosphere pressure have been evaluated. The contribution of the highly anharmonic out-of-plane vibrational mode, including its large coupling with rotation and its coupling with the other vibrational modes, is considered in detail. Tables of $C_P°/R$, $(H° - E_0^c)/RT$, $(E_0° - G°)/RT$, and $S°/R$ have been calculated at closely spaced intervals from 50 to 5000 °K within an overall uncertainty of less than 0.1 percent at 1000 °K.

May-June 1968

Jump rates for point defects in special positions held by a trapping center of noncubic symmetry, H. S. Peiser and J. B. Wachtman, Jr., *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 3, 231-237 (May-June 1968).

Key words: Crystal symmetry; equivalent sites; jump rates; point defects; relaxation; trapping center.

In a previous paper [J. Phys. Chem. Solids **27**, 975 (1966)] the authors have discussed symmetry conditions for equivalence of jump rates operative in point-defect motion between crystallographically equivalent general sites neighboring a trapping center. The treatment is here extended to equivalent special sites to show that the total number of inequivalent jump rates can be expressed as $(N_t/N_d) - q_e - 1$ where N_t and N_d are the orders of the symmetry groups of the trap and defect respectively and where q_e is the number of independently effective pairs of nonself-inverse symmetry operators (paired with their inverses) all in the symmetry group of the trap. The number q_e can be obtained by counting any nonself-inverse operator pair, an element of which, when multiplied by an element of the defect symmetry, equals neither its own inverse nor an element of a pair previously counted.

For thermally activated relaxation processes expressions apply for maximum and minimum numbers of jump frequencies involved in complete and partial relaxation processes. For complete relaxation the maximum number is the number of prime factors in the ratio of the order of the symmetry group of the trap to that of the defect group. The minimum number is the minimum number of generators that will raise the defect position symmetry to that of the trap.

The thermodynamics of the ternary system; water-potassium chloride-calcium chloride at 25 °C, R. A. Robinson and A. K. Covington, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 3, 239-245 (May-June 1968).

Key words: Activity coefficient; calcium chloride; isopiestic measurements; mixed salt solutions; osmotic coefficients; potassium chloride; vapor pressure.

Isopiestic vapor pressure measurements have been made on the system: water-potassium chloride-calcium chloride at 25 °C. The osmotic coefficients of the mixed salt solutions and the activity coefficients of each salt in the presence of the other have been evaluated.

Force field for SiF_4, I. W. Levin and S. Abramowitz, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 3, 247-249 (May-June 1968).

Key words: Band contour; Coriolis constant; force field; infrared; isotopic shift; low temperature; SiF_4.

The force field of SiF_4 has been determined using both Coriolis coupling constants obtained from an investigation of the band contour of ν_3 at 195 °K and isotopic shifts. The force fields are equally well determined using both methods and are in agreement.

Blemish formation in processed microfilm, C. I. Pope, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 3, 251-259 (May-June 1968).

Key words: Archival record film; blemishes due to aging; colloidal silver; microfilm; microfilm storage cartons; permanent record film; peroxides.

Oxidizing and reducing agents generated by paper cartons during storage may react with the image silver to form blemishes. The type of fixing bath, concentration of chlorine in the wash water, washing time and composition of the storage cartons can be factors that accelerate or retard the attack of the peroxide on the image silver. Microfilm washed after fixation in distilled water or chlorine-free tap water formed blemishes when exposed to peroxide paper. A trace of silver chloride in the image silver of processed microfilm augmented the formation of the natural type blemishes when exposed to peroxide paper, but high concentrations of residual silver chloride inhibited blemish formation. During storage, some storage cartons evolved formaldehyde, formic acid, and ammonia which created a chemical environment favorable for blemish formation in microfilm in the presence of peroxide. A correlation was found between the incidence of blemishes and the brand of paper storage cartons. A procedure was developed for testing processed microfilm to determine its susceptibility to blemish formation. According to the present theory, peroxide reacts with the silver in the image, forming colloidal silver which imparts a yellowish or reddish color to the blemishes.

Absolute isotopic abundance ratios of common, equal-atom and radiogenic lead isotopic standards, E. J. Catanzaro, T. J. Murphy, W. R. Shields, and E. L. Garner, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 3, 261-267 (May-June 1968).

Key words: Absolute ratios; abundance; isotopic standards; lead.

Absolute values have been obtained for the isotopic abundance ratios of common, equal-atom, and radiogenic lead

isotopic standards using solid-sample mass spectrometry. Samples of known $^{208}Pb/^{206}Pb$ ratio, prepared from nearly pure separated ^{206}Pb and ^{208}Pb solutions, were used to calibrate the mass spectrometers.

Rate of nickel in Al-10 percent Si composites containing nickel-coated sapphire whiskers, H. Yakowitz, W. D. Jenkins, and H. Hahn, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 3, 269-272 (May-June 1968).

Key words: Al-10 percent Si alloy; electron probe microanalyzer; fiber composites; matrix-whisker bonding; Ni coated sapphire whiskers; optical metallography; sapphire whiskers.

The role of nickel in regard to whisker-matrix bonding in a composite of nickel-coated sapphire whiskers inserted into a matrix of aluminum-10 percent silicon alloy by means of liquid phase hot-pressing was investigated. The study was carried out with the aid of optical and electron microscopy, electron probe microanalysis, and microhardness measurements. Results show that most of the nickel is distributed within the matrix alloy.

Some of the nickel apparently interacts with the matrix and forms $NiAl_3$. The presence of $NiAl_3$ in this form increases the average hardness of the composite but apparently does not contribute significantly to strengthening of the alloy. Occasionally, clusters or clumps of nickel-rich material which also contains aluminum are found at or very near whisker-matrix interfaces. It is concluded that if any bonding of the nickel to the sapphire occurred, it was in these regions. Finally, a heat treatment to improve nickel to sapphire bonding and hence bonding of the entire composite is suggested.

July-August 1968

Mass spectrometric study of photoionization. X. Hydrogen chloride and methyl halides, M. Krauss, J. A. Walker, and V. H. Dibeler, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 4, 281-293 (July-Aug. 1968).

Key words: Dissociation energies; HCl; ionization; mass spectrometry; methyl halides; vacuum ultraviolet spectroscopy.

Photoionization efficiency curves are obtained for hydrogen chloride and several methyl halides, both ordinary and deuterated, from ionization threshold to 600 Å. Discussion is given on electronic structure of ions, autoionizing Rydberg states, and line-shape behavior. Ionization energies, heats of formation of ions, and bond dissociation energies are tabulated without regard to distribution of energy in internal modes, in relative kinetic energy, or other possible modes.

The fourth and fifth spectra of vanadium (V IV and V V), L. Iglesias, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 4, 295-308 (July-Aug. 1968).

Key words: Atomic spectra, V IV and V V; classified lines, V IV and V V spectra; spectra V IV and V V; terms, V IV and V V spectra; vanadium, the fourth and fifth spectra of.

The V IV spectrum has been extended by using as light sources a condensed spark and a hollow cathode discharge. With the new data, the experimental interpretation of levels of the $3d^2$, $3d\,4d$, $3d\,5s$, $3d\,5p$, $3d\,4f$, $3d\,5d$ and $3d\,6s$ configurations has been completed with the exception of three levels of the $3d\,4f$ and $3d\,5d$ configurations. Four levels of the $3d\,5g$ electron configuration have also been found. These levels account for 340 of the 360 lines assigned to V IV in the region 675 Å – 5940 Å.

Three members of the $3d\,ns$ series give an ionization potential of $376730 \pm 40\ cm^{-1} = 46.70$ volts.

The $4d\ ^2D$ term of V V has also been located in the course of this work. With the aid of the new observations between 675 Å and 2200 Å the value of some levels already known has been improved.

Variation of absorptance-curve shape with changes in pigment concentration, G. L. Howett, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 4, 309-340 (July-Aug. 1968).

Key words: Absorption; adaptation; Beer's law; chromatic adaptation; color vision; concentration; cones; curve shape; high luminance; metameric matches; pigment; photopigment; vision.

A complete quantitative analysis is presented of changes in the shape of the spectral absorptance curve of any Beer's-law pigment solution (or other Bouguer's-law material) as concentration of the pigment, or thickness of the solution layer, is varied. The relative absorptance curve, normalized to unit maximum, is taken as defining the shape of the absolute absorptance curve, and the index of shape change is taken to be the difference between the normalized curves. All concentration changes from infinite decrease to infinite increase are covered, with some extreme cases requiring limit methods. Formulas and graphs are given for determining, as a function of concentration change and peak absolute absorptance of the original curve, where along the curve the shape change is greatest, and how large the maximum change is. Implications for color vision theory are discussed and it is shown that the assumption of low peak absorptances (<10%) for the visual photopigments accounts for the constancy of the color-matching functions for moderate luminances, but not, in itself, for the breakdown of matches at high luminances; while the assumption of high peak absorptances (≈ 80%), although it contradicts recent microspectrophotometric measurements, seems to account for both phenomena.

Periodic acid, a novel oxidant of polycyclic, aromatic hydrocarbons, A. J. Fatiadi, *J. Res. Nat. Bur. Stand. (U.S.)*), **72A** (Phys. and Chem.), No. 4, 341-350 (July-Aug. 1968).

Key words: Aprotic solvents; aromatic hydrocarbons; malonic acid; periodic acid; pyrene radical; quinones; reaction mechanism; sodium metaperiodate.

Certain polycyclic, aromatic hydrocarbons can be oxidized with periodic acid in aprotic solvents containing a small proportion of water. A unique, two-fold character of response to periodic acid by these hydrocarbons has been found: (1) production of a coupling reaction through a radical intermediate [conversion of pyrene into 1,1′-bipyrene, and fluorene into 1,2-bis(2,2′-biphenylylene)ethylene] or (2) conversion into quinones by a two-equivalent oxidation mechanism that does not involve a radical intermediate [acenaphthene, anthracene, anthrone, benz[*a*]anthracene, naphthacene, naphthalene, and phenanthrene]. Little or no reaction was observed when oxidation was attempted with sodium metaperiodate instead of periodic acid.

Electron-spin resonance revealed no radical intermediate in the oxidation of malonic acid with either periodic acid or sodium periodate.

A galvanic cell with a low emf-temperature coefficient, G. N. Roberts and W. J. Hamer, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 4, 351-354 (July-Aug. 1968).

Key words: Cell with low temperature coefficient; double salt; galvanic cells; standard cells.

This paper presents data on a modified cadmium sulfate saturated standard cell of the Vosburgh type in which a tertiary amalgam containing 11.2 percent bismuth and 8.4 percent cadmium is used as anode and the double salt, $CdSO_4 \cdot Na_2SO_4 \cdot 2H_2O$ is added to the usual $CdSO_4$ electrolyte in an amount more than

sufficient to saturate the solution with the double salt. Crystals of $CdSO_4 \cdot Na_2SO_4 \cdot 2H_2O$ are placed over the surface of both electrodes. The emf of the cell, as a function of temperature, is given by

$$E \text{ (in volts)} = 1.018243 + 3.0956 \times 10^{-5} t - 8.559 \times 10^{-7} t^2 + 1.3534 \times 10^{-8} t^3.$$

At 25 °C the cell has an emf-temperature coefficient of +13.5 μV/°C while the conventional saturated cadmium sulfate cell has a dE/dT of −49.4 μV/°C. Data on the emf-temperature hysteresis of the cell on cooling and on heating are also given in graphical form. Data on the changes in Gibbs energy, enthalpy, entropy, and heat capacity for the cell reaction are given for the temperature range of 5 to 40 °C.

Synthesis of cerite, J. Ito, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 4, 355-358 (July-Aug. 1968).

Key words: Ca, Mg phosphate; hydrothermal synthesis; inorganic synthesis; mineral chemistry; rare-earth silicate; x-ray powder analysis.

Some compounds isostructural with cerite have been synthesized hydrothermally at temperatures from 500 to 720 °C. The compositional range for cerite, and its phase relation to the silicate apatites are established in terms of ionic radii of rare-earth and divalent ions. The proposed formula for cerite on the basis of isomorphism with whitlockite, $Ca_3(PO_4)_2$, is discussed. A solid-solution series between $Ca_9P_6O_{24} - Ca_7Mg_2P_6O_{24}$ (whitlockite − Mg-whitlockite) has been established.

Tables of collision integrals for the (m,6) potential function for 10 values of m, M. Klein and F. J. Smith, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 4, 359-424 (July-Aug. 1968).

Key words: Collision integrals; diffusion; potential; thermal conductivity; thermal diffusion; transport properties; viscosity.

Tables of collision integrals are presented for the (m,6) potential function for 87 reduced temperatures for each of 10 values of m. The exponents m used were $m = 9$, 12, 15, 18, 21, 24, 30, 40, 50, and 75. Comparisons are made with five other calculations for the case $m = 12$. The accuracy of the calculation appears to be at least several parts in 10,000.

Spectrum of relaxation times in GeO_2 glass, A. Napolitano and P. B. Macedo, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 4, 425-433 (July-Aug. 1968).

Key words: Activation energy; annealing; germania glass; index of refraction; relaxation times; thermal expansion; two relaxation model; viscosity.

Index-of-refraction versus time isotherms have been established for germania glass. Using the crossover technique with air-quenched samples and applying the two relaxation time model previously reported for borosilicate glass, it was found that the width of the spectrum of relaxation times for germania glass was temperature dependent. Upon analyzing this in terms of a distribution of activation energies, the results showed that, similarly to B_2O_3, activation energies smaller than the activation energy present in the Arrhenius region appear at low temperatures.

Extensive viscosity measurements by the fiber elongation method were made from 10^{11} to 6×10^{14} poises. From this data a lower and more precise value of the activation energy ($E\eta$ = 72.3 kcal/mol) was obtained in the annealing range.

Resumé of values of the Faraday, W. J. Hamer, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 4, 435-439 (July-Aug. 1968).

Key words: Coulometers; Faraday; inclusions in silver coulometers; values of Faraday.

A resumé is given of the determinations of the value of the Faraday. Values obtained by silver deposition, iodide oxidation, oxalate oxidation, the omegatron, and silver dissolution are reviewed. All values are converted to the unified ^{12}C international scale of atomic weights using the international atomic weights of 1967. Values of the Faraday are given in terms of both the NBS (legal) and absolute units of electrical measure. In the latter the new value for the acceleration due to gravity is used in computing the absolute value of electric current. On this basis and using the atomic weight of silver determined by Shields, Craig, and Dibeler, and converting to the ^{12}C scale, the value of the Faraday is 96,486.9 ± 1.6 absolute coulombs per gram-equivalent which differs by only 1 part per million from the value recommended by the National Academy of Sciences–National Research Council. If the atomic weight of silver recommended in 1967 by the International Atomic Weight Commission is used, the Faraday on the new gravity value is 96,486.5 ± 1.6 absolute coulombs per gram-equivalent which differs by 5 parts per million from that recommended by the National Academy of Sciences–National Research Council. No change in the value of the Faraday adopted by the NAS–NRC Committee is recommended.

September-October 1968

Studies in bomb calorimetry. A new determination of the energy of combustion of benzoic acid in terms of electrical units, K. L. Churney and G. Armstrong, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 5, 453-465 (Sept.-Oct. 1968).

Key words: Benzoic acid, heat of combustion; bomb calorimetry, procedures and errors; bomb-calorimeter, electrical calibration; Dickinson calorimeter; heat of combustion.

The heat of combustion of NBS Standard Sample 39i of benzoic acid under standard bomb conditions has been determined in terms of electrical units. A value of −26,434.0 J g^{-1} was obtained. The total uncertainty in our determination is estimated to be ±3.3 J g^{-1}. The uncertainty due to random errors was 1.7 J g^{-1} and is based on the appropriate factors for the Student t distribution at the 95 percent confidence limits for eleven determinations of the energy equivalent of the calorimeter and six determinations of the heat of combustion of benzoic acid. The principal systematic error, neglect of surface temperature correction for our calorimeter, has been assigned a value of ±2.6 J g^{-1} until more reliable estimates of the correction can be made. Particular emphasis was placed on improving the precision of a calorimetric measurement over those previously obtained in this laboratory by the use of more sensitive auxiliary measuring equipment and more accurate procedures to evaluate the corrected temperature rise.

Effect of low pressures on the room temperature transitions of polytetrafluoroethylene, G. M. Martin and R. K. Eby, *J. Res. Nat. Bur. Stand. (U.S.)*, **72A** (Phys. and Chem.), No. 5, 467-470 (Sept.-Oct. 1968).

Key words: Dilatometry; enthalpy; entropy; helical molecule; low pressure; phase diagram; polytetrafluoroethylene; transitions; triple point.

Between approximately 20 and 30 °C at atmospheric pressure, polytetrafluoroethylene exhibits a phase (denoted as IV), which has not been observed in P-V-T measurements at pressures above 10^8 Nm^{-2} (1 Kilobar). Data are presented to resolve this phase in the temperature range 0 to 50 °C and the pressure range 0 to 0.686×10^8 Nm^{-2}. The II-IV (20 °C) transition pressure increases with temperature according to the equation $P = (-820$

$+ 26.9t + 0.68t^2) \times 10^5$ and the IV-I (30 °C) transition according to the equation $P = (-91 - 57.8t + 1.99t^2) \times 10^5$ suggesting a possible triple point near 2.6×10^8 Nm^{-2} and 54 °C. However, the IV-I transition probably cannot be resolved by volume measurements at pressures above 2×10^8 Nm^{-2} because its volume of transition is small and the two transitions overlap. The enthalpies of the transitions are calculated for different pressures and some thermodynamic properties of phase IV are determined indirectly. It is shown that, if the effect of volume change is subtracted, random reversals of the hand of the helical conformation of the molecule can account for appreciable fractions of the enthalpy and corresponding entropy change for the combined transitions at atmospheric pressure.

Electrostatic potentials and their spatial derivatives about point defects in ionic crystals, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 471-475 (Sept.-Oct. 1968).

Key words: CaF_2; classical ionic lattice theory; electrostatic potential; lattice distortion; NaCl; point defect.

The electrostatic potential which arises from a lattice array of point ions is computed in terms of a Taylor's series expansion for small distances from a lattice site. This expansion gives the change in electrostatic energy when an ion moves in the background of a perfect point ion lattice potential. The Taylor's series coefficients for terms up to fourth order in the ion displacement are evaluated for the NaCl and CaF_2 lattice structures.

Electric fields produced by a charge density in ionic crystals, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 475-478 (Sept.-Oct. 1968).

Key words: CaF_2; dipole shell coefficient; electric fields; NaCl; polarization; spatially extended defects.

Spatially extended defects such as the *F* center give rise to an effective defect charge density which may produce important polarizations in the crystal. The electric field in the crystal depends upon these induced dipoles. Lattice summations for the contribution to the electric field which arises from ionic shells centered about the defect are evaluated for the NaCl and CaF_2 lattice structures.

Mass spectrometric study of the photoionization of some fluorocarbons and trifluoromethyl halides, C. J. Noutary, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 479-485 (Sept.-Oct. 1968).

Key words: CF_4; C_2F_6; C_3F_8; C_4F_{10}; CF_3H; CF_3Cl; CF_3Br; CF_3I; heats of formation; ionization energies; mass spectrometric; photoionization; vacuum ultraviolet.

The photoionization curves and the threshold energies for the molecule and several abundant fragment ions of CF_4, C_2F_6, C_3F_8, C_4F_{10}, CF_3H, CF_3Cl, CF_3Br, and CF_3I have been measured. The threshold energies are correlated and the ionic heats of formation and some bond dissociation energies are calculated. It is apparent that the values obtained for the CF_3^+ ions are not the adiabatic ones, but include large amounts of excess energy. This excess is the lowest for the CF_3^+ from CF_3I for which an explanation is suggested. Assuming that the excess is not zero for the last compound we obtain the following upper limits: $\Delta Hf_0°(CF_3)^+ \leq +365.3$ kJ $mol^{-1} = +87.3$ kcal mol^{-1}; $I(CF_3)^+ \leq 8.62$ eV; $I(C_2F_5)^+ \leq 8.72$ eV; $I(C_3F_7)^+ \leq 8.70$ eV; $I(C_4F_9)^+ \leq 8.68$ eV. From the mean value $D(C_p - C_p) = 402 \pm 2$ kJ $mol^{-1} = 96.0 \pm 0.5$ kcal mol^{-1} the bond dissociation energies $D(C_p - C_s) = 363 \pm 3$ kJ $mol^{-1} = 86.8 \pm 0.8$ kcal mol^{-1} and $D(C_s - C_s) = 337 \pm 4$ kJ $mol^{-1} = 80.6 \pm 1.0$ kcal mol^{-1} and $D(C_p - F) = 525$ kJ $mol^{-1} = 125.7$ kcal mol^{-1} are calculated.

Infrared matrix spectra of lithium fluoride, S. Abramowitz and N. Acquista, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 487-493 (Sept.-Oct. 1968).

Key words: Force field; infrared; lithium fluoride dimer; low temperature; matrix; vibrational assignment.

Evidence for a linear dimer Li_2F_2 has been obtained by extending the spectral measurements for matrix isolated lithium fluoride into the far infrared region. The vapors from solid ^6LiF, ^7LiF, and $^6LiF/^7LiF$ mixtures were deposited in argon matrices at liquid hydrogen temperatures. Vibrational assignments were made on the basis of the following linear species: $^6Li_2F_2$, $^7Li_2F_2$, $^{6,7}Li_2F_2$ and $^{7,6}Li_2F_2$. Although the specific geometry of the dimer could not be determined, a normal coordinate analysis supported the spectral interpretation of a linear structure ($C_{\infty v}$).

Electronic transition moment integrals for first ionization of CO and the A – X transition in CO^+. Some limitations on the use of the *r*-centroid approximation, P. H. Krupenie and W. Benesch, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 495-503 (Sept.-Oct. 1968).

Key words: CO; CO^+; electronic transition moment integrals; Franck-Condon factors; Franck-Condon principle; transition probabilities.

Integrals necessary for the determination of transition moment matrix elements from experimental data have been evaluated numerically by use of vibrational wave functions derived from RKR potentials. A power series expansion for the electronic transition moment has been assumed. The significant quantities which can be related to an arbitrary center of expansion are vibrational overlap integrals and quantities of the form $\int \psi_v r'' \psi_{v''} dr$. Experimental band intensities and relative populations for vibrational levels of the initial electronic state are needed to determine the expansion coefficients. Transition moment integrals have been calculated for first ionization from the ground electronic state of CO and for the $A^2\Pi_i - X^2\Sigma^+$ transition of CO^+. Comparison of these integrals with previous calculations based on Morse functions has shown them to be rather sensitive to the wave-functions [potentials] used. Characteristics generally attributed to the *r*-centroid and related integrals are examined, and some limitations on the use of the *r*-centroid approximation are discussed, following a review of assumptions made in the use of that approximation.

The configurations $3d^n4p$ in doubly ionized atoms of the iron group, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 505-520 (Sept.-Oct. 1968).

Key words: βQ and T corrections; configurations $3d^n4p$; energy levels; interaction parameters; iron group; third spectra.

Experimental levels of the configurations $3d^n4p$ in the third spectra of the iron group were compared with corresponding calculated values. Besides the electrostatic and spin-orbit interactions the $\alpha L(L+1)$, βQ and T corrections were considered in the individual and general treatments. The insertion of the parameters β and T improved the results by about 25 percent. The root-mean-square (rms) error on fitting 581 experimental levels by means of 21 free interaction parameters was 138 cm^{-1}. Altogether 912 energy levels were predicted.

Electron impact excitation of hydrogen Lyman-α radiation, R. L. Long, Jr., D. M. Cox, and S. J. Smith, *J. Res. Nat. Bur. Stand. (U.S.),* **72A** (Phys. and Chem.), No. 5, 521-535 (Sept.-Oct. 1968).

Key words: Atomic hydrogen; beams; electron impact excitation; experimental; high vacuum; Lyman-α.

An experimental investigation of electron impact excitation of the $2p$ state of atomic hydrogen is described. A beam of elec-

trons was passed through a chopped beam of hydrogen atoms in a high vacuum apparatus. The modulated flux of Lyman-α photons emitted in the radiative decay of the $2p$ state was taken as a measurement of the excitation probability resulting from direct excitation plus indirect excitation resulting from cascading. The region surrounding the intersection of the two beams was electrically and magnetically shielded to prevent quenching of metastable $2s$ atoms and thereby to ensure that the observed Lyman-α flux resulted from decay of the short-lived $2p$ state. The experimental results are consistent with those obtained by Fite, Stebbings, and Brackmann [1959], and confirm the existence of a large discrepancy between theoretical and experimental results in the electron energy range below 50 eV.

November-December 1968

Interaction energy surfaces for Li(2^2S) and Li(2^2P) with H_2, M. Krauss, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 553-557 (Nov.-Dec. 1968).

Key words: Charge-transfer; energy surface; energy transfer; Hartree-Fock; $H_2(X^1\Sigma_g^+)$; Li(2^2P); Li(2^2S); resonance state.

Interaction energy surfaces for the interaction of Li(2^2S) and Li(2^2P) with H_2 are calculated using approximate Hartree-Fock trial functions. The crossing of energy curves is observed for C_{2v} conformations if the H_2 internuclear distance is sufficiently large. No crossing is observed for colinear collisions for any H_2 distance.

The wave function of the strongly attractive state involved in the crossing is related to the metastable negative-ion states that are postulated to account for resonant electron-molecule scattering. Such a charge-transfer state can only be bound for C_{2v} conformations for the H_2 molecule. The likelihood and geometry of the crossing complexes for other molecules interacting with alkalis is discussed in terms of the formation of these resonance charge-transfer states.

Energy levels and classified lines in the first spectrum of technetium (Tc I), W. R. Bozman, C. H. Corliss, and J. L. Tech. *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 559-608 (Nov.-Dec. 1968).

Key words: Atomic spectra; energy levels, Tc I; spectrum of technetium; technetium.

Progress in the classification of Tc I lines is reported. About 2200 of the known Tc I lines between 2154 and 8918 Å are now classified as transitions between 108 even and 147 odd energy levels. Tables of levels and classified lines are given.

The first spectrum of tungsten (W I), D. D. Laun and C. H. Corliss, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 609-755 (Nov.-Dec. 1968).

Key words: Atomic spectra; energy levels; spectroscopy; spectrum of tungsten; tungsten; wavelengths.

The first spectrum of tungsten (W I) has been observed in the region between 2000 Å and 10500 Å. Of the 6800 spectral lines reported here, about 5500 have been classified as transitions between 91 even and 365 odd levels.

Theoretical interpretation of the even levels in the first spectrum of tungsten, Y. Shadmi and E. Caspi, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 757-760 (Nov.-Dec. 1968).

Key words: Atomic spectrum, W I; energy levels, W I; spectrum of tungsten; tungsten; W I.

The calculated even levels of W I up to the height of about 40,000 cm^{-1}, which is the height of the ground level of the d^6 configuration, are reported. Fifty-seven observed levels are fitted to them, with a mean error of 100 cm^{-1}. *L-S* coupling and configuration assignments are usually meaningless because of a between 108 even and 147 odd energy levels. very strong spin-orbit interaction and configuration interaction. For every level, the largest squared *L-S* coupling components of its eigenvector are reported, as well as observed and calculated *g*-values.

Stable carbon isotope ratio measurements with a gas density meter, S. P. Wasik and W. Tsang, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 761-764 (Nov.-Dec. 1968).

Key words: Carbon-13; carbon dioxide; ethyl acetate; gas chromatography; gas density meter; isotope ratios.

A method is presented for measuring C^{13}/C^{12} isotope ratio of organic compounds by burning the material in a stream of normal CO_2, separating the combustion products by gas chromatography and sequentially measuring the density of the enriched CO_2 peak with a gas density meter. Data are presented for the analysis of enriched ethyl acetate from 15 to 1 percent enrichment. The method is applicable for other stable isotope analysis.

The single crystal spectrum of hexakis(imidazole)nickel(II)nitrate, C. W. Reimann, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 765-768 (Nov.-Dec. 1968).

Key words: Crystal spectrum; hexakis(imidazole)nickel(II)nitrate; octahedral nickel(II); spin-forbidden bands.

The crystal spectrum of hexakis(imidazole)nickel(II)nitrate from 7000 cm^{-1} to 30,000 cm^{-1} at liquid nitrogen temperature has been measured. Three spin-allowed and three spin-forbidden bands in this spectrum were assigned on the basis of octahedral ligand field symmetry. These assignments are compared with those made in several related materials. Important differences and similarities in spectral detail and their bearing on assignments in other strong field nickel(II) complexes, are discussed.

Crystalline alpha and beta forms of 3-*O*-α-D-glucopyranosyl-D-arabinopyranose, H. S. Isbell, H. L. Frush, and J. D. Moyer, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 769-771 (Nov.-Dec. 1968).

Key words: Anomeric sugars; calcium maltobionate; maltose-*1*-^{14}C; mutarotation of 3-*O*-α-D-glucopyranosyl-D-arabinopyranose; Ruff degradation of; sugars; 3-*O*-α-D-glucopyranosyl-D-arabinopyranose.

Crystalline 3-*O*-α-D-glucopyranosyl-α-D-arabinopyranose monohydrate, mp 120 to 121 °C, and 3-*C*-α-D-glucopyranosyl-β-D-arabinopyranose, mp 155 to 157 °C, were prepared from a sirup obtained by the Ruff degradation of calcium maltobionate. For the *alpha* monohydrate, $[\alpha]_D^{20} = +16.7 \times 10^{-0.024t} - 9.6 \times 10^{-0.098t} + 46.6$, and for the anhydrous *beta* form, $[\alpha]_D^{20} = -25.6 \times 10^{-0.025t} - 9.4 \times 10^{-0.097t} + 49.2$. The structure of the sugar was established by converting it into maltose.

Treatment of the *alpha* form with pyridine-acetic anhydride gave a heptaacetate, mp 127 to 128 °C, $[\alpha]_D^{20}$ + 62.4° (*c* 2.5, chloroform). The *beta* form gave a heptaacetate, mp 194.5 – 195.5 °C, $[\alpha]_D^{20}$ + 13.4° (*c* 2.5, chloroform).

Preparation and solubility of hydroxyapatite, E. C. Moreno, T. M. Gregory, and W. E. Brown, *J. Res. Nat. Bur. Stand.* (*U.S.*), **72A** (Phys. and Chem.), No. 6, 773-782 (Nov.-Dec. 1968).

Key words: Apatite; hydroxyapatite; calcium phosphates; solubility; solubility isotherms; solubility product.

Two portions of a synthetic hydroxyapatite (HA), $Ca_5OH(PO_4)_3$, fully characterized by x-ray, infrared, petrographic, and chemical analyses, were heated at 1,000 °C in air

and steam atmospheres, respectively. Solubility isotherms for these two samples in the system $Ca(OH)_2$-H_3PO_4-H_2O were determined in the *p*H range 5 to 7 by equilibrating the solids with dilute H_3PO_4 solutions. Both samples of HA dissolved stoichiometrically. The activity products $(Ca^{++})^5(OH^-)(PO_4^{\equiv})^3$ and their standard errors—obtained by a least squares adjustment of the measurements (Ca and P concentrations and *p*H of the saturated solutions) subject to the conditions of electroneutrality, constancy of the activity product, and stoichiometric dissolution—were $3.7_3 \pm 0.5 \times 10^{-58}$ for the steam-heated HA and $2.5_1 \pm 0.4 \times 10^{-55}$ for the air-heated HA. Allowance was made in the calculations for the presence of the ion pairs $[CaHPO_4]^0$ and $[CaH_2PO_4]^+$. The higher solubility product for the air-heated HA is ascribed either to a change in the heat of formation brought about by partial dehydration or to a state of fine subdivision resulting from a disproportionation reaction. The solubility product constants were used to calculate the points of intersection (i.e., singular points) of the two HA solubility isotherms with the isotherms of $CaHPO_4 \cdot 2H_2O$ and $CaHPO_4$; it was found that the *p*H's of the singular points for the air-heated HA were a full unit higher than those of the steam-heated preparation. Conditions are described for the precipitation of HA crystals suitable for solubility measurements.

High temperature dehydroxylation of apatitic phosphates, T. Negas and R. S. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, 72A (Phys. and Chem.), No. 6, 783-787 (Nov.-Dec. 1968).

Key words: Apatite; dehydroxylation; high temperature; phosphates; x-ray diffraction.

$Sr_{10}P_6O_{24}(OH)_2$, (Hex. $a = 9.765$ Å, $c = 7.280$ Å), and $Ba_{10}P_6O_{24}(OH)_2$, (Hex. $a = 10.177$ Å, $c = 7.731$ Å), undergo cell parameter contractions at elevated temperatures in air. These can be correlated with progressive dehydroxylation, although neither can be completely dehydrated. $Pb_{10}P_6O_{24}(OH)_2$, (Hex. $a = 9.878$ Å, $c = 7.432$ Å), also does not completely dehydrate in air.

A new apatite-like strontium phosphate, (Hex. $a = 9.872$ Å, $c = 7.199$ Å), was prepared at elevated temperatures in vacuum.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 73A, JANUARY-DECEMBER 1969

January-February 1969

Specific heats of oxygen at coexistence, R. D. Goodwin and L. A. Weber, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 1-13 (Jan.-Feb. 1969).

Key words: Coexistence; experimental; heat capacity; liquid phase; oxygen; saturated liquid; specific heat.

Specific heats of saturated liquid, along the coexistence path, are useful for computing thermodynamic properties throughout the compressed liquid phase. We report 86 experimental heat capacities of oxygen for the two-phase system, liquid plus vapor, from the triple-point to near the critical-point and corresponding derived values for the liquid phase. These results are represented by a formula which can be integrated for heat absorbed and for entropy. The changes in value of internal energy, enthalpy, and entropy of the saturated liquid are tabulated from the triple-point to the critical-point.

Specific heats C_v of fluid oxygen from the triple point to 300 K at pressures to 350 atmospheres, R. D. Goodwin and L. A. Weber, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 15-24 (Jan.-Feb. 1969).

Key words: Compressed liquid; heat capacities; liquid; oxygen; specific heats; thermodynamic properties.

Experimental specific heats at constant volume for oxygen in single phase domains are reported from the triple point to 300 K at pressures to 350 atmospheres. An empirical equation with seven constants describes these specific heats over the entire domain of ρ-T coordinates to within the experimental accuracy of 1 to 2 percent. Values for the terminal slopes of PVT isochores at the coexistence boundary, $(\partial P/\partial T)_v$, are derived for the liquid.

Thermodynamic properties of fluid oxygen at temperatures to 250 K and pressures to 350 atmospheres on isochores at 1.3 to 3.0 times critical density, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 25-36 (Jan.-Feb. 1969).

Key words: Compressed liquid; enthalpy; entropy; internal energy; oxygen; saturated liquid; thermodynamic properties.

The starting point for these calculations is liquid oxygen at the triple point. An analytical formula is used for specific heats of saturated liquid along the coexistence path to obtain internal energies and entropies of the saturated liquid. With these initial values, the calculations next are made as a function of temperature along isochores, using an "equation of state" for the specific heats $C_v(\rho, T)$ in the single-phase domain. Enthalpies are obtained by adding Pv to the internal energies. Results are tabulated at uniform densities and temperatures. Based on uncertainties of one percent in the specific heat data, the uncertainty of thermal properties also is taken to be 1 percent.

Two new standards for the pH scale, B. R. Staples and R. G. Bates, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 37-41 (Jan.-Feb. 1969).

Key words: Acidity; carbonate; citrate; emf; hydrogen electrode; pH; standards for pH.

Two new primary standards for the NBS pH scale, supplementing the five already available, are proposed. The new reference solutions are the 0.05 molal solution of potassium dihydrogen citrate and a mixture of sodium bicarbonate and sodium carbonate, each 0.025 molal. The citrate solution has a pH of 3.776 at 25 °C and is more stable under certain conditions than either the tartrate or phthalate standards. The carbonate solution has a pH of 10.012 at 25 °C. It therefore extends the NBS pH scale above its present upper limit of 9.180 at this temperature. Reference values pH(S), based on emf measurements of cells with hydrogen electrodes and silver-silver chloride electrodes, have been assigned to these two standard solutions at 11 temperatures from 0 to 50 °C.

Calculation of diffusion coefficients in ternary systems from diaphragm cell experiments, P. R. Patel, E. C. Moreno, and T. M. Gregory, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 43-49 (Jan.-Feb. 1969).

Key words: Diaphragm cell; diffusion coefficients; least squares calculation; ternary system.

Using a generalized least square procedure, a method is developed to estimate diffusion coefficients, D_{ij}, from concentration measurements made in a set of experiments of varying duration but with the same initial conditions. The method requires neither approximations nor restrictions in the flow equations. The D_{ij} and their errors are calculated simultaneously with the adjustment of the weighted observables—concentrations of the two solute components and time. A procedure is described to insure convergence in a given experimental set. The effect of the duration of the longest experiment, and errors in the observables on the estimated values of D_{ij} and their errors, are investigated. Application of the method to available data yielded values for D_{ij} in agreement with those previously calculated by more involved procedures.

Calculated line strengths for the transition array $(3d^3 + 3d^24s) = 3d^24p$ in Ti II, H. Mendlowitz, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 51-64 (Jan.-Feb. 1969).

Key words: Calculated line strengths; configuration interaction; intermediate coupling; Ti II; $3d^3$, $3d^24s$, $3d^24p$ configurations; transition array.

The transition array for the transitions between the configurations $(3d^3+3d^24s)$ and $3d^24p$ in Ti II are presented here. The relative line strengths have been calculated in the intermediate coupling scheme, taking into account interaction between configurations. The relative phase and magnitude of the radial transition integrals $(s-p)$ and $(d-p)$ for the jumping electron in the LS coupling have been determined empirically.

Morphological stability of a cylinder, S. R. Coriell and S. C. Hardy, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 65-68 (Jan.-Feb. 1969).

Key words: Cylinder; ice; interface kinetics; morphological stability; solute diffusion; surface tension.

The stability of the shape of a solid cylinder crystallizing in a supercooled liquid is treated. The effects of solute diffusion, slightly anisotropic surface tension and interface kinetics are included. The resulting stability equations are applied to the specific case of ice cylinders.

Distorted tetrahedra in strontium copper åkermanite, J. Ito and H. S. Peiser, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 69-74 (Jan.-Feb. 1969).

Key words: Åkermanite; crystal chemistry; crystal growth; cupric silicate; flux growth; ion polyhedron distortion; melilite; Mössbauer spectroscopy; silicate gels; silicate synthesis; x-ray powder data.

New analogs of åkermanite: $Sr_2CuSi_2O_7$ and $Sr_2CdSi_2O_7$ as well as many previously synthesized analogs were obtained by a simple technique consisting of heating in air of precipitated gels of the right composition. X-ray data revealed an anomaly of the Cu^{2+} and (to a lesser extent) Fe^{2+} åkermanites which is explained by a simple geometric argument in terms of a small (~3°) angular distortion of the oxygen tetrahedron surrounding the smaller divalent cation. This interpretation is consistent with previous theoretical discussions and Mössbauer data on the iron analog prepared for this study. Single crystals of cobalt åkermanites can be grown from a sodium tungstate flux.

Tritium-labeled compounds XII. Note on the synthesis of D-glucose-2-*t* and D-mannose-2-6, H. S. Isbell, H. L. Frush, C. W. R. Wade, and A. J. Fatiadi, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 75-77 (Jan.-Feb. 1969).

Key words: D-Gluconic-*2-t* acid, synthesis of; D-Glucose-*2-t,* synthesis and radioanalysis of; D-Mannonic-*2-t* acid, synthesis of; D-Mannose-*2-t,* synthesis and analysis of; Sodium 2-*keto*-D-gluconate, reduction with lithium borohydride-*t*; sugars, tritium-labeled; tritium-labeled compounds, D-mannose-2-*t* and D-glucose-2-*t*.

D-Glucose-*2-t* and D-mannose-*2-t* have been synthesized from sodium 2-*keto*-D-gluconate (sodium D-*arabino*-hexulosonate). Reduction of the salt with lithium borohydride-*t* produced the epimeric, 2-labeled aldonic acids in almost equal proportions. The acids, separated by carrier techniques, were lactonized, and the lactones were reduced with sodium amalgam to the corresponding sugars. The specificity of the labeling was established by converting each sugar into D-*arabino*-hexulose phenylosazone and determining that the osazone was substantially tritium-free.

A survey of blemishes on processed microfilm, C. S. McCamy, S. R. Wiley, and J. A. Speckman, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 1, 79-97 (Jan.-Feb. 1969).

Key words: Aging blemishes; archival records; blemishes; microfilm blemishes; microscopic spots; redox blemishes.

As part of an investigation of the formation of six types of redox blemishes on microfilm, 7411 rolls of microfilmed records in 36 Federal Government agencies were microscopically inspected by 34 inspectors trained by the National Archives and the National Bureau of Standards. About 350,000 observations were statistically analyzed. Careful photographic processing, adequate washing, careful handling, cool and dry storage in inert containers, and adequate ventilation, are among the conditions that have been found beneficial in preventing blemish formation. Data are compiled in an appendix.

March-April 1969

Color representation of electron microprobe area-scan images by a color separation process, H. Yakowitz and K. F. J. Heinrich, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 2, 113-123 (Mar.-Apr. 1969).

Key words: Color photography; metallography; petrography; photomicrography; scanning electron microprobe; x-ray microscopy.

Composite color photographs were prepared using x-ray area scanned images from the electron probe microanalyzer. Three-color composites are completely interpretable in terms of the primary color (red, green or blue) chosen to represent each element. The color pictures were obtained by preparing conventional black-and-white scanning images which were then used as color-separation-positives, with appropriate filters, to make color prints. Methods for preparing and interpreting color composites are considered. Specifically, color mixing, proper choice of filters to match film characteristics, exposure criteria, and choice for each partial image are discussed in detail. Finally, typical applications drawn from the fields of metallurgy, mineralogy, and biology are shown to illustrate the principles described. With the use of Polaroid film this procedure is quite convenient.

Configurations $3d^n4p$ in singly ionized atoms of the iron group, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 2, 125-157 (Mar.-Apr. 1969).

Key words: Configurations $3d^n4p$; β and T corrections; energy levels; interaction parameters; iron group; second spectra.

Experimental levels of the configuration $3d^n4p$ in the second spectra of the iron group were compared with corresponding calculated values. Besides the electrostatic and spin-orbit interactions the α, β and T corrections were considered in the individual and general treatments. The insertion of the parameters β and T improved the results by about 21 percent. The rms error on fitting 703 levels by means of 21 free interaction parameters was 231 cm^{-1}. Altogether 912 energy levels were predicted.

Configurations $3d^n4p + 3d^{n-1}4s4p$ in Sc II, Ti II, and V II, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 2, 159-171 (Mar.-Apr. 1969).

Key words: Configurations $3d^n4p + 3d^{n-1}4s4p$; energy levels; interaction between configurations; iron group; second spectra.

Experimental levels of the configurations $3d^n4p + 3d^{n-1}4s4p$ for Sc II, Ti II, and V II were compared with corresponding calculated values. Electrostatic, spin-orbit interactions, as well as the α, β and T corrections, whenever possible, were considered for $3d^n4p$ and $3d^{n-1}4s4p$. The electrostatic interaction between the configurations $3d^n4p$ and $3d^{n-1}4s4p$ was included explicitly. The rms errors for Sc II, Ti II and V II were 4.6, 75 and 66 cm^{-1}, respectively.

Effective interactions in the even configurations of the third spectra of the iron group, Y. Shadmi, E. Caspi, and J. Oreg, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 2, 173-189 (Mar.-Apr. 1969).

Key words: Atomic theory; iron group; third spectra.

Four hundred eighty-three levels belonging to the configurations $3d^n + 3d^{n-1}4s$ of all third spectra of the iron group were calculated, and 334 observed levels were fitted to them. In addition to the usually used approximation, we first introduced a complete set of two-body and three-body effective-interaction parameters between $3d$ electrons. Using only two-body effective interactions, we obtained a rms error of 175 cm^{-1}; while the addition of three-body effective interactions reduced the rms error to 46 cm^{-1}. When a parameter representing three-body effective interaction between $3d$ and $4s$ electrons was also introduced, the rms error was reduced to 38 cm^{-1}.

Test of a kinetics scheme: emission in $H(^2S)+NO(^2\Pi)$, M. Krauss, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 2, 191-193 (Mar.-Apr. 1969).

Key words: Hartree-Fock; $HNO(^1A', ^3A'', ^1A')$; interaction energy; ionic state; radiative recombination; reaction barrier.

The mechanism to explain the afterglow in the collision of $H(^2S)$ and $NO(^2\Pi)$ is critically examined by calculating part of

the energy surface of the $^3A''$ state. It is found that the long range interaction energies are consistently repulsive even though at shorter distances attractive ionic interactions dominate. It is concluded that the essential feature of the Clyne and Thrush mechanism is missing; intimate interaction of $H(^2S)$ and $NO(^2\Pi)$ is not possible at room temperature along the $^3A''$ surface. This study was undertaken to provide an example where a theoretical calculation is required to critically test a kinetics mechanism.

A nuclear magnetic resonance and relaxation study of dimethoxyborane, T. C. Farrar and T. Tsang, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 195-199 (Mar.-Apr. 1969).

Key words: Boron-10; boron-11; dimethoxyborane; proton: pulsed nuclear magnetic resonance; scalar and quadrupolar coupling constants and relaxation effects.

Proton and boron-11 c.w. nuclear magnetic resonances have been studied in solid $H^{11}B(OCD_3)_2$ and $H^{10}B(OCD_3)_2$. For $^{11}3$, only the $-1/2 \rightarrow 1/2$ transition, broadened by second order quadrupolar effects and by proton dipolar interaction can be seen; from the spectrum at several rf frequencies, the quadrupolar coupling constant $|e^2qQ/h|$ was found to be 3.0 ± 0.2 MHz ($\pm$ always refers to rms errors). In $H^{10}B(OCD_3)_2$, the proton line shapes at 53 and 10 MHz are considerably different; this may be interpreted as due to changes in the directions of ^{10}B nuclear quantization. Nuclear magnetic relaxation studies have been made in the liquid phase. From the ^{10}B and ^{11}B relaxation times, the activation energy for molecular reorientation was found to be 8.7 ± 0.4 kJ/mol (2.1 ± 0.1 kcal/mol). Consistent values for $|e^2qQ/h|$ were obtained from relaxation measurements in liquid phase and from c.w. spectra in solid phase. The temperature dependence of proton relaxation times deviates significantly from the activation energy model at higher temperatures, where spin-rotation interactions may be important. Proton transverse relaxation times (T_2) have also been measured and are consistent with the Allerhand-Thiele theory.

The effects of low energy irradiation on organometallics. Organometal halides of group IVA, F. E. Brinckman, G. F. Kokoszka, and N. K. Adams, Jr., *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 201-206 (Mar.-Apr. 1969).

Key words: EPR; free radicals; germanium; irradiation; low-temperature reaction; organometallic compounds; silicon; tin.

A group of selected group IVA halides of the type $(CH_3)_nMCl_{4-n}$, where $n = 0$, 1, 3 and M = Si, Ge, Sn have been subjected to low-energy irradiation (254 and 370 nm) in the condensed phase at -196 °C. This survey also examined related compounds including $HSiCl_3$, $CH_2ClSiCl_3$, CH_3SiF_3, CH_3SiHCl_2 as well as cocondensed mixtures. It is demonstrated by EPR spectroscopy that these conditions suffice to cleave M–C bonds. By following spectral changes during or following irradiation, as a function of time, it is demonstrated that both primary and secondary reactions occur. Some general features of the spectra are discussed and certain conclusions are projected to additional studies on low temperature reactions in 1:1 cocondensed mixtures of organometal halides. Some preliminary supporting evidence from mass spectrometric observations is discussed.

Measurements of gaseous diffusion coefficients by a gas chromatographic technique, S. P. Wasik and K. E. McCulloh, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 207-211 (Mar.-Apr. 1969).

Key words: Argon; diffusion coefficient; gas chromatography; helium; krypton; nitrogen; oxygen.

A method is presented for measuring gaseous diffusion coefficients using a gas chromatographic technique. Diffusion coefficients were measured for the systems: argon, krypton, oxygen, and nitrogen diffusing into helium at temperatures from 77 to 400 K.

Phase relations in the Ru-Ir-O_2 system in air, C. L. McDaniel and S. J. Schneider, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 213-219 (Mar.-Apr. 1969).

Key words: Dissociation; oxidation; phase relations; Ru-Ir-O_2 system; RuO_2-IrO_2 system; solid solution.

The equilibrium phase relations were determined in an air environment for the system Ru-Ir-O_2. In air Ru oxidizes at moderate temperatures, to form RuO_2, which in turn dissociates at 1405 °C. Similarly Ir oxidizes to form IrO_2 and dissociates at 1020 °C. The dissociation of RuO_2 and IrO_2 are reversible processes. A ternary equilibrium phase diagram was constructed indicating selected oxygen reaction lines and isotherms. A binary representation of the Ru-Ir-O_2 system in air is given. Up to 1020 °C, RuO_2 reacts with IrO_2 to form a complete solid solution series having the rutile-type structure. At 1345 °C three solid phases, $rutile_{ss}$, Ru_{ss}, and Ir_{ss}, exist in equilibrium for compositions between approximately 2 and 45 mole percent IrO_2. Above 1405 °C dissociation is complete for all compositions and the phase relations are represented by the Ru-Ir system. At 1500 °C solid solution of Ru and Ir occurs with the addition of up to 45 mole percent Ir and up to 44 mole percent Ru, respectively.

Heats of reaction of natural rubber with sulfur, N. Bekkedahl and J. J. Weeks, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 221-231 (Mar.-Apr. 1969).

Key words: Aneroid calorimeter; calorimeter; heat measurements; heat of vulcanization; rubber; rubber-sulfur reaction; volume change on vulcanization; vulcanization.

An adiabatic copper calorimeter was used to determine the heats of vulcanization of pale crepe natural rubber with sulfur for mixtures varying in composition from 0 to 32 percent added sulfur. The side reaction that produces hydrogen sulfide was avoided by using reaction temperatures near 155 °C. Heats of reaction at 25 °C and at 155 °C are reported. The enthalpy change at 25 °C for compounds containing up to about 18 percent sulfur is given in joules per gram of vulcanizate by the equation, $\Delta H_{25} = -21.1 \cdot S$ with a standard deviation of 11 J/g. Here S is the percentage of combined sulfur. Above 18 percent sulfur the heat of reaction at 25 °C remains approximately constant at 380 ± 8 J/g. A comparison is made between the heat of vulcanization and the volume change on vulcanization, both as functions of combined sulfur, by making use of data in the literature.

A table of rotational constants of symmetric top molecules giving rise to microwave spectra, M. S. Lojko and Y. Beers, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 233-239 (Mar.-Apr. 1969).

Key words: Asymmetric, linear, and symmetric top molecules; "B" rotational constants; formaldehyde; microwave spectra; spectral lines; water.

This paper lists, in order of increasing value, the "B" rotational constants of most of the linear and symmetric top molecules which have been observed by microwave spectroscopy. Also are listed the microwave spectral lines which have been observed for the asymmetric tops water and formaldehyde. These data are useful for making a quick selection of a molecule which has a spectral line close to some previously selected frequency.

Energy levels, wave functions, dipole and quadrupole transition of Fe^{+++} ions in sapphire, J. Lewiner and P. H. E. Meijer, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73A** (Phys. and Chem.), No. 2, 241-268 (Mar.-Apr. 1969).

Key words: Energy levels of Fe^{+++} in Al_2O_3; iron doped Al_2O_3; magneto elastic tensor; paramagnetic resonance; quadrupole transitions; spin hamiltonian; transition probabilities; ultrasonic (paramagnetic) resonance; ultrasonic transition probabilities; wave functions of Fe^{+++}.

A computation is made of energy levels, wave functions and transition probabilities of the Fe^{3+} ion in Al_2O_3. The crystal field parameters used were those determined by Symmons and Bogle at 4 K. The magnetic field direction is described by the angles θ and φ indicating the directions with respect to and around the c axis of the crystal. The values of θ go from 0 to $\pi/2$ with $\pi/12$ intervals, the angles φ are 0 and $2\pi/3$ corresponding to the two nonequivalent sites of the crystal. The transition probabilities are given for dipole radiation in three polarization directions and for ultrasonic work the six components of the quadrupole transitions were computed.

May–June 1969

New even levels and classified lines in the first spectrum of tungsten (W I), C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 277-279 (May-June 1969).

Key words: Atomic energy levels in W I; classified lines of W I; spectrum, W I; tungsten, first spectrum; W I.

Ten new even levels, which classify 161 previously unclassified lines, have been found in the first spectrum of tungsten. Nine of these fit levels in the $(5d+6s)^6$ mixture of configurations calculated theoretically by Shadmi and Caspi.

The heat of combustion of beryllium in fluorine, K. L. Churney and G. T. Armstrong, *J. Res. Nat. Bur. Stand. (U. S.)*, **73A** (Phys. and Chem.), No. 3, 281-297 (May-June 1969).

Key words: Analysis of methane-hydrogen mixtures; beryllium fluoride; beryllium metal; combustion calorimetry; fluorine; heat of formation; molecular-sieve gas analysis; polytetrafluoroethylene.

An experimental determination of the energies of combustion in fluorine of polytetrafluoroethylene film and powder and of mixtures of beryllium with polytetrafluoroethylene gives for reaction (1) $\Delta H^\circ_{25°C} = -1022.22$ kJ mol^{-1} (-244.32 kcal mol^{-1}) with an overall precision of 0.96 kJ mol^{-1} (0.23 kcal mol^{-1}) at the 95 percent confidence limits. The total uncertainty is estimated not to exceed ± 3.2 kJ mol^{-1} (± 0.8 kcal mol^{-1}). The measurements on polytetrafluoroethylene give for reaction (2a) and reaction (2b) $\Delta H^\circ_{25°C} = -10369.7$ and -10392.4 Jg^{-1}, respectively. Overall precisions expressed at the 95 percent confidence limits are 3.3 and 6.0 Jg^{-1}, respectively.

$$\mathrm{Be(c) + F_2(g) = BeF_2(amorphous)} \qquad (1)$$

$$\mathrm{C_2F_4(polymer\ powder) + 2F_2(g) = 2CF_4(g)} \qquad (2a)$$

$$\mathrm{C_2F_4(polymer\ film) + 2F_2(g) = 2CF_4(g)} \qquad (2b)$$

Be_2C and Be metal were observed in a small carbonaceous residue from the combustion of the beryllium-polytetrafluoroethylene mixtures. Methods of analysis for these substances were developed. Gases resulting from the solution of the solid residues in aqueous KOH were analyzed for H_2 and CH_4 by differential absorption in molecular sieves at low temperatures.

Deuterium isotope effect on the dissociation of weak acids in water and deuterium oxide, R. A. Robinson, M. Paabo, and R. G. Bates, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 299-308 (May-June 1969).

Key words: Acidic dissociation; acidity; deuterium isotope effect; dissociation constants; heavy water; isotope effect pK values.

The dissociation constants of *o*-nitroanilinium ion, *m*-nitroanilinium ion, and 4-chloro-2,6-dinitrophenol in deuterium oxide at 25 °C have been determined by a spectrophotometric method, and an emf method has been used to obtain $(pK_1 + pK_2)/2$ for citric acid in deuterium oxide. In addition, data for the dissociation constants of other weak acids in ordinary and heavy water have been critically examined with a view to clarifying the relationship between the deuterium isotope effect and the intrinsic strength of the acid. The difference ΔpK between the pK value in deuterium oxide and that in water varies linearly with pK above $pK = 7$. Two stronger inorganic acids (sulfuric and phosphoric) also appear to lie on an extension of this same line. On the contrary, a considerable group of organic acids with pK less than 7 have values of Δpk that are more or less constant near $\Delta pK = 0.55$. It appears, therefore, that the isotope effect is more complex than has heretofore been assumed.

Vortex motions in ideal Bose superfluid, M. J. Cooper, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 309-312 (May-June 1969).

Key words: Coherent Bose gas; superfluid; vortices.

A general nonlinear field equation is derived for the macroscopic order parameter of an ideal coherent Bose gas. It is shown that this noninteracting system can support stable quantized vortex-like motions within the superfluid phase. It is suggested that this coherent phase of the ideal Bose gas describes the dominant physical features of real superfluid liquid helium.

Franck-Condon factors for the ionization of H_2O and D_2O, R. Botter and H. M. Rosenstock, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 313-319 (May-June 1969).

Key words: D_2O; Franck-Condon principle; geometry; H_2O; ion; photoionization; photoelectron spectroscopy.

Franck-Condon factors have been calculated for vertical transitions of H_2O and D_2O involving both bond length and angle changes. It is shown that even in the harmonic oscillator approximation different Franck-Condon factors are obtained for positive and negative angle changes. The results are used to obtain the geometry of the ion ground state. Satisfactory agreement is obtained for the isotope effect on the vibrational transition probabilities. The effects of anharmonicity are discussed semiquantitatively.

Topological features of hot carrier induced anisotropic breakdown on silicon diode surfaces, G. G. Harman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 321-331 (May-June 1969).

Key words: Anisotropy; crystallographic orientation; hot carriers; semiconductor breakdown; silicon diodes.

Both Gunn and Morozov have reported breakdown paths (tracking) on the surface of germanium under hot carrier conditions. Many silicon and gallium arsenide device failures appear to have been caused by similar breakdown tracks extending between contacts or across junctions. In the present work on silicon, extremely anisotropic tracking has been observed on the surface of long, thin, forward biased, $n^+ - p - p^+$, silicon diodes. The tracks propagate only in ⟨100⟩ crystallographic directions, independent of the applied field orientation, the temperature, or the crystal growth direction. For example, on a sample with a {100} surface plane, having the field oriented along a ⟨110⟩ direction, the tracks propagate along ⟨100⟩ directions which are 45° away from the applied field. Tracks on {100}-plane, disk shaped diodes, propagate radially from the center (positive biased) ohmic contact region and mark off the ⟨100⟩ directions

within 2°. Tracking requires both high current densities (~ 5 × 10^3 A/cm²) and high fields (~ 15 kV/cm), and occurs most readily on the *p*-region of 10 Ω cm, $n^+ - p - p^+$, ⟨100⟩ oriented diodes. Diodes with $n^+ - n - p^+$ structures having *n*-regions ~1 Ω cm, and $n^+ - n - n^+$, structures of ~ 1 Ω cm will also track, but require much higher fields and the ⟨100⟩ tracking orientation is not clearly defined. Tracking does not occur on diodes having the field oriented along a ⟨111⟩ direction.

Two basic types of tracks are observed. The first resembles a series of tiny explosion craters (~ 10μ m diam). The second appears to be continuous in nature, even though it is extended by each applied pulse. These tracks may be several micrometers wide and deep.

It is also shown that hot-minority-carrier sample explosions are anisotropic and not, as generally assumed, caused by thermal breakdown. Typically a {110} ⟨111⟩ oriented $n^+ - p - p^+$ sample requires 4 to 6 times more impulse energy to explode than a {100} ⟨100⟩ oriented sample.

The third spectrum of praseodymium (Pr III) in the vacuum ultraviolet, J. Sugar, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 3, 333-381 (May-June 1969).

Key words: Energy levels; interaction parameters; praseodymium; third spectrum; vacuum ultraviolet; wavelengths.

Measurements of the spectrum of doubly ionized praseodymium from 821 to 2103 Å are given. One hundred fifty-three energy levels deduced from these wavelengths and an earlier line-list of longer wavelengths are presented. These levels are identified with the configurations $4f^26s$. $4f^27s$. $4f^28s$. $4f^26p$. $4f^26d$. $4f^25f$. $5d^24f$. and $4f5d6s$ and are given term designations. Radial energy integrals belonging to these configurations are parametrically deduced from the known levels.

A value of 21.625 eV (174420 cm^{-1}) for the ionization energy of Pr III, with an estimated uncertainty of 0.016 eV (130 cm^{-1}), is derived from the $4f^2ns$ series ($n = 6, 7, 8$).

July-August 1969

Classical path methods in line broadening. I. The classical path approximation, E. W. Smith, C. R. Vidal, and J. Cooper, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 4, 389-404 (July-Aug. 1969).

Key words: Classical path methods; line broadening theory.

The classical path approximation is reviewed in a manner which permits definitive statements concerning its region of validity.

Classical path methods in line broadening. II. Application to the Lyman series of hydrogen, E. W. Smith, C. R. Vidal, and J. Cooper, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 4, 405-420 (July-Aug. 1969).

Key words: Classical path; impact theory; line broadening theory; one-electron theory.

The use of the classical path approximation in line broadening theory is illustrated in a development of the familiar impact and one-electron theories. The one-electron theory which is presented is an improved version of the usual one-electron theory; this improved version of the theory provides a consistent description of a line profile from the halfwidth to the quasi-static wings. The validity criteria for the impact and one-electron theories are discussed in detail and a comparison of the theories is made with a view toward the development of a more general theory containing elements of both. To avoid unnecessary mathematical complications and to provide a more transparent comparison of the theories, the Stark broadening of the Lyman series in hydrogen is used as a specific example.

The second virial coefficient for the realistic pair potential, H. W. Woolley, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 4, 421-423 (July-Aug. 1969).

Key words: Hypergeometric series; London interaction; pair potential function; realistic potential; second virial coefficient; spherical potential.

An analytical formulation for the second virial coefficient is given for a spherically symmetric potential function of a simple form which has been called a realistic pair potential. This potential, given as an inverse relationship with r as a function of U, is capable of being much softer than a Lennard-Jones in the extreme of close approach. Differing forms of the result are given, including an expression by means of the generalized hypergeometric series. The result is also expressed in terms of the second virial coefficient for the (12, 6) potential.

Synthesis of barium ferrates in oxygen, T. Negas and R. S. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 4, 425-430 (July-Aug. 1969).

Key words: Ferrates; hexagonal barium ferrate; perovskite; phase equilibria; tetravalent iron.

Phase relations in the system $BaO - Fe_2O_3 -$ "FeO_2" at 1 atm (1 atm = 1.013 × 10^5 N/m²) oxygen and between 800 to 1050 °C are shown in the vicinity (high Ba portion) of the 1:1 cation-cation ratio composition. A hexagonal $BaTiO_3$-like phase, $BaFeO_{3-x}$ (a = 5.676 Å, c = 13.934 Å), exists below 960 °C. A perovskite-like phase $BaFeO_{3-x'}$ occurs between 960 and 1050 °C. Single-phase tetragonal perovskite can be obtained at room temperature by quenching compositions with Ba-Fe ratios of 67:66 (a = 3.985 Å, c = 4.005 Å, 1000 °C) and 27:26 (a = 3.988 Å, c = 4.003 Å, 1000 °C) from above 960 °C. At the 17:16 ratio, single phase cubic perovskite (a = 3.994 Å, 1000 °C), can be synthesized. Influence of temperature, additions of barium, and use of Pt-containers on phase relations are discussed.

The system SrO – "chromium oxide" in air and oxygen, T. Negas and R. S. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **73A** (Phys. and Chem.), No. 4, 431-442 (July-Aug. 1969).

Key words: Chromium oxide; phase equilibria; strontium chromates; strontium-"chromium oxide" system, $SrCrO_4$, $Sr_3Cr_2O_8$.

Phase relations in the system SrO – "chromium oxide" were determined in air and 1 atm O_2 (1 atm = 1.013 × 10^5 N/m²) and are shown as isobaric projections on the $SrO - Cr_2O_3$ pseudobinary. At both oxygen pressures, the system consists of three joins in the $SrO - Cr_2O_3$-oxygen ternary, (1) $SrO - Sr_3Cr_2O_8$, (2) $Sr_3Cr_2O_8 - SrCrO_4$, and (3) $SrCrO_4 - Cr_2O_3$. The former is binary from 1065 °C to liquidus temperatures in air and includes a eutectic near 79 mol percent SrO (in terms of $SrO - Cr_2O_3$ starting materials). $Sr_3Cr_2O_8$ melts congruently at 1453 °C. Below 1065 °C in air, phase relations are complicated by reactions with atmospheric water vapor resulting in the formation of $Sr_{10}Cr_6O_{24}$ $(OH)_2$ which decomposes to SrO and $Sr_3Cr_2O_8$ above 1065 °C. In air, below 775 °C, $Sr_3Cr_2O_8$ reacts with water vapor and oxygen to form $Sr_{10}Cr_6O_{24}$ $(OH)_2$ and $SrCrO_4$. Water vapor reactions are restricted in 1 atm O_2. The $Sr_3Cr_2O_8 - SrCrO_4$ join contains a binary eutectic between 69-70 mol percent SrO but liquidus relations are ternary below 69 (air) and 68 (oxygen) mol percent SrO, as reduction of Cr^{6+} occurs. Likewise, the $SrCrO_4 - Cr_2O_3$ join is not binary at solidus and liquidus temperatures. In air, $SrCrO_4$ melts at 1251 °C to Cr_2O_3 plus liquid with release of oxygen. In oxygen, the compound melts at 1283 °C with evolution of oxygen.

September-October 1969

Conversion of existing calorimetrically determined thermodynamic properties to the basis of the International Practical Temperature Scale of 1968, T. B. Douglas. *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 451-470 (Sept.-Oct. 1969).

Key words: Existing property tables; IPTS–48; IPTS–68; practical-scale differences; temperature-scale conversion; thermodynamic properties.

Formulas are derived for converting the relative enthalpy, heat capacity, entropy, and Gibbs energy from the basis of one practical temperature scale to the basis of another, when these properties on either scale have been derived from calorimetric measurements of enthalpy as though that scale were the thermodynamic one. These formulas are directly applicable for converting certain other properties as well. The conversion relates the values of the property at the same numerical temperature on both scales. The formulas, given as exact infinite series, are applicable to widely differing scales, one of which may vary linearly with a temperature-measuring quantity such as electrical resistance. However, great simplification is well within most calorimetric accuracy when the conversion is from the International Practical Temperature Scale of 1948 to the corresponding scale of 1968, which has recently replaced it, provided the heat capacity is not changing abnormally rapidly, as in a transition region. For convenient application to conversion between these two scales, relatively simple numerical equations are derived giving the differences between the two scales at temperatures from 90 K to 10,000 K. The problem of avoiding the introduction of discontinuities with temperature in converted tables, arising from the existing discontinuities in the temperature derivative of the differences between the two scales, is discussed.

Measured enthalpy and derived thermodynamic properties of alpha beryllium nitride, Be_3N_2, from 273 to 1200 K, T. B. Douglas and W. H. Payne, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem). No. 5, 471-477 (Sept.-Oct. 1969).

Key words: Beryllium nitride; drop calorimetry; enthalpy data; light-element compounds; refractory crystals; thermodynamic properties.

The relative enthalpy of a sample of alpha beryllium nitride, Be_3N_2, of 95 percent purity was precisely measured over the temperature range 273 to 1173 K using a drop calorimetric method. Corrections were applied for the impurities, and the resulting heat capacity–temperature function was required to join smoothly that from recent precise NBS adiabatic calorimetry which covered the range 20 to 315 K. The enthalpy, heat capacity, entropy, and Gibbs free-energy function were computed from empirical functions of temperature and tabulated from 273 to 1200 K.

Measured enthalpy and derived thermodynamic properties of solid and liquid lithium tetrafluoroberyllate, Li_2BeF_4, from 273 to 900 K, T. B. Douglas and W. H. Payne. *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 479-485 (Sept.-Oct. 1969).

Key words: Drop calorimetry; enthalpy data; lithium beryllium fluoride; lithium tetrafluoroberyllate; premelting; thermodynamic properties.

The enthalpy of a sample of lithium tetrafluoroberyllate, Li_2BeF_4, of 98.6 percent purity was measured relative to 273 K at eleven temperatures from 323 to 873 K. Corrections were applied for the impurities and for extensive premelting below the melting point (745 K). The enthalpy and heat capacity, and the entropy and Gibbs free-energy function relative to the undetermined value of $S°_{298.15}$, were computed from empirical functions of temperature derived from the data, and are tabulated from 273 to 900 K.

Nonanalytic vapor pressure equation with data for nitrogen and oxygen, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 487-491 (Sept.-Oct. 1969).

Key words: Critical point; equation; formula; liquid; nitrogen; nonanalytic; oxygen; vapor pressure.

The specific heat of a two phase liquid-vapor system at constant volume apparently increases without limit at temperatures approaching the critical point, suggesting (via a thermodynamic relation) that the vapor pressure derivative d^2P/dT^2 may behave similarly. This nonanalytic behavior at the critical point is used in the present vapor pressure formula to gain simplicity and accuracy, as seen by use of data for nitrogen and oxygen.

Some precise measurements of the vapor pressure of water in the range from 25 to 100 °C, H. F. Stimson. *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 493-496 (Sept.-Oct. 1969).

Key words: Manometer; precision manometer; pressure; *p-t* relation; *p-t* relation of water; standard resistance thermometers; temperature; vapor pressure; vapor pressure of water; water.

The vapor pressure of water was measured at seven temperatures in the range from 25 to 100 °C using the boiler and precision manometer with which standard resistance thermometers were calibrated at the NBS in the 1940's. A table gives measured values of pressure, adjusted to even degrees, and indicates estimates of the standard deviations of pressure and of the corresponding temperatures. Except for the measurement at 25 °C, the values of pressure were consistent within one part in 50 000. The temperature measurements had an estimated standard deviation of 0.000 40 degree.

The configurations $(3d + 4s)^n 4p$ in neutral atoms of calcium, scandium, and titanium, C. Roth. *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 497-510 (Sept.-Oct. 1969).

Key words: Configurations $(3d + 4s)^n 4p$; energy levels; first spectra; *g*-factors; interactions between configurations; iron group.

Experimental levels of the configurations $(3d + 4s)^n 4p$ for neutral atoms of calcium, scandium, and titanium were compared with corresponding calculated values. The rms errors in the calculated values for Ca I, Sc I, and Ti I were 23, 126, 126 cm^{-1}, respectively.

Absolute isotopic abundance ratio and atomic weight of terrestrial rubidium, E. J. Catanzaro, T. J. Murphy, E. L. Garner, and W. R. Shields, *J. Res. Nat. Bur. Stand. (U.S.),* **73A** (Phys. and Chem.), No. 5, 511-516 (Sept.-Oct. 1969).

Key words: Absolute ratio; atomic weight; isotopic abundances; rubidium.

An absolute value has been obtained for the isotopic abundance ratio of terrestrial rubidium, using solid-sample thermal ionization mass spectrometry. Samples of known isotopic composition, prepared from nearly isotopically pure separated rubidium isotopes, were used to calibrate the mass spectrometers. The resulting absolute $^{85}Rb/^{87}Rb$ ratio is 2.59265 ± 0.00170 which yields atom percents of: $^{85}Rb = 72.1654 \pm 0.0132$ and $^{87}Rb = 27.8346 \pm 0.0132$. The atomic weight calculated from this isotopic composition is 85.46776 ± 0.00026. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for the effects of known sources of possible systematic error.

Fundamental aspects of dislocation theory: A conference report with abstracts, J. A. Simmons, R. deWit, and R. Bullough,

J. Res. Nat. Bur. Stand. (U.S.), 73A (Phys. and Chem.), No. 5, 517-552 (Sept.-Oct. 1969).

Key words: Abstracts; conference; dislocations; fundamental aspects; theory.

A brief description of the Conference "Fundamental Aspects of Dislocation Theory" held at NBS, April 21-25, 1969, is given. This is followed by the abstracts of the papers, which will be published in 1970 in the hardbound Proceedings.

November-December 1969

Scaling analysis of thermodynamic properties in the critical region of fluids, M. Vicentini-Missoni, J. M. H. Levelt Sengers, and M. S. Green, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 563-583 (Nov.-Dec. 1969).

Key words: CO_2; chemical potential; critical point parameters; critical region; fluids; He^4; scaling laws; specific heat; thermodynamic properties; vapor pressure; xenon.

A review of the scaled equation of state proposed for the critical region of fluids and magnets is given using the language appropriate for fluids. The experimental evidence for the validity of the basic hypothesis underlying this equation of state is discussed in detail. Experimental data in the critical regions of CO_2, Xe, and He^4 are then analyzed using a closed-form expression for the chemical potential as a function of density and temperature, based on scaling ideas. Agreement between the proposed equation and the experimental data is found for the three substances. The results of the scaling of $\Delta\mu$, $\Delta\rho$, t data are shown not to be in contradiction with the analysis, also based on scaling ideas, of independent experimental measurements of both specific heat and vapor pressure.

Formulation of a nonanalytic equation of state for parahydrogen, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 585-591 (Nov.-Dec. 1969).

Key words: Critical point; equation of state; hydrogen; parahydrogen; specific heats; thermodynamic properties.

A method is described for building an equation of state which gives an infinite specific heat C_v at the critical point approached from the one-phase domain. Interpolated PVT data are used on isochores up to 100 K at densities to the liquid triple point. In addition to an accurate representation of these data, the equation gives specific heats which agree well with experimental data along near-critical isochores.

Dynamical model for Brillouin scattering near the critical point of a fluid, R. D. Mountain, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 593-598 (Nov.-Dec. 1969).

Key words: Brillouin scattering; critical opalescence; critical phenomena; density fluctuations in fluids; light scattering; volume viscosity.

A dynamical model for density fluctuations in a one-component fluid near the critical point is proposed and compared with existing measurements in carbon dioxide. The model is described by a set of linearized hydrodynamic equations modified to include a nonlocal pressure density relationship and to include relaxation in the volume viscosity. Parameters for the model are found which are consistent with bulk measurements. With these parameters the model reproduces, within experimental uncertainty, the observed Brillouin spectrum of critical opalescence in CO_2. The low frequency volume viscosity is found to diverge as the $-1/3$ power of $T - T_c$. An additional modification of the hydrodynamic equations, a frequency dependent thermal conductivity, is considered, but no definite conclusions can be reached as the Brillouin line-width data lack sufficient precision.

Odd configurations in singly-ionized copper, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 599-609 (Nov.-Dec. 1969).

Key words: Copper; energy levels; interaction between configurations; odd configurations; parameters; second spectra.

Experimental levels of the configurations $3d^94p$, $3d^95p$, $3d^96p$, $3d^84s4p$, $3d^94f$, and $3d^95f$ of Cu II were compared with corresponding calculated values. The electrostatic interactions between the configuration $3d^84s4p$ and the configurations $3d^94p$, $3d^95p$, and $3d^96p$ were considered explicitly. It was shown that the configurations $3d^94f$ and $3d^95f$ of Cu II do not interact strongly with other configurations.

Capillary depressions for nearly planar menisci, M. C. I. Siu, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 611-613 (Nov.-Dec. 1969).

Key words: Bessel functions; calculus of variations; capillary depression; Laplace's equation; meniscus; meniscus height; nearly planar meniscus.

It is demonstrated analytically that the capillary depression C of a nearly planar meniscus is linearly related to its meniscus height h by the relationship $C = h/[1 - I_0(r/a)]$. Here $a^2 = \gamma/\rho g$, ρ and γ are the density and surface tension of the liquid respectively, g, the acceleration due to gravity, r is the radius of the capillary tube at the liquid-solid-gas interface, and $I_0(z)$ is the modified Bessel function of the first kind and zero order.

Phase transformation in barium tetraborate, C. R. Robbins and E. M. Levin, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 615-620 (Nov.-Dec. 1969).

Key words: BaB_8O_{13}; heats of transformation; orthorhombic form; polymorphism; tetragonal form.

Orthorhombic BaB_8O_{13} ($a = 8.550$, $b = 17.352$, $c = 13.211$ Å. $D = 2.927$ g/cm³ at 25 °C) transforms reversibly at 700 °C to a high-temperature tetragonal form ($a = 8.629$, $c = 13.252$ Å, $D = 2.906$ g/cm³) stable from 700 °C to the congruent melting point (889 °C) of the compound. The transition is rapid and probably displacive in character. At the transformation point cell constants change discontinuously, doubling of the b axis is lost and cell contents are reduced from $Z = 8$ to $Z = 4$. Doubling of the b axis reappears with cooling to the transformation temperature and volume strain is relieved by formation of multiple twins or domains. The latent heat of transformation is 2100 J/mol (0.50 kcal/mol) and $dT/dP = -0.0363$ K/bar.

Crystallography and preparation of some $ABCl_3$ compounds, H. F. McMurdie, J. de Groot, M. Morris, and H. E. Swanson, *J. Res. Nat. Bur. Stand. (U.S.)*, 73A (Phys. and Chem.), No. 6, 621-626 (Nov.-Dec. 1969).

Key words: Chlorides, crystal structures; double chlorides; lattice constants; melting point; perovskites; polymorphism; x-ray diffraction.

Compounds of the composition $ABCl_3$, in which A is K, Rb, NH_4, or Cs and where B is a divalent element, have been reviewed. Ten new compounds were prepared on which there was little or no previous crystallographic information. Refined unit cell parameters were obtained on these and on fifteen other compounds in this group. A general review of the structural information on this group is presented in tables, and a comprehensive list of references is included.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 74A, JANUARY- DECEMBER 1970

January-February 1970

Standardization of cesium-137 gamma-ray sources in terms of exposure units (roentgens), T. P. Loftus, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 1-6 (Jan.-Feb. 1970).

Key words: Calibration; cavity ionization chamber; cesium-137; exposure rate; scattered radiation; standardization.

^{137}Cs γ-ray sources, which have been proposed by the Public Health Service as a substitute for radium in the treatment of malignant diseases, require suitable calibration if consistency is to be achieved in radiation treatment.

Several ^{137}Cs sources were calibrated using a graphite cavity ionization chamber in an open-air geometry. The contribution of scatter from the room surfaces was calculated and the source measurements corrected for this effect.

A large-volume aluminum-walled ionization chamber was designed and fabricated for use in routine calibrations. This chamber will be used as a means for intercomparison of the source to be calibrated with one of the standards.

Calculations of Zn II $3d^9 4s5s$ and Ag I $4d^9 5s6s$, and some new levels in these spectra, W. C. Martin and J. Sugar, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 7-10 (Jan.-Feb. 1970).

Key words: Atomic spectra; energy levels; silver; zinc.

Results of intermediate-coupling calculations are given for Zn II $3d^9 4s5s$ and Ag I $4d^9 5s6s$. A $[(4d^9)J_I, (5s6s)J_{II}]J$ coupling scheme is appropriate for the latter. New $3d^9 4s(^3\mathrm{D})5s\ ^2\mathrm{D}_{2\,1/2}$ and $3d^9 4s(^1\mathrm{D})5s\ ^2\mathrm{D}_{2\,1/2}$ levels were found in Zn II, and a few other additions and revisions are given for the analysis. The combinations of the new levels $3d^9(^2\mathrm{D})4s4p(^3\mathrm{P}^\circ)\ ^4\mathrm{F}^\circ_{4\,1/2}$ in Zn II and $4d^9(^2\mathrm{D})5s5p(^3\mathrm{P}^\circ)\ ^2\mathrm{F}^\circ_{2\,1/2}$ in Ag I are also listed.

New vacuum ultraviolet wavelengths and revised energy levels in the second spectrum of zinc (Zn II), W. C. Martin and V. Kaufman, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 11-22 (Jan.-Feb. 1970).

Key words: Atomic energy levels of Zn II; ionized zinc; spectral wavelengths of Zn II.

Spectra from sliding spark discharges between zinc electrodes and from a hollow-cathode source were photographed in the range 2105-1400 Å with the NBS 10.7 m vacuum spectrograph. New measurements of 130 Zn II lines in this region, combined in some cases with previous measurements in the air region, were used to derive revised positions for the known levels. Wavelengths calculated from these levels are given for 267 lines in the region 2570-730 Å. The line list also includes unclassified Zn II lines below 2570 Å, based on the most complete description of this spectrum [A. M. Crooker and K. A. Dick, Can. J. Phys. **46,** 1241 (1968)]. A few additions to the line list of Crooker and Dick above 2700 Å are given. The line and level lists take into account recent work at the National Bureau of Standards on the Zn II analysis.

CIE 1960 UCS diagram and the Müller theory of color vision, D. B. Judd and G. T. Yonemura, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 23-30 (Jan.-Feb. 1970).

Key words: Chromaticity; color; perception; protanopia; tritanopia; vision.

A close relationship has been shown to exist between the second stage of the Müller theory and the MacAdam 1937 (u, ϵ)-diagram recommended in 1960 by the CIE for interim use as a chromaticity diagram having approximately uniform scales. By considering normal vision as a combination of protanopia and tritanopia as suggested by the Müller second stage, a more general measure of the perceived size of a chromaticity difference is developed than the length of the line connecting the two chromaticity points. The general measure is the square root of the sum of the squares of the angles subtended by the line at the convergence points of the chromaticity confusion lines for protanopia and tritanopia, respectively. By this measure the chromatic sensibility to wavelength change in the spectrum is accounted for quantitatively not only for protanopic and tritanopic vision, but also for normal vision including the secondary maximum of sensibility in the neighborhood of 420 nm.

Blemish formation in processed microfilm II, C. I. Pope, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 31-36 (Jan.-Feb. 1970).

Key words: Archival record film; microfilm; microfilm storage cartons; permanent record film; peroxides; redox blemishes; zinc powder.

Gaseous peroxides form blemishes on some processed microfilms. Two procedures are given for testing the blemish susceptibility of processed microfilm, one using peroxide paper and the other zinc powder as a source of peroxide. The susceptibility of microfilm to blemish formation decreased when conditioned at 86 percent relative humidity and 26 °C. Coarse-grain microfilms are less susceptible to blemish formation than fine-grain microfilm. Fine-grain microfilms fixed in ammonium thiosulfate were less susceptible to blemish formation than those fixed in sodium thiosulfate. Oven-aged microfilm storage cartons were found to generate peroxide when wetted. The microfilm base readily absorbed hydrogen peroxide.

Positive and negative ion sublimation from transition metal surfaces: A review of some recent results, M. D. Scheer, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 1, 37-43 (Jan.-Feb. 1970).

Key words: Mass spectrometry; positive and negative ions; sublimation; transition metals.

Singly charged, positive and negative, atomic ions have been observed to sublime freely from 4*d* and 5*d* transition metal surfaces in the 1800 to 2600 K temperature range. The rates of

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

sublimation were found to be about equal to those which would be observed under conditions of thermal equilibrium. Ion sublimation energies were obtained from the temperature dependence of these sublimation rates. The energies were found to be consistent with currently accepted values for the atom sublimation energy, electron work function, and first ionization potentials of the elements investigated.

The electron affinities of these metal atoms were determined from an isothermal measurement of the ratio of positive to negative ion sublimation rates. The results were compared with some recent theoretical estimates of this quantity for those $3d$ transition metals whose valence electron configurations are analogous to the $4d$ and $5d$ elements considered here.

Generation of controlled low pressures of nitrogen by means of dissociation equilibria, R. H. Orcutt, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 1, 45-49 (Jan.-Feb. 1970).

Key words: Barium nitride; dissociation equilibria; nitrides; nitrogen; thermodynamic properties; vacuum; vacuum measurement.

It is shown that fixed low pressures of nitrogen in the vacuum region can be generated by chemical dissociation in a system at equilibrium at constant temperature. Dissociation pressures ranging from 2×10^{-5} to 0.7 torr (3×10^{-3} to 90 $N \cdot m^{-2}$), corresponding to temperatures of 740 to 1150 K, for the reaction

$$Ba_3N_2 \rightleftarrows 3/2\ Ba_2N + 1/4\ N_2$$

have been measured. The pressures, p, in $N \cdot m^{-2}$ are represented by the equation

$$\ln p = (22.02 \pm 0.14) - (20{,}080 \pm 140)/T,$$

where T is the absolute temperature, and the uncertainties are least squares estimates of the standard deviations of the parameters.

Temperature coefficient of the bismuth I-II transition pressure, J. C. Houck, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 1, 51-63 (Jan.-Feb. 1970).

Key words: Bismuth transition; calibration point; high pressure; pressure measurement; temperature coefficient.

A rotatable piston in a supported cylinder was used to determine the temperature coefficient of the bismuth I-II transition pressure for the temperature range of 20 to 50 °C. The temperature coefficient of the transition pressure is −40.6 bar/°C.

Isothermal diffusion in the dilute range of the system $Ca(OH)_2 - H_3PO_4 - H_2O$: Theory, E. C. Moreno, P. R. Patel, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 1, 55-63 (Jan.-Feb. 1970).

Key words: Diffusion; phenomenological coefficients; polycomponent systems; reciprocal relations.

The equations describing isothermal diffusion in the dilute range of the ternary system $Ca(OH)_2 - H_3PO_4 - H_2O$ are derived in two ways, first, assuming that the components are electroneutral species and, second, considering the actual ionic species present in solution. It is shown that the two models are thermodynamically equivalent. The theory permits the calculation of the four fundamental diffusion coefficients (phenomenological coefficients) in the concentration range where the Debye-Hückel theory suffices for the calculation of ionic activity coefficients. The equations can be used to test the Onsager reciprocal relations for the diffusion process in the above system. The ionic model was used to calculate practical diffusion coefficients for the electroneutral components from the limiting equivalent conductances of the ions in solutions saturated with respect to hydroxyapatite, $Ca_{10}(OH)_2(PO_4)_6$. Large diffusion interferences, as revealed by relatively large values for the cross-terms in D_{ij}, are predicted even for solutions with total molarity in the order of 10^{-5}. Therefore, diffusion models based on independent fluxes of the components appear to be invalid.

High-speed (subsecond) measurement of heat capacity, electrical resistivity, and thermal radiation properties of molybdenum in the range 1900 to 2800 K, A. Cezairliyan, M. S. Morse, H. A. Berman, and C. W. Beckett, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 1, 65-92 (Jan.-Feb. 1970).

Key words: Electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; molybdenum; thermal radiation properties; thermodynamics.

A technique is described for the high-speed measurement of heat capacity, electrical resistivity, hemispherical total and normal spectral emittances of electrical conductors at high temperatures (above 1900 K) with millisecond resolution. Duration of an individual experiment, in which the specimen is heated from room temperature to close to its melting point, is less than one second. Temperature measurements are made with a high-speed photoelectric pyrometer. Quantities are recorded by a high-speed digital data acquisition system which has a resolution of approximately one part in 8000. Time resolution of the entire system is 0.4 ms. Results on the above properties of molybdenum in the temperature range 1900 to 2800 K are reported and are compared with those in the literature. Estimated inaccuracy of measured properties in the above temperature range is: 2 to 3 percent for heat capacity, 0.5 percent for electrical resistivity, 3 percent for hemispherical total emittance and 2 percent for normal spectral emittance.

P−V−T, thermodynamic and related properties of oxygen from the triple point to 300 K at pressures to 33 MN/m², L. A. Weber, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 1, 93-129 (Jan.-Feb. 1970).

Key words: Density; enthalpy; entropy; equation of state; fixed points (PVT); Joule-Thomson; latent heat; melting curve; oxygen; properties of fluids; saturated liquid and vapor; specific heat; vapor pressure; velocity of sound.

The results of new experimental pressure-volume-temperature measurements on oxygen are presented. The data range in temperature from 54 to 300 K and in pressure from 0.1 to about 33 MN/m². The following properties are tabulated for selected isobars: molar volume, $(\partial P/\partial \rho)_T$, $(\partial P/\partial T)_\rho$, internal energy, enthalpy, entropy, specific heats at constant volume and at constant pressure, and the velocity of sound. Additional tables present the above properties for saturated liquid and vapor, the freezing liquid P−V−T relationship, and the derived Joule-Thomson inversion curve. New values for the critical density and triple point density are presented, and the second and third virial coefficients are tabulated.

March-April 1970

A theoretical investigation of the configurations $(3d+4s)^4 4p$ in neutral vanadium (V I), C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 2, 141-156 (Mar.-Apr. 1970).

Key words: Configurations in V I; configurations $(3d + 4s)^4 4p$ in V I; configuration interaction; energy levels of V I; first spectrum; g-values V I; parameters; theory; vanadium; V I; Zeeman effect.

Experimental levels of the configurations $(3d + 4s)^4 4p$ in V I were compared with corresponding calculated values. On fitting 228 experimental levels by means of 20 free parameters an rms error in the calculated values of 216 cm^{-1} was obtained. All the 438 theoretically predicted levels and g-factors were calculated.

A theoretical investigation of the configurations $(3d+4s)^5 4p$ in neutral chromium (Cr I), C. Roth, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 157-179 (Mar.-Apr. 1970).

Key words: Chromium; configurations in Cr I; configurations $(3d + 4s)^5 4p$ in Cr I; configuration interaction; Cr I; energy levels of Cr I; first spectrum; g-values Cr I; parameters; theory; Zeeman effect.

Experimental levels of the configurations $(3d + 4s)^5 4p$ in Cr I were compared with corresponding calculated values. On fitting 296 experimental levels by means of 20 free parameters an rms error of 183 cm^{-1} was obtained. All the 684 theoretically predicted levels and g-factors are calculated.

It is shown that the correction parameters β and T are not significant here.

A theoretical investigation of the configurations $(3d+4s)^7 4p$ in neutral iron, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 181-202 (Mar.-Apr. 1970).

Key words: Arc spectrum; configurations $(3d + 4s)^7 4p$; configuration interactions; energy levels; g-factors; iron.

Experimental levels of the configurations $(3d + 4s)^7 4p$ were compared with corresponding calculated values. On fitting 248 experimental levels by means of 20 free parameters an rms error of 213 cm^{-1} was obtained.

It was shown that the correction parameters β and T were not significant.

The intensity as a function of temperature of the low-angle x-ray diffraction maxima of the *n*-paraffins: Hexatriacontane, tetratetracontane, and tetranonacontane, P. K. Sullivan and J. J. Weeks, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 203-214 (Mar.-Apr. 1970).

Key words: Defects; *n*-paraffins; phase transition; temperature dependence; x-ray diffraction.

The diffraction of x-rays by the crystalline *n*-paraffins, $C_{36}H_{74}$, $C_{44}H_{90}$, and $C_{94}H_{190}$, was examined at small angles—below seven degrees 2θ—as a function of temperature. The Bragg maxima (00*l*) that occur at these angles result from a lamellar repeat distance which depends on the molecular length. In general the intensity of these maxima was found to increase with increasing temperature in an approximately reversible manner. All the samples experienced solid-solid phase transitions in the temperature range of observation. Several possible mechanisms consistent with the temperature dependence of the intensity are considered.

Photoelastic constants of ruby, R. M. Waxler and E. N. Farabaugh, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 215-220 (Mar.-Apr. 1970).

Key words: Birefringence; crystals, lasers; photoelasticity; ruby.

The eight piezo-optic and eight elasto-optic constants of synthetic, single crystal ruby have been determined using the cadmium red radiation of 643.8 nanometers (nm). All the constants are found to be negative in value, or to have very small positive values. The data indicate that changes in the polarizability of the oxygen ion and changes in the local field are primarily responsible for the observed changes in refractive index. Hydrostatic pressure has been used for the first time as part of a complete photoelastic investigation, and a new, screw-clamp device for easily attaining high, uniaxial stress is described.

Estimation of critical constants T_c, ρ_c from the $\rho(T)$ and $T(\rho)$ relations at coexistence, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 221-227 (Mar.-Apr. 1970).

Key words: Coexistence; coexistence temperatures; critical constants; critical density; critical temperatures; fluorine; neon; oxygen; orthobaric densities; parahydrogen; saturated liquid and vapor densities.

The critical temperature T_c and the critical density ρ_c are estimated from new equations (1) for the double-valued $\rho(T)$ relation, and (2) for the single-valued $T(\rho)$ relation. For method (1) this report gives concise descriptions of the rectilinear diameter and of the densities of liquid oxygen. Calculated vapor densities agree well with experimental oxygen data over the wide range from triple- to critical-point. Method (2) is applied to hydrogen, oxygen, fluorine, and neon, giving the $T(\rho)$ relation and estimates for T_c and ρ_c all in one step from the complete set of liquid and vapor data.

Synthesis and growth of fresnoite ($Ba_2TiSi_2O_8$) from a TiO_2 flux and its relation to the system $BaTiO_3$-SiO_2, C. R. Robbins, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 229-232 (Mar.-Apr. 1970).

Key words: $Ba_2TiSi_2O_8$; $BaTiSiO_5$; crystal growth; fresnoite; phosphor; piezoelectric; system $BaTiO_3$-SiO_2; TiO_2 solvent.

Crystals of $Ba_2TiSi_2O_8$ (synthetic fresnoite) up to 5 mm in longest dimension have been grown by slow cooling of a TiO_2-rich liquid of initial composition $1BaO{:}1TiO_2{:}1SiO_2$. The synthetic crystals are essentially identical to their mineral equivalent in morphology, cleavage, optical properties and unit cell dimensions. X-ray powder diffraction data previously reported for the compound $BaTiSiO_5$ ("barium sphene") is that of $Ba_2TiSi_2O_8$. Apparently the compound $BaTiSiO_5$ has never been synthesized and the system $BaTiO_3$-SiO_2 is not binary.

Photoionization study of $Fe(CO)_5$ and $Ni(CO)_4$, G. Distefano, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 233-238 (Mar.-Apr. 1970).

Key words: Dissociation energies; $Fe(CO)_5$; heats of formation; ionization; mass spectrometry; $Ni(CO)_4$; vacuum ultraviolet spectroscopy.

Photoionization yield curves from onset to 600 Å, and ionization threshold values have been obtained for the ions $Fe(CO)_5^+$, $Fe(CO)_4^+$, $Fe(CO)_3^+$, $Fe(CO)_2^+$, $Fe(CO)^+$, Fe^+ and CO^+ from iron pentacarbonyl, and for $Ni(CO)_4^+$, $Ni(CO)_3^+$, $Ni(CO)_2^+$, $Ni(CO)^+$, Ni^+, and CO^+ from nickel tetracarbonyl. From these curves, information on the ionization-fragmentation processes of $Fe(CO)_5$ and $Ni(CO)_4$ under photon impact, have been obtained. Differences in the threshold energies as determined by photon and by electron impact methods increase with the fragmentation. The appearance potentials and the heats of formation of the metal-ions, agree within 0.1 eV, with those calculated from thermochemical data. The average bond dissociation energy of the neutral molecule agrees within 0.02 eV, with the thermochemical values. The kinetic shift for the formation of Fe^+ and Ni^+ ions is very small. The Ni^+ ion is most likely formed directly from the molecule ion rather than by a cascade fragmentation process.

The band structure problem, J. M. Ziman, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 241-252 (Mar.-Apr. 1970).

Key words: APW; band structure; density of states; disordered systems; KKR; pseudopotential; t-matrix; molecular crystals.

The numerical solution of the Schrödinger equation for an electron in a dense assembly of atoms (i.e., a solid or liquid metal or semiconductor) has made great progress in the past ten years. This is not merely a consequence of greater computer power; we now have a much better grasp of the mathematical theory of such solutions.

By 1960 a number of practical methods had been devised for the computation of the electronic structure of ordered crystals, but these lacked intuitive interpretation. The first advance was to rewrite the OPW method in terms of pseudopotentials, thus making sense of the free-electron theory of metals. This development has proved particularly valuable in semiquantitative and empirical investigations of Fermi surfaces, transport properties, lattice dynamics, cohesion, etc., but we have had to wait until recently for a rigorous analysis of the criteria for convergence of the various types of model potential or pseudopotential that have been postulated.

The next step was to show that the KKR (Green function) method could also be expressed as a pseudopotential, and then to demonstrate that this was also a form of APW expansion. The relative computational power of these two methods can thus be analyzed, and questions answered concerning the fulfillment of the empty lattice test, the apparent lack of uniqueness of the expansions, the advantages of "folding" matrix elements from distant points of the reciprocal lattice, and the introduction of contributions from the interstitial potential.

At this stage, the connections between the band structure problem and the t-matrix theory of scattering were uncovered, and d-bands were seen to arise as resonances of the muffin-tin wells. The KKR matrix could now be rewritten as a mixture of pseudopotential and tight-binding elements, in harmony with the empirical model Hamiltonian representations of hybridized s-p and d-bands. This method not only permits more rapid computations, but shows clearly how the width and position of such bands should depend on the atomic potential.

Some problems still remain. For example, present techniques do not seem adequate for first-principles calculations on molecular crystals, where the anisotropy of the interstitial potential (i.e., easy channels along bonds, but high hills between layers or chains) is probably the dominant feature.

As for disordered systems—we know little for certain and nothing quantitatively. The linear chain model has been fully studied but is quite irrelevant to the three-dimensional case. The present theoretical confusion is exemplified by the equiconcentration substitutional alloy in the tight-binding limit; some formulae give only one band, others allow two. Again, the very possibility of producing band gaps by diffraction of free electrons in a topologically disordered system (e.g., amorphous Ge) has not been demonstrated mathematically with any rigor.

Optical properties and electronic density of states, M. Cardona, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 253-265 (Mar.-Apr. 1970).

Key words: Critical points; density of states; dielectric constant; modulated reflectance; optical absorption.

The fundamental absorption spectrum of a solid yields information about critical points in the optical density of states. This information can be used to adjust parameters of the band structure. Once the adjusted band structure is known, the optical properties and the density of states can be generated by numerical integration. We review in this paper the parametrization techniques used for obtaining band structures suitable for density of states calculations. The calculated optical constants are compared with experimental results. The energy derivative of these optical constants is discussed in connection with results of modulated reflectance measurements. It is also shown that information about density of empty states can be obtained from optical experiments involving excitation from deep core levels to the conduction band.

A detailed comparison of the calculated one-electron optical line shapes with experiment reveals deviations which can be interpreted as exciton effects. The accumulating experimental evidence pointing in this direction is reviewed together with the existing theory of these effects.

A number of simple models for the complicated interband density of states of an insulator have been proposed. We review in particular the Penn model, which can be used to account for response functions at zero frequency, and the parabolic model, which can be used to account for the dispersion of response functions in the immediate vicinity of the fundamental absorption edge.

Excitonic effects in x-ray transitions in metals, G. D. Mahan, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 267-272 (Mar.-Apr. 1970).

Key words: Density of states; exciton; many body effects; phase shifts; soft x ray; transition probability.

In the study of soft x-ray transitions in solids, there has always been some hope that the results provide a direct measure of the density of states. This assumes that (a) matrix element variations over the band and (b) final state interactions are small. Both of these assumptions are now known to be incorrect. To illustrate the possible strength of these effects, two approximate calculations are presented: the one electron oscillator strength of a simple bcc metal as a function of energy; and the strength of the Nozieres—DeDominicis singularity at threshold, with phase shifts estimated from an assumed Yukawa interaction between conduction electrons and core hole.

Soft x-ray band spectra and their relationship to the density of states, G. A. Rooke, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 273-279 (Mar.-Apr. 1970).

Key words: Alloys; auger transitions; density of states; many-body interactions; plasmons; singularities; soft x rays.

The paper concentrates on the similarities and differences between the one-electron spectrum and the density of states; many-body effects, although important, are listed but they are not considered in detail. It is shown that the only reliable information about the density of states that can be obtained from soft x-ray spectroscopy are the energies of the Fermi surface and the van-Hove singularities, although the shape of the density of states can be derived indirectly from the energies of the van-Hove singularities.

It is the differences between the density of states and the one-electron spectra that may prove to be most important. These differences can give information about the symmetry and the local nature of the screening electrons. This is particularly interesting when studying alloys.

The Li K, the Al L_{23} and the Zn L_3 spectra are given as examples which illustrate the above arguments. Finally, a brief discussion on the soft x-ray spectra from the Al-Mg system show how the results may be used to study alloys.

The electronic structure of disordered alloys, J. L. Beeby, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 281-291 (Mar.-Apr. 1970).

Key words: Density of states; disordered alloys; one-electron propagator; perturbation expansion; sum rule.

The problem of calculating the electronic density of states in an alloy is considered from first principles. Choosing a suitably simplified model potential a diagrammatic expansion is discussed within which the various existing theories can be compared. Some comments are made on the comparison with experiment.

Summary of the conference on electronic density of states, H. Ehrenreich, *J. Res. Nat. Bur. Stand. (U.S.),* **74A** (Phys. and Chem.), No. 2, 293-299 (Mar.-Apr. 1970).

May-June 1970

The crystal structure of hydrazinium trinitromethide, $(N_2H_5^+[C(NO_2)_3]^-$ at ~ — 160 °C), D. Dickens, *J. Res. Nat.*

Bur. Stand. (U.S.), **74A** (Phys. and Chem.), No. 3, 309-318 (May-June 1970).

Key words: Crystal structure; hydrazinium; hydrazinium trinitromethide; hydrogen bonding; trinitromethide; x-ray diffraction.

The crystal structure of hydrazinium trinitromethide ($N_2H_5^+[C(NO_2)_3]^-$) has been determined using 1914 x-ray data collected photographically from a single crystal held at ~ -160 °C. The unit cell at ~ -160 °C is $a=7.91(2)$, $b=11.77(2)$, $c=13.98(2)$ Å, $\beta=104.9(3)°$, and contains eight formula weights in space group $P2_1/n$. The calculated density is 1.93 g·cm^{-3}. The structure has been refined isotropically to $R=0.10$ by full-matrix least-squares procedures. The two crystallographically independent trinitromethide anions are propeller shaped, with angles of 41°, 7°, 8°, and 74°, 5°, 4°, respectively, between the NO_2 and CN_3 plane normals. The central CN_3 part of each anion is almost planar. In one anion, the C atom is 0.008 Å out of the N_3 plane; in the other, the C atom is 0.033 Å out of the N_3 plane. Hydrogen atoms have been located approximately in an electron density difference synthesis. Their positions agree with those obtained from independent calculations involving the minimization of a function which is a first approximation to the electrostatic hydrogen bonding energy. These analyses provide evidence that one hydrazinium ion is eclipsed and the other is staggered.

A refinement of the crystal structure of $Na_2CO_3 \cdot H_2O$, B. Dickens, F. A. Mauer, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 319-324 (May-June 1970).

Key words: Crystal structure; hydrated carbonates; hydrogen bonding; sodium carbonate; thermonatrite; x-ray diffraction.

The crystal structure of synthetic $Na_2CO_3 \cdot H_2O$ has been refined using 1231 unique x-ray diffraction data collected by the peak height method on a diffractometer. $R=0.034$. The unit cell is $a=6.474(2)$, $b=10.724(3)$ and $c=5.259(2)$ Å with $z=4$ and space group $P2_1ab$. The calculated density is the same as the observed density, 2.26 g·cm^{-3}. The structure contains sheets of CO_3^{2-} ions bonded to Na^+ ions and water molecules roughly halfway between the sheets. Each CO_3^{2-} bonds edgewise to both Na^+ ions. The Na^+ ions have irregular but similar coordinations of seven neighbors. Each water molecule is bonded to both Na^+ ions and forms hydrogen bonds to both neighboring CO_3^{2-} layers.

Anisotropic reaction kinetics of oxygen with pyrolytic graphite, W. S. Horton, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 325-330 (May-June 1970).

Key words: Chemical anisotropy; chemisorption; oxidation; pyrolytic graphite.

Because of the possible use of pyrolytic graphite in aerospace vehicles its reaction with oxygen-containing gases is of interest, particularly with respect to chemical anisotropy. Although several authors have found different degrees of reactivity of graphite in different directions they disagree regarding the existence of a temperature coefficient. This disagreement, however, is probably due to investigators studying single crystals in some cases and pyrolytic graphite in others and in some cases different oxidizers. New data for pyrolytic graphite are presented which were obtained by oxidizing in each run several pieces of differing geometry. These together with earlier data show that the rate ratio for the two major directions is temperature dependent with an activation energy difference of about 19 kilojoules (4500 thermochemical calories) per gram atom of carbon reacted. It is shown that this difference in rates probably arises because the relative number of sites available in these directions is sufficiently different to cause a shift in which reaction step is rate-controlling. On the "faces" chemisorption is the rate controlling step followed by rapid decomposition of surface oxides. On the "edges" decomposition is the rate controlling step. This interpretation applied to the data yield 131 kJ/mol for the activation energy of chemisorption and 150 kJ/mol for decomposition (31 and 36 kcal/mol, respectively).

The viscosity and thermal conductivity of dilute gaseous hydrogen from 15 to 5000 K, H. J. M. Hanley, R. D. McCarty, and H. Intemann, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 331-353 (May-June 1970).

Key words: Dissociation; hydrogen; intermolecular potential functions; kinetic theory; quantum gas; thermal conductivity; viscosity.

Measurements of the viscosity and thermal conductivity of dilute gaseous para and normal hydrogen are critically evaluated and correlated by means of dilute gas kinetic theory. Numerical results are presented from 15 to 5000 K including the dissociation region.

Temperature classification of the spectra of dysprosium (Dy I, Dy II), A. S. King, J. G. Conway, E. F. Worden, and C. E. Moore, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 355-394 (May-June 1970).

Key words: Intensity estimates, Dy spectra; dysprosium spectra, temperature classification; temperature classification, Dy I and Dy II; spectra, Dy I and Dy II.

The Temperature Classifications are listed for 4584 lines of Dy I and Dy II, as taken from an unpublished manuscript of the late A. S. King. In recording his observations, King used a wavelength list compiled mostly from the early literature. A homogeneous and extensive line list based on new observations has been prepared at the Lawrence Radiation Laboratory (LRL). King's data have been edited and adjusted by the present authors to fit the new wavelength list.

In the Table, King's estimated intensities of Dy lines in the spectra of the Arc, Spark, and Furnace are given along with the Temperature Classification. Some of his earlier published work has been used to fill the gaps in this manuscript, which was forwarded to the late W. F. Meggers in 1956.

Optical density of states ultraviolet photoelectric spectroscopy, W. E. Spicer, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 397-415 (May-June 1970).

Key words: Copper; copper nickel alloys; density of states; GaAs; Ge; nondirect transitions; optical density of states; PbTe; ultraviolet photoemission.

The use of ultraviolet photoemission to determine the density of valence and conduction states is reviewed. Two approaches are recognized. In one, the photoemission as well as other studies are used to locate experimentally a limited number of features of the band structure. Once these are fixed, band structure calculations could be carried out throughout the zone and checked against other features of the photoemission data. If the agreement is sufficiently good, the density of states is then calculated from the band structure. The second method depends only on experimental data. Using this approach, features of the density of states are determined directly by the photoemission experiment without recourse to band calculations. In cases where bands are wide and k clearly provides an empirically important optical selection rule, this is possible only for portions of the bands which are relatively flat. Successful determinations of this type are cited for PbTe, and GaAs. In metals with narrow *d* bands such as Cu, it has been found empirically that one may explain fairly well the experimental energy distribution curves in terms of transitions between a density of initial and final states

(the optical density of states, ODS) requiring only conservation of energy.

The ODS determined by such ultraviolet photoemission studies have more strong detailed structure than the density of states determined by any other experimental method. Studies on a large number of materials indicate that the position in energy of this structure correlates rather well with the position in energy of structure in the calculated density of states. It is suggested, following the very recent theoretical work of Doniach, that k conservation becomes less important (and nondirect transitions more important) as the mass of the hole becomes larger. This is due to the change in k of electrons in states near the Fermi level as they attempt to screen the hole left in the optical excitation process. These electrons take up the excess momentum. One would expect the k conservation selection rule to play an increasingly important role as the mass of the hole decreases. This is in agreement with experiment.

Beyond the one-electron approximation: Density of states for interacting electrons, L. Hedin, B. I. Lundqvist, and S. Lundqvist, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 417-431 (May-June 1970).

Key words: Density of states; interacting electrons; one-particle Green function; oscillator strengths; quasi particle density of states; x-ray emission and absorption.

The concept "density of states" can be given many different meanings when we go beyond the one-electron approximation. In this survey we concentrate on the definition tied to excitation processes, where one electron is added or removed from the solid. We discuss the one-particle spectral function for conduction and core electrons in metals, how it can be approximately calculated, and how it can be related to different types of experiments like x-ray photoemission, x-ray emission and absorption, photoemission and optical absorption in the ultraviolet, and the Compton effect. We also discuss the form of the exchange-correlation potential for use in band structure calculations.

Ion-neutralization spectroscopy, H. D. Hagstrum, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 433-441 (May-June 1970).

Key words: Auger processes; autoionization; density of states; ion-neutralization; transition probability.

The ion-neutralization spectroscopy (INS) is discussed in comparison with other spectroscopies of solids. It is shown that INS probes the local density of states of the solid at or just outside the solid surface. It is believed that this accounts for the clear-cut differences between INS results and those of other spectroscopies. Because of its unique specificity to the surface region INS is particularly useful in studying the surface electronic structures of atomically clean surfaces and of surfaces having ordered arrays of known atoms adsorbed upon them. In the latter case INS determines a portion of the molecular orbital spectrum of surface molecules formed from the adsorbed foreign atom and surface atoms of the bulk crystal. Such spectra provide information on local bonding symmetry and structure and electrical charging within the surface molecule which is as yet unavailable by any other method. INS is the first attempt to base a spectroscopy of electronic states on a two-electron process. More recent work on experimental and mathematical problems which such a spectroscopy entails are also briefly mentioned in this paper.

Local theory of disordered systems, W. H. Butler and W. Kohn, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 443-447 (May-June 1970).

Key words: Binary alloys; density of states; disordered systems; periodically continued neighborhood.

The most striking characteristic of crystalline solids is their periodicity. As a result of this feature, theoretical descriptions of physical phenomena in such systems are usually given in wave number or *momentum* space. The reciprocal lattice of a crystal and the Fermi surface of a metal are examples. In a disordered system, on the other hand, there is no such periodicity and momentum space descriptions are much less natural. However, in such systems, physical conditions near a point **r**, in *coordinate* space, become independent of the conditions at a distant point **r'**, provided that $|\mathbf{r'}-\mathbf{r}|$ is large compared to either a characteristic mean free path or some other appropriate length. This suggests that one can analyze a macroscopic disordered system by averaging over the properties of microscopic neighborhoods.

In the present paper we report some details of such a program. Although the point of view is of quite general applicability we have, for the sake of definiteness, studied so far only one type of system: Noninteracting electrons moving in the field of interacting, disordered scattering centers. We have focused especially on the electronic density of states. The macroscopic system is represented by an average over small neighborhoods. If one did not take special precautions, one would encounter one class of errors of the order of d/L where L is a characteristic dimension of the neighborhood, and d is a characteristic atomic dimension; and another class of errors of the order of $1/N$ where N is the number of ions. Both are too large to be tolerable for practical purposes. However, by an appropriate treatment of the statistical mechanics of the scatterers and by periodic repetition of the small neighborhoods, these errors can be avoided. The remaining errors are exponentially small in the ratio $\gamma(L/R)$ where γ is of order unity and R is the smaller of the electronic mean free path of the deBroglie wavelength of the electrons. This exponential convergence of the small neighborhood theory promises to make it a useful practical method for the study of disordered systems, especially very highly disordered ones.

Numerical examples are presented and discussed.

Density of states information from low temperature specific heat measurements, P. A. Beck and H. Claus, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 3, 449-454 (May-June 1970).

Key words: Alloys; density of states; low temperature specific heat; magnetic specific heat; many-body effects; superconductivity.

The calculation of one-electron density of state values from the coefficient γ of the term of the low temperature specific heat linear in temperature is complicated by many-body effects. In particular, the electron-phonon interaction may enhance the measured γ as much as twofold. The enhancement factor can be evaluated in the case of superconducting metals and alloys. In the presence of magnetic moments, additional complications arise. A magnetic contribution to the measured γ was identified in the case of dilute alloys and also of concentrated alloys where parasitic antiferromagnetism is superimposed on an over-all ferromagnetic order. No method has as yet been devised to evaluate this magnetic part of γ. The separation of the temperature-linear term of the specific heat may itself be complicated by the appearance of a specific heat anomaly due to magnetic clusters in superparamagnetic or weakly ferromagnetic alloys.

July-August 1970

Solubility of $CaHPO_4 \cdot 2H_2O$ in the system $Ca(OH)_2 - H_3PO_4 - H_2O$ at 5, 15, 25, and 37.5 °C, T. M. Gregory, E. C. Moreno, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 461-475 (July-Aug. 1970).

Key words: Calcium phosphate; dicalcium phosphate dihydrate; ion pairs; solubility; solubility isotherms; solubility product.

Solubility isotherms for $CaHPO_4 \cdot 2H_2O$, dicalcium phosphate dihydrate, DCPD, in the ternary system $Ca(OH)_2-H_3PO_4-H_2O$ were determined at 5, 15, 25, and 37.5 °C in the pH range 3.5 – 7; the relative positions of the isotherms indicate that DCPD has a negative thermal coefficient of solubility. The solubility product, K_s, of DCPD and the stability constants K_x and K_y for the ion pairs $[CaHPO_4^0]$ and $[CaH_2PO_4^+]$, respectively, were obtained as functions of temperature by the use of a generalized least squares procedure subject to three condition functions – constancy of the solubility product, electrical neutrality in the solution, and congruent dissolution of the solid. The equations obtained are

$$\ln K_s = -8403.5/T + 41.863 - 0.09678T$$

$$\ln K_x = 51090/T - 341.14 + 0.5880T$$

$$\ln K_y = 19373/T - 122.81 + .0.1994T.$$

The existence of a maximum in K_s in the neighborhood of 25 °C is plausible on the basis of available thermodynamic data for DCPD. Thermodynamic functions are reported for the solution of DCPD and for the association of the ion pairs.

Effect of oxide additions on the polymorphism of tantalum pentoxide. II. "Stabilization" of the high temperature structure type, R. S. Roth, J. L. Waring, and W. S. Brower, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 477-484 (July-Aug. 1970).

Key words: High temperature polymorph; single crystals; stabilization; tantalum oxide.

The high temperature, apparently tetragonal, polymorph of tantalum pentoxide can be obtained at room temperature by quenching a specimen containing 2-5 mole percent of the following oxides: SnO_2, Ga_2O_3, Cr_2O_3, Fe_2O_3, Sc_2O_3, or MgO. All the x-ray patterns can be indexed on a body centered tetragonal cell with $a \approx 3.830$ Å, $c \approx 35.68$ Å. However, P_2O_5, V_2O_5, Nb_2O_5, ZrO_2, Lu_2O_3, NiO, or ZnO do not stabilize the tetragonal form at room temperature. Single crystals of scandium "stabilized" Ta_2O_5 have been grown by the Czochralski technique.

Effect of oxide additions on the polymorphism of tantalum pentoxide. III. "Stabilization" of the low temperature structure type, R. S. Roth and J. L. Waring, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 485-493 (July-Aug. 1970).

Key words: Low temperature polymorph; single crystals; stabilization; tantalum oxide.

The "low temperature structure type" of Ta_2O_5 has been found to occur in two distinct forms with the lowest temperature form having a unit cell 14 times the subcell and an intermediate temperature form with a unit cell 11 times the subcell. The two types form intermediate partially ordered mixtures which are apparently in thermal equilibrium at various temperatures between ~1000 and 1350 °C. The addition of MoO_3, WO_3, SiO_2, GeO_2, ZrO_2, TiO_2, B_2O_3 and Al_2O_3 each affect the multiplicity of the true unit cell in different ways. WO_3, SiO_2, GeO_2, B_2O_3, and Al_2O_3 form phases structurally similar to "low-Ta_2O_5" which are stable up to the solidus temperatures of the corresponding systems.

The dissociation constant of *m*-nitroanilinium ion in water-tetrahydrofuran solvents at 25 °C, R. A. Robinson, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 495-497 (July-Aug. 1970).

Key words: Dissociation constant; ionization constant; mixed solvents; *m*-nitroaniline; tetrahydrofuran.

The dissociation constant of *m*-nitroanilinium ion has been determined in water and in six water-tetrahydrofuran mixtures. The results are compared with those for water-methanol mixtures.

Specific heats of fluorine at coexistence, R. D. Goodwin and R. Prydz, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 499-505 (July-Aug. 1970).

Key words: Fluorine; liquid-vapor coexistence; saturated liquid; saturation; specific heats; thermodynamic properties; two-phase.

Experimental specific heats of fluorine at constant total volume are reported for the two-phase liquid-vapor system from triple- to the critical point. Specific heats of liquid along the coexistence path are derived by use of PVT data for the two-phase system, and are represented by a formula to facilitate computations of thermodynamic properties.

A theoretical investigation of the configurations $(3d+4s)^6 4p$ in neutral manganese (Mn I), C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 507-520 (July-Aug. 1970).

Key words: Energy levels Mn I; *g*-factors Mn I; interactions between configurations Mn I; manganese spectrum; Mn I configurations $(3d + 4s)^6 4p$.

Experimental levels of the configurations $(3d + 4s)^6 4p$ in Mn I were compared with corresponding calculated values. On fitting 228 experimental levels by means of 20 free parameters an rms error of only 170 cm^{-1} was obtained.

It was shown that the correction parameters β and T were not significant.

A literature survey of the chemistry of flame inhibition, E. C. Creitz, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 521-530 (July-Aug. 1970).

Key words: Flame chemistry; flame extinction; flame inhibition.

Evidence is beginning to accumulate indicating that catalytic recombination of oxygen atoms may be the mechanism of extinction of flames by halogenated extinguishing agents. The literature of flame inhibition and of oxygen atom chemistry has been examined to ascertain whether the available data would support such a mechanism. Considerable sustentative evidence was found.

Kinetic rate-constant data are not available covering all reactions of interest, but those that are reported indicate that catalytic recombination of oxygen atoms can probably compete successfully with normal flame processes which require them.

The NBS Alloy Data Center: Description of index to the literature, G. C. Carter, D. J. Kahan, L. H. Bennett, J. R. Cuthill, and R. C. Dobbyn, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 531-533 (July-Aug. 1970).

Key words: Alloy data; bibliography; index; information; Knight shifts; NMR; soft x ray.

Computerized listings of 10,000 research papers, indexed at the Alloy Data Center, are now being made available in two forms. In the first, the Permuted Materials Index, all records are arranged alphabetically by chemical symbol. Records referring to alloys or compounds are listed under each of the constituent elements. In the second, the Author Index, all papers are listed alphabetically by first author in three groupings: the first, the NMR papers; the second, the soft x-ray papers; and the third, a broad group of papers that have been of general interest to the Alloy Physics Section. The magnetic tape on which the indexed file is stored will be made available at a future date.

What is a quasi-particle?, J. R. Schrieffer, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 537-541 (July-Aug. 1970).

Key words: Density of states; Green's function; mass enhancement; quasi-particle; superconductors.

The concept of a quasi-particle excitation in an interacting many-body system will be discussed from both the physical and the mathematical points of view. The physical origin of mass enhancement, wave function renormalization, interactions between quasi-particles, etc. will be presented. Landau's Fermi liquid theory, including the quasi-particle kinetic equation, will be reviewed. Finally, the domain of validity of the quasi-particle approximation will be discussed.

Electronic densities of states from x-ray photoelectron spectroscopy, C. S. Fadley and D. A. Shirley, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 543-558 (July-Aug. 1970).

Key words: $CdCl_2$; density of states; HgO; noble metals; rigid band model; transition metals; x-ray photoemission; ZnS.

In x-ray photoelectron spectroscopy (XPS), a sample is exposed to low energy x rays (approximately 1 keV), and the resultant photoelectrons are analyzed with high precision for kinetic energy. After correction for inelastic scattering, the measured photoelectron spectrum should reflect the valence band density of states, as well as the binding energies of several core electronic levels. All features in this spectrum will be modulated by appropriate photoelectric cross sections, and there are several types of final-state effects which could complicate the interpretation further.

In comparison with ultraviolet photoelectron spectroscopy (UPS), XPS has the following advantages: (1) the effects of inelastic scattering are less pronounced and can be corrected for by using a core reference level, (2) core levels can also be used to monitor the chemical state of the sample, (3) the free electron states in the photoemission process do not introduce significant distortion of the photoelectron spectrum, and (4) the surface condition of the sample does not appear to be as critical as in UPS. XPS seems to be capable of giving a very good description of the general shape of the density-of-states function. A decided advantage of UPS at the present time, however, is approximately a fourfold higher resolution.

We have used XPS to study the densities of states of the metals Fe, Co, Ni, Cu, Ru, Rh, Pd, Ag, Os, Ir, Pt, and Au, and also the compounds ZnS, $CdCl_2$, and HgO. The *d* bands of these solids are observed to have systematic behavior with changes in atomic number, and to agree qualitatively with the results of theory and other experiments. A rigid band model is found to work reasonably well for Ir, Pt and Au. The *d* bands of Ag, Ir, Pt, Au and HgO are found to have a similar two-component shape.

Tunneling measurements of superconducting quasi-particle density of states and calculation of phonon spectra, J. M. Rowell, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 559-565 (July-Aug. 1970).

Key words: Density of states; phonons; semiconductors; superconductivity; tunneling.

It is an unfortunate fact that the tunneling technique, which has proved incredibly successful in the study of superconductivity, has given little information about the normal state properties of metals and semiconductors. It will be shown that, in the determination of the superconducting quasi-particle density of states, it is the change in density induced by the onset of superconductivity which is measured rather than the total density.

Returning to the problem of normal materials, a review of the limited achievements and failures of tunneling will be presented. This will include the influence of band edges on tunneling in *p-n* diodes and metal-semiconductor contacts, the structures observed in tunneling into bismuth and the negative results obtained in nickel and palladium. The dominant effect of the change in barrier shape in most of these tunneling characteristics will be illustrated.

Pauli paramagnetism in metals with high densities of states, S. Foner, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 567 (July-Aug. 1970).

Relevance of Knight shift measurements to the electronic density of states, L. H. Bennett, R. E. Watson, G. C. Carter, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 4, 569-610 (July-Aug. 1970).

Key words: Electronic density of states; hyperfine fields; Knight shift; nuclear magnetic resonance; susceptibility; wave functions.

The Knight shift, $\mathscr{K}$, measures the magnetic hyperfine field at the nucleus produced by the conduction electrons which are polarized in a magnetic field. Knight shifts are often dominated by the Pauli term and, in its most simple form, can be written as $\mathscr{K} = \langle a \rangle \chi_p$. Here χ_p is the conduction electron Pauli spin susceptibility which depends on the density of states at the Fermi level, $N(E_F)$, and $\langle a \rangle$ is an average magnetic hyperfine coupling constant associated with the wave function character at the nucleus, $|\psi_F(0)|^2$, for conduction electrons at the Fermi surface.

The Knight shift therefore provides, through $\langle a \rangle$, insight into the wave function character associated with $N(E_F)$. Calculations of $\langle a \rangle$ involving an averaging over *k*-space have been attempted for a few simple metals up to the present time. For alloys and intermetallic compounds, rather different $\langle a \rangle$'s are experimentally observed for different local environments, indicating that $\mathscr{K}$ samples the variation in *local* wave function character, or a variation in *local* density of states. There is no unique way of separating the local variation of $N(E_F)$ from $|\psi_F|(0)|^2$.

In this article the methods developed for relating $\mathscr{K}$ to the electronic properties for most of the types of cases encountered in the literature are reviewed. We discuss "simple" metals including problems of orbital magnetism and changes in $\mathscr{K}$ caused by electronic transitions such as melting. Knight shifts and their temperature dependence in metals and intermetallic compounds involving unfilled *d* shells, are discussed. We give estimates of atomic hyperfine fields due to single electrons, appropriate to those cases where problems due to electronic configurations do not make deductions from experiment too ambiguous. A density of states curve calculated for Cu is given, showing the relative importance of *s-p*, and *d* character for that metal. In a qualitative sense this Cu curve implies such information for other transition metals. We discuss alloy solid solutions for the cases where a "rigid" band model might be used to explain the results, and for cases where local effects have to be taken into account. The charge oscillation and RKKY approaches and their limitations are reviewed for cases of dilute nonmagnetic and *d*- or *f*-type impurities.

September-October 1970

Heat capacity and thermodynamic properties of α-beryllium nitride, Be_3N_2, from 20 to 315 K, G. T. Furukawa and M. L. Reilly, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 617-629 (Sept.-Oct. 1970).

Key words: Calorimeter; entropy; heat capacity; specific heat; thermodynamic properties; α-beryllium nitride.

The heat capacity of α-beryllium nitride, Be_3N_2, was determined from 20 to 315 K and the thermodynamic properties calculated from 0 to 315 K. The entropy at 298.15 K was found to be 34.4 ± 0.3 *J/K*·mol (8.23 ± 0.08 cal/K·mol). The precision using a calorimeter of a new design is shown to be ±0.01 percent over most of the temperature range of the measurements.

Heat capacity and thermodynamic properties of β-lithium hexafluoroaluminate, Li_3AlF_6, from 15 to 380 K, G. T. Furukawa,

W. G. Saba, and J. C. Ford, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 631-639 (Sept.-Oct. 1970).

Key words: Calorimetry; entropy; heat capacity; thermodynamic properties; β-lithium hexafluoroaluminate.

The heat capacity of β-lithium hexafluoroaluminate, Li_3AlF_6, was determined from 15 to 380 K and the thermodynamic properties calculated from the results. The entropy at 298.15 K was found to be 187.88 ± 0.38 J/K·mol (44.904 ± 0.090 cal/K·mol).

Thermodynamics of hydrochloric acid in 80 weight percent 2-methoxyethanol and 20 weight percent water from 10 to 50 °C, H. P. Thun, B. R. Staples, and R. G. Bates, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 641-645 (Sept.-Oct. 1970).

Key words: Activity coefficients; non-aqueous emf; standard emf; thermodynamic constants for HCl transfer.

Electromotive-force measurements of cells of the type Pt, $H_2|HCl(m)$ in 2-methoxyethanol $+H_2O|AgCl$, Ag at nine temperatures ranging from 10 to 50 °C were used to derive (a) the standard emf of the cell in 80 weight percent 2-methoxyethanol (methylcellosolve), (b) the activity coefficient of HCl, (c) the relative partial molal enthalpy and heat capacity of HCl, and (d) the thermodynamic constants for the transfer of HCl from water to 80 weight percent methylcellosolve. The molality of the acid ranged from 0.006 to 0.106 mol kg^{-1}. To obtain the standard emf it was necessary to correct for ion-pair formation and to use the extended terms of the Debye-Hückel theory. The standard emf varied with temperature (t, °C) according to the equation $E_t^\circ = 0.14382 - 1.517 \times 10^{-3}t - 3.8317 \times 10^{-6}t^2 - 2.3838 \times 10^{-9}t^3$. Vapor pressures and dielectric constants for this mixture were measured over the temperature range. At 25 °C the solvent has a vapor pressure of 2506.5 Nm^{-2} (18.8 mm Hg) and a dielectric constant of 31.5.

Vapor pressure and heat of sublimation of platinum, E. R. Plante, A. B. Sessoms, and K. R. Fitch, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 647-653 (Sept.-Oct. 1970).

Key words: Heat of sublimation; Langmuir vaporization; platinum; rate of vaporiztion; vapor pressure.

The vapor pressure of platinum was measured by the Langmuir method in the temperature range 1700-2000 K using a vacuum microbalance. Eight series of data gave concordant results and an average third-law heat of sublimation of 564.49 kJ mol^{-1} with an estimated overall uncertainty of 2.1 kJ mol^{-1} (134.92 ± 0.5 kcal mol^{-1}). Three out of eight second-law heats agreed with the third-law heats within one standard error but there was a tendency for second-law heats to be low. This was attributed to small systematic errors in the measurements. A vapor-pressure equation representing the data is $\log P(\text{atm}) = -29020/T + 7.502$, based on our third-law heat and tabulated entropies evaluated at 1800 K. Our data agree well with several previous Langmuir determinations but significantly decrease the error in the heat previously accepted.

Inability to obtain saturation pressures at lower temperatures, previously reported in the literature, was confirmed. It was shown that microgram quantities of carbon are capable of blocking the sublimation reaction.

Thermophysical properties of methane: Virial coefficients, vapor and melting pressures, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 655-660 (Sept.-Oct. 1970).

Key words: Melting pressures; methane; thermophysical properties; vapor pressures; virial coefficients.

For use in the computation of thermodynamic properties in gaseous and liquid states at $T < 300$ K there are given concise descriptions of the properties named in the title. Numerous published data on methane are combined with some new analytical expressions which give more acceptable behavior than previously could have been achieved.

Specific heats, C_v, of compressed liquid and gaseous fluorine, R. Prydz and R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 661-665 (Sept.-Oct. 1970).

Key words: Compressed gas; compressed liquid; fluorine; heat capacities; specific heats.

Experimental specific heats at constant volume for compressed gaseous and liquid fluorine are reported from 80 K to 300 K at pressures to about 23 MN/m^2.

Acidic dissociation of diprotonated piperazine in methanol-water solvents from 10 to 40 °C, M. Paabo and R. G. Bates, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 667-671 (Sept.-Oct. 1970).

Key words: Dissociation constant; ionization constant; methanol; mixed solvents; piperazine; pK; thermodynamics.

The first dissociation constant of piperazinium ion has been determined by the emf method in five methanol-water solvents (10 to 70 wt % MeOH) at 25 °C and in three solvents (10, 20, and 50 wt % MeOH) from 10 to 40 °C. From the variation of the dissociation constant with temperature, the changes of enthalpy, entropy, and heat capacity were derived and compared with similar data for piperazinium ion in water. The variation of pK, ΔS°, and ΔC_p° have been used to interpret the effect of the double positive charge on the solute-solvent interactions as compared to the effect exhibited by a single positive or a negative charge.

Thermal conductivity standard reference materials from 4 to 300 K. I. Armco iron: Including apparatus description and error analysis, J. G. Hust, R. L. Powell, and D. H. Weitzel, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 673-690 (Sept.-Oct. 1970).

Key words: Cryogenics; electrical resistivity; equipment; error analysis; iron; Lorenz ratio; Seebeck effect; thermal conductivity; transport properties.

An apparatus for the measurement of thermal conductivity, electrical resistivity, and thermopower of solids from 4 to 300 K is described. This apparatus, a modified version of the one used earlier in this laboratory, utilizes the steady-state, axial heat flow method. Included is a detailed discussion of the limitations of the apparatus, probable errors, and data analysis methods.

Thermal conductivity, electrical resistivity, Lorenz ratio, and thermopower data are reported for several specimens of Armco iron for temperatures from 4 to 300 K. At low temperatures the electrical resistivity and thermal conductivity vary from specimen to specimen by more than 10 percent. However, the Lorenz ratios of these specimens differ by less than 2.5 percent; and the intrinsic resistivities calculated by using Matthiessen's rule differ by less than 0.5 percent of the total resistivities. Thus, Armco iron specimens can be used as standards by measuring the residual resistivities and utilizing the Lorenz ratio reported here.

Mössbauer spectrometer calibration using TiFe, L. J. Swartzendruber and L. H. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 691-697 (Sept.-Oct. 1970).

Key words: Calibration; chemical shift; iron; Knight shift; Mössbauer effect; sodium nitroprusside; TiFe.

The splitting of the ^{57}Fe Mössbauer spectrum in TiFe has been carefully measured in a magnetic field and compared with the zero-field quadrupolar splitting of sodium nitroprusside. The

comparison gives a value of 1.699 mm/s at 295 K for the sodium nitroprusside splitting. This determination makes use of the known Knight shift of Fe in TiFe and is independent of any velocity measurement. Comparison is made with the splitting of the inner two lines of a pure Fe spectrum.

Energies of $1snl$ ($1 \geq 3$) configurations in He^4 I as calculated from polarization theory, W. C. Martin, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 699-702 (Sept.-Oct. 1970).

Key words: Atomic energy levels; atomic theory; helium; polarizability.

The calculated singlet-triplet mean energies are given for all He^4 I configurations having $3 \leq l \leq n - 1$ from $4f$ to $8k$. Since only Stark-shifted transitions have been observed for such configurations with $l \geq 4$, the calculated positions are the most accurate available. The polarization energy (to the quadrupole approximation) for two-electron ions may be evaluated for higher nl or Z from the simple formulas. The calculated and observed positions of the $1snf$ configurations in He^4 I and Li^7 II agree within the experimental uncertainties.

A theoretical investigation of the configurations $(3d+4s)^8 4p$ in neutral cobalt (Co I), C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 703-713 (Sept.-Oct. 1970).

Key words: Cobalt; configurations $(3d + 4s)^8 4p$; energy levels; g-factors; interactions between configurations.

Experimental levels of the configurations $(3d + 4s)^8 4p$ were compared with corresponding calculated values. On fitting 154 levels by means of 19 free parameters an rms error of only 164 cm^{-1} was obtained.

Odd configurations in neutral nickel (Ni I), C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 715-722 (Sept.-Oct. 1970).

Key words: Energy levels; g-factors; interactions between configurations; nickel; $(3d + 4s)^9 4p$; $3d^9 4p + 3d^8 4s 4p + 3d^9 5p$.

Experimental levels of the configurations $3d^9 4p$, $3d^8 4s 4p$ and $3d^9 5p$ of Ni I were compared with corresponding calculated values. The electrostatic interactions between the configurations $(3d + 4s)^9 4p$ as well as between $3d^8 4s 4p$ and $3d^9 5p$ were considered explicitly.

For the configuration $(3d + 4s)^9 4p$, 71 experimental levels were fitted by means of 17 free parameters to yield an rms error of 131 cm^{-1}. On fitting 83 levels of the configurations $3d^9 4p + 3d^8 4s 4p + 3d^9 5p$ by means of 25 free parameters an rms error of 147 cm^{-1} was obtained.

Electron-spin resonance study of an alkaline solution of copper(II) oxalate-*meso*-tartrate complex (the Somogyi reagent) and related complexes, A. J. Fatiadi, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 5, 723-731 (Sept.-Oct. 1970).

Key words: Alkaline; complex; copper, e.s.r.; ligand; paramagnetic; reagent; spectra; structure; superoxide.

Electron-spin resonance (e.s.r.) studies of the structure of four reagents commonly used in the carbohydrate field, namely, the Somogyi reagent, the Fehling reagent, the Benedict reagent, and the Reeves reagent, in frozen aqueous solution at 77 K, gave definite indications of dimer in the Fehling reagent only; the Benedict reagent contains a relatively low concentration of dimer as compared to monomer. The presence of an "extra" peak at 3.245 kgauss in the e.s.r. spectrum of the Somogyi reagent at 25 °C may be associated with a paramagnetic, superoxide, ion-ligand O_2^-; at 77 K, extra peaks were observed for the Somogyi, Fehling, and Benedict reagents.

November-December 1970

***PVT* measurements, virial coefficients, and Joule-Thomson inversion curve of fluorine,** R. Prydz and G. C. Straty, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 747-760 (Nov.-Dec. 1970).

Key words: Isochores; isotherms; Joule-Thomson inversion curve; liquid densities along melting line; PVT data; second virial coefficient; third virial coefficient.

Experimental *PVT* measurements on gaseous and liquid fluorine from the triple point (53.5 K) to 300 K at pressures to about 21 MN/m^2 are presented. The data are represented by a truncated virial equation in the low-density region. Comparisons of the second virial coefficient from this equation are made with published data. The *PVT* relationship along the Joule-Thomson inversion curve was obtained from the isotherm-isochore representation of the high density region.

The activity coefficients of hydrofluoric acid in water from 0 to 35 °C, W. J. Hamer and Y.-C. Wu, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 761-768 (Nov.-Dec. 1970).

Key words: Activities of HF; equilibrium constant of HF dissociation; ionic concentrations in HF; pH values of HF.

The mean stoichiometric activity coefficients of hydrofluoric acid in aqueous solutions have been calculated from measurements of electrolytic conductivity, the electromotive forces of galvanic cells without liquid junction, and the freezing-point depression. Values obtained from freezing-point depressions were converted to values for 25 °C using known values of the heats of dilution and apparent molal heat capacities of aqueous solutions of hydrofluoric acid of various concentrations. It is also shown that values for the concentrations of the various ionic species in hydrofluoric acid, namely, H^+, F^-, HF_2^-, and HF depend on the functions used to represent the ionic activity coefficients whereas values of the mean activity, $a_{H^+}a_{F^-}$, are independent of such functions. Values of the pH of various concentrations of hydrofluoric acid are given for temperatures of 0 to 35 °C; these, likewise, are nearly independent of activity-coefficient function used to obtain values for the ionic concentrations.

Fluorine flame calorimetry III. The heat of formation of chlorine trifluoride at 298.15 K, R. C. King and G. T. Armstrong, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 769-779 (Nov.-Dec. 1970).

Key words: Bond energy (Cl — F); chlorine reaction with hydrogen; chlorine trifluoride, heat of formation; flame calorimetry; flow calorimetry; fluorine compounds; heat of formation; heat of reaction; hydrogen chloride (aqueous), heat of formation; mixed acids; $(HCl + 3HF)_{aq}$, heat of formation; reaction calorimetry; reaction with hydrogen.

The standard heat of formation of chlorine trifluoride (gas) at 298.15 K has been determined to be — 164.65 kJ mol^{-1} (— 39.35 kcal mol^{-1}) with an overall experimental uncertainty of 5.14 kJ mol^{-1} (1.23 kcal mol^{-1}). This value is derived from the enthalpies of the following reactions which were measured directly in a flame calorimeter operated at 1 atm pressure and 303.5 K, together with data from previous investigations.

$$ClF_3(g) + 2H_2(g) + 100H_2O(l) \rightarrow [HCl \cdot 3HF \cdot 100H_2O](l)$$

$$(1/2)Cl_2(g) + 1/2H_2(g) + [3HF \cdot 100H_2O](l) \rightarrow [HCl \cdot 3HF \cdot 100H_2O](l)$$

The enthalpy of formation of $[HCl \cdot 100H_2O](l)$ was also measured. The average Cl — F bond energy in chlorine trifluoride is calculated to be 160.1 kJ mol^{-1} (38.26 kcal mol^{-1}).

A review of oscillator strengths for lines of Cu I, C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 781-790 (Nov.-Dec. 1970).

Key words: Atomic spectra; copper; Cu I; oscillator strengths; spectral lines of Cu I.

New determinations of oscillator strengths made by Kock and Richter provide for the first time reference standards which permit the adjustment of five previous sets of measurements to an improved scale of absolute oscillator strengths for lines of Cu I. Critical discussions of the several sets of measurements and a consistent list of values for 272 lines in the region 2024 to 8092 Å are presented.

Stark effect and hyperfine structure of HCN measured with an electric resonance maser spectrometer, H. E. Radford and C. V. Kurtz, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 791-799 (Nov.-Dec. 1970).

Key words: Dipole moment; HCN resonance spectrum; maser spectrometer; Stark effect; voltage standard.

The 449 MHz *l*-type doubling spectrum of HCN has been measured to high precision with a molecular beam maser spectrometer. Hyperfine structure due to both the nitrogen nucleus and the proton was resolved, and the coupling constant of the proton $\mathbf{I} \cdot \mathbf{J}$ interaction was found to be -27.3 ± 1.6 kHz. The spectrometer is also suited to precise measurements of Stark effects in molecules of the linear and symmetric top variety, and Stark shifts of up to 10^4 times the zero-field line width have been measured in the HCN spectrum. Analysis of these measurements yields the value $\mu = 2.940 \pm 0.001$ D for the dipole moment of the $\epsilon_2 = 1$ state of HCN.

The second spectrum of nickel (Ni II), A. G. Shenstone, *J. Res. Nat. Bur. Stand. (U.S.)*, **74A** (Phys. and Chem.), No. 6, 801-855 (Nov.-Dec. 1970).

Key words: Energy levels; ionization potential; nickel; spectral series; spectroscopy; wavelength.

An analysis of Ni II based on 4300 observed lines is presented. The low structures are $3d^9$, $3d^8 4s$ and $3d^7 4s^2$ which are now complete except for $3d^8(^1S)4s^2S$ and $3d^7 4s^2\ ^2P_{1/2}$ and the higher of the two ^2D terms of $3d^7 4s^2$. Long series occur such as $3d^8 4s$ to $9s$, $4d$ to $8d$, $4f$ to $7f$, $5g$ to $7g$. The analysis also includes many terms of the complex structure $3d^7 4s 4p$ but only 55 percent of the levels within reach of the hollow cathode source have been found. The identification of the levels of $3d^8 4d$ and $5d$ was assisted by the calculations of N. Spector. The $4d^7 4s^2$ levels were calculated by Y. Shadmi, who also provided calculated positions for all the levels of $3d^7 4s 4p$ without which much of the analysis would have been impossible. The $3d^8 ns$ and $3d^8 nd$ series give a limit of 146532.0 but the $3d^8 ng$ series give 146541.56. The latter has been adopted though no explanation of the discrepancy has been found.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 75A, JANUARY-DECEMBER 1971

January-February 1971

High-speed (subsecond) measurement of heat capacity, electrical resistivity, and thermal radiation properties of tantalum in the range 1900 to 3200 K, A. Cezairliyan, J. L. McClure, and C. W. Beckett, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 1-13 (Jan.-Feb. 1971).

Key words: Electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; tantalum; thermal radiation properties; thermodynamics.

Measurements of heat capacity, electrical resistivity, hemispherical total and normal spectral emittances of tantalum above 1900 K by a pulse heating technique are described. Duration of an individual experiment, in which the specimen is heated from room temperature to near its melting point, is less than one second. Temperature measurements are made with a photoelectric pyrometer. Experimental quantities are recorded with a digital data acquisition system. Time resolution of the entire system is 0.4 ms. Results on the above properties of tantalum in the range 1900 to 3200 K are reported and are compared with those in the literature. Estimated inaccuracy of measured properties in the above temperature range is 2 to 3 percent for heat capacity, 0.5 percent for electrical resistivity, 3 percent for hemispherical total emittance, and 2 percent for normal spectral emittance.

Thermophysical properties of methane: orthobaric densities and some thermal properties, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 15-21 (Jan.-Feb. 1971).

Key words: Heats of vaporization; methane; orthobaric densities; specific heats of the saturated liquid; thermofunctions for ideal gas states; thermophysical properties.

For use in the computation of thermodynamic functions, analytical descriptions are given for the following properties: the orthobaric densities and saturation temperatures; the heats of vaporization; the specific heats of saturated liquid; and the thermodynamic functions for ideal gas states.

The infrared spectrum of matrix isolated BaO_2, S. Abramowitz and N. Acquista, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 23-25 (Jan.-Feb. 1971).

Key words: Barium; barium oxides; high temperature; infrared; matrix isolations.

The infrared spectra of matrix isolated BaO_2 have been observed and assigned. Ba atoms were allowed to react with an argon oxygen mixture and condensed on a liquid hydrogen cooled surface. Spectra observed using $^{18}O_2$ and $^{16}O^{18}O$ confirm this assignment.

Refinement of the crystal structure of the aragonite phase of $CaCO_3$, B. Dickens and J. S. Bowen, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 27-32 (Jan.-Feb. 1971).

Key words: Calcium carbonates; carbonates; crystal structure; single crystal x-ray diffraction.

Aragonite ($CaCO_3$) crystallizes in the unit cell $a = 4.9598(5)$ Å, $b = 7.9641(9)$ Å, and $c = 5.7379(6)$ Å at 25 °C with four formula weights in space-group *Pmcn*. The structure has been refined to $R_w = 0.024$, $R = 0.040$ using 765 x-ray reflections from a single crystal. The Ca ion is coordinated to nine oxygens with Ca . . . O distances in the range 2.414(2) Å to 2.653(1) Å. The two unique C – O distances in the CO_3 group are 1.288(2) Å (on the mirror plane) and 1.283(1) Å. The two unique O – C – O angles are 119.6(2)° (across the mirror plane) and 120.13(8)°. The distances and angles in the CO_3 group are not significantly different at the 95 percent confidence level.

Simple shearing flows in polyisobutylene solutions, L. J. Zapas and J. C. Phillips, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 33-40 (Jan.-Feb. 1971).

Key words: BKZ fluid; nonlinear behavior; polyisobutylene; stress relaxation; viscosity.

Measurements of shear stress for various shearing flow histories at 25 °C are correlated through the BKZ elastic fluid theory. The data are on 10 percent P1B solution in cetane. The histories include single step stress relaxation, suddenly applied steady shear, steady shearing flow, stress relaxation after steady shear.

Synthesis of fluorodienes, J. E. Fearn, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 41-56 (Jan.-Feb. 1971).

Key words: Cyclic inter-intramolecular mechanism; diene polymerization; fluorodienes; intermediates; polymerization; purity; synthesis; telomerization.

In a comprehensive study of the cyclic, inter-intramolecular mechanism in diene polymerization, all of the completely fluorinated dienes from C_5 to C_8 have been prepared with a high degree of purity. Also prepared were 4-chloroperfluoro-1,6-heptadiene and perfluoro-1,11-dodecadiene, the latter inadvertently. The successful syntheses involved, in most cases, a telomerization which utilized, as the starting material, I_2, ICl, CF_2CFCl, or CF_2CF_2. From these telomers, not only the dienes but many new intermediate compounds were prepared; they were then purified and characterized. The chemistry of these compounds, especially that relating to their polymerization, is briefly discussed.

Quantum corrections to the second virial coefficient for the Lennard-Jones (*m*-6) potential, M. E. Boyd, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 1, 57-89 (Jan.-Feb. 1971).

Key words: Lennard-Jones gas; (*m*-6) intermolecular potential; quantum corrections; second virial coefficient; statistical mechanics; thermodynamics.

Tables are presented for the second virial coefficient of a Lennard-Jones (*m*-6) gas in reduced variables for seven values of *m*.

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

A wide range of reduced temperatures, in a mesh chosen for ease of interpolation, is covered. Values are given for the classical term and three quantum corrections as well as the first two temperature derivatives of each of these terms. A discussion of the variation of behavior with m, especially at the limits $m=6$ and $m=\infty$, is included.

March-April 1971

Tentative set of key values for thermodynamics—Part 1. Report of the ICSU-CODATA Task Group on key values for thermodynamics, October, 1970, S. Sunner, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 97-101 (Mar.-Apr. 1971).

Key words: CODATA; key values; thermodynamics.

This paper is a preliminary report from the Task Group on Key Values for Thermodynamics of the Committee on Data for Science and Technology (CODATA) of the International Council of Scientific Unions (ICSU). It gives values agreed upon by the Committee for enthalpies of formation and entropies of 32 atoms, molecules, and ionic species. Sources of the data are also tabulated.

Expanded formulation of thermodynamic scaling in the critical region, M. J. Cooper, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 103-107 (Mar.-Apr. 1971).

Key words: Critical region; equation of state; liquid-gas transition; phase boundary; phase transition; thermodynamic scaling.

A description of the thermodynamic properties in the critical region of a physical system is obtained from a scaled expression for the free-energy $F(\rho, T)$. In general, a nonsymmetric coexistence curve is predicted, with the symmetric case (e.g., magnets) included as a special example. For fluids, deviations from symmetry give rise to an expression for the average density below the critical point nonlinear in the temperature near T_c (in contrast to the usual "law of rectilinear diameter"); these asymmetries also contribute to the discontinuity in the specific heat along the critical isochore. To lowest order, the formulation reduces to Widom's homogeneous scaling; the classical equations of state of the van der Waals type are incorporated as a special case.

Table of spin-orbit energies for *p*-electrons in neutral atomic (core) *np* configurations, W. C. Martin, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 109-111 (Mar.-Apr. 1971).

Key words: Atomic spectra; atomic theory; spin-orbit interaction.

Data are given in support of the recently proposed formula $\zeta_{np}n^{*3}=0.450Z^{2.33}$ cm^{-1} ($Z \geq 5$). The table includes evaluations of this formula, which are probably accurate to ~ 15 percent for all atoms $Z=10$ to 90. For many (core) *np* configurations, the accuracy of ζ_{np} rom the formula is greater than that to be expected from fitting the observed levels to intermediate coupling theory.

Heat capacities of *cis*-1,4-polyisoprene from 2 to 360 K, S. S. Chang and A. B. Bestul, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 113-120 (Mar.-Apr. 1971).

Key words: Annealed and quenched glass; calorimetry; *cis*-1,4-polyisoprene; glass transformation; heat capacity; natural rubber; normal and supercooled liquid; rubber, natural; thermal diffusivity; thermodynamic properties.

Heat capacities of amorphous synthetic *cis*-1,4-polyisoprene have been determined for the quenched and annealed glasses from 2 to T_g (around 200 K) and for the liquid from T_g to 360 K, with a precision of better than 0.05 percent above 15 K. T_g, as determined from H versus T plots, is 203 K for the quenched glass and 198 K for the annealed glass. For the glasses the heat capacity values from this research are about 1 percent higher than that reported in 1935 for natural rubber hydrocarbon. For the liquid the result from this research agrees better (within 1 percent) with recently (1967) proposed values than those from the earlier experiment cited. Effects of crystallization and melting, stark rubber crystals, and additives (antioxidants and stabilizers) were also studied.

Combined low-pressure and high-pressure measurements of density and bulk modulus of aviation instrument oil and 2-methylbutane and their mixtures, J. C. Houck and P. L. M. Heydemann, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 121-127 (Mar.-Apr. 1971).

Key words: Bulk modulus; compressibility; density; dilatometric measurements; high pressure; liquids; ultrasonics; 2-methylbutane.

Dilatometric measurements were made on mixtures of aviation instrument oil and 2-methylbutane at low pressures. These results are combined with previous dilatometric and ultrasonic measurements at high pressures to give density, relative volume, and isothermal bulk modulus of the mixtures to pressures of 20 kilobars. The ratio of the adiabatic bulk modulus to isothermal bulk modulus for 2-methylbutane is also given.

Crystal structure of $Ca_2Na_2(CO_3)_3$ (shortite), B. Dickens, A. Hyman, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 2, 129-135 (Mar.-Apr. 1971).

Key words: Calcium sodium carbonate; crystal structure; shortite; single-crystal x-ray diffraction.

$Ca_2Na_2(CO_3)_3$ crystallizes in the orthorhombic unit cell $a=4.947(1)$ Å, $b=11.032(2)$ Å, and $c=7.108(1)$ Å at 25 °C with two formula weights in space-group Amm2. The structure has been redetermined, corrected, and refined to $R_w=0.025$, $R=0.020$ using 684 "observed" x-ray reflections from a single crystal. Corrections were made for absorption and isotropic extinction. In the extinction refinements, r refined to 0.00017(1) cm. The structure consists of Ca_2NaCO_3 layers interleaved with $Na(CO_3)_2$ layers. The Ca ion is coordinated strongly to nine oxygens, including three CO_3 edges, with Ca . . . O distances varying from 2.401(2) Å to 2.576(2) Å. One Na ion is coordinated strongly to eight oxygens, including two CO_3 edges, with Na . . . O distances from 2.429(2) Å to 2.605(1) Å. The other Na ion is coordinated strongly to six oxygens, including one CO_3 edge, at 2.296(1) Å to 2.414 Å, and weakly to a seventh at 3.050(3) Å. One CO_3 group is coordinated to seven cations, the other is coordinated to eight. The CO_3 groups have seemingly maximized their edge sharing with Ca ions rather than Na ions.

May-June 1971

The solid phase photolysis and radiolysis of ethylene at 20 to 77 K, R. Gorden, Jr., and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 3, 141-146 (May-June 1971).

Key words: Ethylene; free radical reactions; ion-molecule reactions; photolysis; polymerization; radiolysis.

Films of ethylene condensed onto a cold finger maintained at 20 K were irradiated with photons whose energy ranged from 8.4 to 21.2 eV. At the higher photon energies the relative yields of products compare well with those seen in the radiolysis of solid ethylene. Experiments on CH_2CD_2 demonstrate that in the photolysis hydrogen is mainly formed by the elimination processes $CH_2CD_2^* \rightarrow H_2(D_2) + C_2D_2(C_2H_2)$ and $CH_2CD_2^* \rightarrow HD + C_2HD$. The relative probabilities of these three processes

are independent of the energy of the incident photons from 8.4 to 11.6 eV and are within experimental error identical to those observed in earlier gas phase photolysis experiments. Relative to acetylene, cyclobutane is a minor product at 8.4 eV but increases by an order of magnitude at higher energies where ions play a role. Cyclobutane, 1-butene and methylcyclopropane formed upon irradiation of frozen $C_2H_4-C_2D_4$ mixtures consisted mainly of C_4D_8, $C_4D_4H_4$, and C_4H_8. Plausible mechanisms which may account for the formation of the latter products are examined. In the solid phase as in the gas phase the relative importance of H-atom production is seen to increase with increasing photon energy. Cyclopropane, apparently formed by insertion of CH_2 into C_2H_4, is observed as a product at all wavelengths in the photolysis, and in the radiolysis.

Kinetic mass spectrometric investigation of the ion-molecule reactions occurring in C_4 and C_5 alkanes following photoionization at 106.7 and 104.8 nm, L. W. Sieck, S. K. Searles, and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 147-153 (May-June 1971).

Key words: Gas phase; hydrocarbons; ion-molecule reactions; mass spectrometry; photoionization; rate constants.

The photoionization of C_4 and C_5 alkanes has been investigated at 106.7 and 104.8 nm in a mass spectrometer specifically designed for the investigation of ion-molecule reactions occurring at thermal kinetic energies. Absolute rate constants are reported for the reactions of various fragment ions with the corresponding parent molecule.

The rate constants found for reactions of *sec*-$C_3H_7^+$ ions with *i*-C_4H_{10}, *n*-C_4H_{10}, *i*-C_5H_{12}, and *n*-C_5H_{12} were found to be 3.3, 4.4, 4.7, and 5.2×10^{-10} cm³/molecule-second respectively. The $C_4H_9^+$ ions were also found to be highly reactive, exhibiting rate constants of 3.6 and 3.8×10^{-10} cm³/molecule-second in reactions with *i*-C_5H_{12} and *n*-C_5H_{12}. The rate constants for reaction of $C_3H_6^+$ with *i*-C_4H_{10}, *n*-C_4H_{10}, *i*-C_5H_{12}, and *n*-C_5H_{12} were found to be 4.9, 4.9, 7.6, and 7.9×10^{-10} cm³/molecule-second, respectively. Butene ions are less reactive by an order of magnitude. The results are compared with complementary data derived from electron impact experiments, and the relationship between the structure and reactivity of the various ions is discussed.

An alumina standard reference material for resonance frequency and dynamic elastic moduli measurement. I. For use at 25 °C, R. W. Dickson and J. B. Wachtman, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 155-162 (May-June 1971).

Key words: Alumina; elastic modulus; resonance frequency; shear modulus; standard reference material; Young's modulus.

Bars of sintered polycrystalline alumina were machined to nominal dimensions of 12.7 by 1.27 by 0.32 cm. Surfaces were machined flat and parallel. The mass, dimensions, and resonance frequencies (flexural and torsional) were measured at 25 °C. The exact frequency is specified for each bar and is typically about 2030 Hz for flexural resonance and 11250 Hz for torsional resonance. The effect of suspension loading on resonance frequency was determined and a correction made. Each bar can be used as a frequency standard with an uncertainty for values measured in air of about ± 0.03 Hz for flexure and ± 0.08 Hz for torsion. The effect of atmosphere on resonance frequency was determined and a correction was made for this effect. The uncertainty for resonance frequencies in vacuum is about ± 0.06 Hz for flexure and ± 0.18 Hz for torsion. Each bar can also be used as a dynamic elasticity standard with an uncertainty estimated to be about 0.2 percent for the shear modulus and 0.4 percent for Young's modulus.

Optical and mechanical properties of some neodymium-doped laser glasses, R. M. Waxler, G. W. Cleek, I. H. Malitson, M. J. Dodge, and T. A. Hahn, *J. Res. Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 163-174 (May-June 1971).

Key words: Chemical composition; density; glasses; hardness; laser; optical homogeneity; photoelasticity; refractive index; thermal conductivity; thermo-optic properties; transmittance.

Studies have been made to evaluate thermo-optic and piezo-optic properties of five laser glasses. Measurements were made at the Cd red line, $\lambda = 0.6438$ μm, over a wide range of temperatures and pressures using interferometric and polarimetric techniques. The refractive index-temperature data show both positive and negative values and small changes with temperature. The changes in index with applied compressive stress are positive in value. Other optical properties evaluated were homogeneity, transmittance, and refractive index as a function of wavelength. An ultrasonic pulse-echo technique was used to determine the elastic constants, Young's modulus, shear modulus, bulk modulus, and Poisson's ratio. Data for thermal expansion, thermal conductivity, density, hardness and chemical composition are also given. Calculations were made of the thermal change of refractive index at constant volume. These data can be used to calculate corrections for the distortions of the wavefront of light generated in lasers.

Effect of environment on viscous flow in inorganic oxide glasses, J. H. Simmons and P. B. Macedo, *J. Res Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 175-184 (May-June 1971).

Key words: Critical point theories; immiscibility; phase transitions; structural relaxation; transport phenomena; viscous flow.

Results from viscosity and shear structural relaxation measurements conducted above the liquid-liquid phase transition of a series of immiscible inorganic oxide glasses are analyzed. A model is proposed which relates the temperature dependence of the complex modulus and viscosity to the behavior of microstructure in the glass resulting from supercritical fluctuations in composition. It is suggested that the critical microstructure induces differences in local environment in the glass which in turn cause the appearance of distributions of relaxation times. The model is formulated using elementary fluctuation theory and the resulting equations are successfully compared to the data.

Phase relations in the SrO-IrO_2-Ir system in air, C. L. McDaniel and S. J. Schneider, *J. Res. Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 185-196 (May-June 1971).

Key words: Dissociation; equilibrium; phase relations; SrO:IrO_2 compounds; SrO-IrO_2-Ir system.

The equilibrium phase relations for the SrO-IrO_2-Ir system were determined in an air environment at atmospheric pressure. A ternary equilibrium phase diagram was constructed indicating selected oxygen reaction lines and tie lines. A binary representation is given for the ternary system in air. Of the nine phases detected in this study, three are stable and six are probably metastable under atmospheric conditions. The stable compounds, $4SrO\cdot IrO_2$, $2SrO\cdot IrO_2$, and $SrO\cdot IrO_2$ dissociate at 1540, 1445, and 1205 °C, respectively. The metastable phases include low-$4SrO\cdot IrO_2$, $2SrO\cdot 3IrO_2$, $xSrO\cdot IrO_2 (x > 2)$, $ySrO\cdot IrO_2 (4 > y > 2)$, $zSrO\cdot IrO_2 (2 > z > 1)$, and $3SrO\cdot 2IrO_2$. The specific composition of the metastable phases could not be ascertained with certainty. The x-ray patterns of all phases detected in this study were indexed with the exception of that of the $zSrO\cdot IrO_2 (2 > z > 1)$ compound. A summary of x-ray data is given for all known phases occurring in the system.

The crystal structure of $BaCa(CO_3)_2$ (barytocalcite), B. Dickens and J. S. Bowen, *J. Res. Nat. Bur. Stand. (U.S.),* **75A** (Phys. and Chem.), No. 3, 197-203 (May-June 1971).

Key words: Aragonite; barium calcium carbonate; calcium carbonate; crystal structure; single crystal x-ray diffraction.

The barytocalcite phase of $BaCa(CO_3)_2$ crystallizes in the monoclinic unit cell $a=8.092(1)$ Å, $b=5.2344(6)$ Å, $c=6.544(1)$ Å, $\beta=106.05(1)°$ at 25 °C with cell contents of $2[BaCa(CO_3)_2]$. The structure previously reported by Alm is correct in its coarse details but has been redetermined here and refined to $R_w=0.028$, $R=0.023$ in space-group $P2_1/m$ using 1652 observed reflections. Corrections were made for absorption, isotropic extinction, and anomalous dispersion.

The structure of barytocalcite has an ... ABCABC ... stacking of cation layers and repeat every 3 layers. The calcite phase of $CaCO_3$ has an ABC cation layer sequence and repeats every 6 layers. The orientations of the CO_3 groups in barytocalcite are like the CO_3 group orientation in the aragonite phase of $CaCO_3$, and are rotated about 30° from the CO_3 group orientation in calcite. The cation layer sequence in aragonite is ... ABAB ... and the structure repeats every 2 layers.

The Ca ion in barytocalcite is coordinated to seven oxygens, including an edge of a CO_3 group, with Ca ... O distances in the range 2.305(2) Å to 2.518(2) Å. The Ba ion is coordinated to five edges and one apex of the CO_3 groups with Ba ... O distances ranging from 2.729(3) Å to 3.140(2) Å. The distances of the C atoms in the CO_3 groups from the planes of the O atoms are 0.025(5) Å and 0.022(4) Å for C(1) and C(2), respectively.

Ionization of hydrofluoric acid at 25 °C, P. R. Patel, E. C. Moreno, and J. M. Patel, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 3, 205-211 (May-June 1971).

Key words: Hydrofluoric acid; ionization constant; lanthanum fluoride electrode; least squares procedure; potentiometric measurements.

The ionization constant, K_1, for the reaction $HF \rightleftarrows H^+ + F^-$ was calculated on the basis of potentiometric measurements in the cell Ag; AgCl, Cl^-, $F^-||LaF_3||NaF$, HCl, $H_2O|KCl$(Satd.), Hg_2Cl_2; Hg at 25 °C. A least squares procedure was applied to the experimental data yielding a best estimate for K_1 of 5.85×10^{-4} with a standard error of 0.03×10^{-4}.

Vapor pressure equation for water in the range 0 to 100 °C, A. Wexler and L. Greenspan, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 3, 213-230 (May-June 1971).

Key words: Clausius-Clapeyron equation; saturation vapor pressure over water; steam; vapor pressure; vapor pressure of water; virial coefficients; water vapor.

Some precise measurements of the vapor pressure of liquid water at seven temperatures in the range 25 to 100 °C were reported recently by H. F. Stimson of NBS. These measurements have an estimated standard deviation of 20 ppm or less, except at 25 °C where the estimated standard deviation is 44 ppm. We have derived a formula which yields computed values of vapor pressure agreeing with Stimson's measurements to within 7 ppm.

We integrated the Clausius-Clapeyron equation using the accurate calorimetric data of Osborne, Stimson, and Ginnings and the Goff and Gratch formulations for the virial coefficients of water vapor to obtain an equation that has a rational basis. This equation was then adjusted to bring it into closer accord with Stimson's pressure measurements. Two tables are given of the vapor pressure, expressed in pascals, as a function of temperature at 0.1-deg intervals over the range 0 to 100 °C, one on the International Practical Temperature Scale of 1948 and the other on the International Practical Temperature Scale of 1968.

July-August 1971

Inclusions in laser materials, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 247-260 (July-Aug. 1971).

Key words: Antimony; heat conduction; laser materials; Nd-doped glass; platinum; stress components; thermoelastic theory.

One of the severe problems encountered in high-power-solid-state laser systems is the thermal damage to laser rods and optical elements. One such type of damage is thought to arise from metallic or dielectric inclusions; i.e., impurities with physical and optical properties which differ substantially from those of the host material. Such inclusions may absorb an appreciable amount of the incident radiation and thereby may undergo thermal expansion. This produces major stresses within the host material. Estimating such thermal properties requires the consideration of solutions to the heat diffusion equation and to the thermal stress equations with appropriate boundary conditions. The optical path length change for a probing light ray passing near the inclusion, the radial and tangential stress components, and the changes of the refractive index for radially polarized and tangentially polarized light due to the thermal stress field are computed. The dependence of the maximum value of the tensile stress upon the size of the inclusion and upon the physical properties of the host is examined. The feasibility of using optical techniques to detect metallic and dielectric inclusions in laser materials before they cause damage also is studied. The computations suggest that the use of laser pulse widths of the order of microseconds or longer may be more promising for the detection of small incipient absorbing centers than the use of nanosecond pulse widths.

Heat diffusion near absorbing centers in laser materials, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 261-268 (July-Aug. 1971).

Key words: Absorbing center; complementary error function; heat diffusion; laser host.

The solutions to the heat diffusion equation for spherical absorbing centers in laser materials are presented. The ratio of the volume specific heats for the absorbing center and the laser host is found to determine three regions of behavior. Series expansions for small times and for very large times also are given in each of the three regions. Rapidly converging representations for the complementary error function of complex arguments are developed in order to evaluate numerically the region for which the volume specific heat ratio is greater than three fourths.

Thermal conductivity, electrical resistivity, and thermopower of aerospace alloys from 4 to 300 K, J. G. Hust, D. H. Weitzel, and R. L. Powell, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 269-277 (July-Aug. 1971).

Key words: Aluminum alloy; cryogenics; electrical resistivity; Lorenz ratio; nickel alloys; Seebeck effect; thermal conductivity; titanium alloy; transport properties.

Thermal conductivity, electrical resistivity, and thermopower have been measured for several aerospace alloys: titanium alloy A110—AT, aluminum alloy 7039, Inconel 718, and Hastelloy X. Tables and graphs of the measured properties and Lorenz ratio are presented over the range 4 to 300 K. Comparisons to other measurements and theoretical analysis of the data are included. The uncertainties of the property data are estimated as (1) 0.7 to 2.5 percent for thermal conductivity, (2) 0.25 percent in electrical resistivity, and (3) about 0.1 μV/K in thermopower.

Refractive indices of fused silica at low temperatures, R. M. Waxler and G. W. Cleek, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 279-281 (July-Aug. 1971).

Key words: Fused silica; glasses; interferometry; optics; refractive index.

The refractive indices of a commercial fused silica specimen were determined at ten wavelengths from 404.7 to 667.8 nm over the temperature range from − 200 to +20 °C. The data are needed for the design of optical systems for space applications where the extremes of temperature are encountered. Values of the thermal coefficient of refractive index were found to be positive and varied from about 9×10^{-6}/°C at room temperature to 3×10^{-6}/°C at liquid nitrogen temperature. The data also showed that there is an increase in dispersion with increasing temperature. These results bear out the predictions of the theory for the thermo-optic behavior of solids.

High-speed (subsecond) measurement of heat capacity, electrical resistivity, and thermal radiation properties of tungsten in the range 2000 to 3600 K, A. Cezairliyan and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 283-290 (July-Aug. 1971).

Key words: Electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; thermal radiation properties; thermodynamics; tungsten.

Measurements of heat capacity, electrical resistivity, hemispherical total emittance, and normal spectral emittance of tungsten above 2000 K by a pulse heating technique are described. Duration of an individual experiment, in which the specimen is heated from room temperature to near its melting point, is less than one second. Temperature measurements are made with a photoelectric pyrometer. Experimental quantities are recorded with a digital data acquisition system, which has a full-scale signal resolution of one part in 8000. Time resolution of the entire system is 0.4 ms. Results on the above properties of tungsten in the range 2000 to 3600 K are reported and are compared with those in the literature. Estimated inaccuracy of measured properties in the above temperature range is: 2 to 3 percent for heat capacity, 1 percent for electrical resistivity, 3 percent for hemispherical total and normal spectral emittances.

The calculated continuous emission of a LTE hydrogen plasma, J. R. Roberts and P. A. Voigt, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 291-333 (July-Aug. 1971).

Key words: Emission coefficient; hydrogen; hydrogen continuum; LTE; spectral radiance standard; Stark-broadening.

The total continuous emission coefficient for a LTE hydrogen plasma at one atmosphere is calculated for a temperature range from 8000 to 16000 K and a wavelength range from 400 to 15000 Å. Contributions involving the species H, H_2^+, H^-, and H_2, as well as the wings of Stark-broadened hydrogen lines are included. This calculation will permit the radiation emitted from a laboratory hydrogen plasma to be used as a high intensity spectral radiance calibration standard.

The second spectrum of nickel (Ni II) (addenda and errata), A. G. Shenstone, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 335-336 (July-Aug. 1971).

Key words: Energy levels; ionization potential; nickel; spectral series; spectroscopy; wavelength.

This paper provides additional information which came to light too late for the original publication [J. Res. Nat. Bur. Stand. (U.S.) **74A**, 801 (1970)].

Tables of second virial coefficients and their first and second derivatives for the Stockmayer (m, 6, 3) potential function, J. S. Gallagher and M. Klein, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 4, 337-385 (July-Aug. 1971).

Key words: Dipole; gas; intermolecular potential function; polar; second virial coefficient; Stockmayer.

Expressions are developed for the second virial coefficient and its first two temperature derivatives for polar molecules on the Stockmayer model of a dipole imbedded in a spherical core. In the case considered, the core molecules interact according to an (m, 6) intermolecular potential function. Terms describing the dependence of these quantities on the polarizability of the dipole are also included. Tables are given for the cases $m = 9$, 12, 18, 24, 36, and 60. These tables can be used to calculate the first density corrections to all of the thermodynamic properties of a fluid of polar molecules. The adequacy and accuracy of the tables are discussed in some detail.

September-October 1971

Measurement of the relative enthalpy of pure α-Al_2O_3 (NBS heat capacity and enthalpy standard reference material No. 720) from 273 to 1173 K, D. A. Ditmars and T. B. Douglas, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 401-420 (Sept.-Oct. 1971).

Key words: Alumina; aluminum oxide; corundum; drop calorimetry; enthalpy; heat capacity standard; specific heat; standard reference material; synthetic sapphire; thermodynamic functions.

The relative enthalpy of NBS Standard Reference Material No. 720 (99.98 percent pure, single-crystal α-Al_2O_3, a calorimetric heat-capacity standard) was measured over the range 273 to 1173 K by the drop method using a highly precise Bunsen ice calorimeter. Enthalpy data over the same temperature interval were obtained also on the Calorimetry Conference Sample of this substance. These results are believed to be more accurate than similar NBS results on the latter sample published in 1956, and show no significant discontinuity with the NBS data on the same substance that covered the ranges 13 to 380 K and 1173 to 2257 K. The average deviation from the mean for all enthalpy measurements on the SRM 720 sample was 0.017 percent, and the smooth enthalpy values derived from the data were estimated to be accurate to 0.1 percent. The precautions observed in order to minimize measuring errors are described in detail. The data are compared with many sets of the most reliable published data available and new recommended values for the thermodynamic functions of α-Al_2O_3 are presented for the interval 0 to 1200 K.

High-precision coulometric titrations of boric acid, G. Marinenko and C. E. Champion, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 421-428 (Sept.-Oct. 1971).

Key words: Accurate analysis; boric acid; coulometric titration; high-precision acidimetry; high-precision coulometry.

An absolute method was developed for the determination of boric acid by coulometric titrimetry. The precision of the method, expressed as the standard deviation of a single determination is 0.0033 percent. Changes in the investigated titration parameters produced no significant effects on the titration results. Indications are that within the uncertainty of measurements the method is bias free.

Determination of trace elements in ruby laser crystals by neutron activation analysis, B. A. Thompson and E. C. Miller, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 429-433 (Sept.-Oct. 1971).

Key words: Activation analysis; Al_2O_3; interfering reactions; laser; nondestructive analysis; ruby; trace elements.

Methods are described by which concentration levels have been determined for up to ten different trace elements and upper limits established for over 40 additional elements at the parts per million level or below in ruby crystals using neutron activation analysis. This information is required to determine the effect of trace element levels on laser performance. With conventional

analytical methods difficulties arise because of both the refractory and insulating properties of the material. Because the crystals cannot be readily dissolved, the activation analysis was carried out nondestructively, irradiating the samples with highly thermalized neutrons to minimize formation of ^{24}Na and ^{27}Mg from (n, α) and (n, p) reactions on the Al_2O_3 matrix, and using a 47-cm^3 Ge(Li) detector.

Crystallography of some double sulfates and chromates, H. F. McMurdie, M. C. Morris, J. deGroot, and H. E. Swanson, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 435-439 (Sept.-Oct. 1971).

Key words: Chromates; langbeinites; lattice constants; sulfates; Tutton salts.

New information is given on cell parameters, density and methods of preparation of 50 compounds of the langbeinite and Tutton salt groups. The langbeinites have the general formula $(A^+)_2(B^{2+})_2(XO_4)_3$ and the Tutton salts the general formula $(A^+)_2(B^{2+})(XO_4)_2 \cdot 6H_2O$, where A is K, Rb, (NH_4), Tl or Cs; B is Mg, Ni, Cu, Co, or Zn; and X is S or Cr. A comprehensive list of references on the crystallography of the compounds is included.

Discrimination between equations of state, J. R. Macdonald and D. R. Powell, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 441-453 (Sept.-Oct. 1971).

Key words: Curve fitting; data analysis; equations of state; model discrimination; surface fitting.

Eight isothermal equations of state are analyzed to yield quantitative measures of the degrees to which equation pairs can be discriminated for real data, data of limited span and precision. Calculated curves allow one to assess the span and precision necessary in *P-V* data to allow unambiguous discrimination of various pairs. Some discussion is presented of bias and systematic error which may arise in least squares fitting. Using exact synthetic data, we also illustrate for seven equation pairs the very large relative systematic errors in parameter and standard deviation estimates which arise from such fitting of data of limited span with an incorrect but "close" equation model. General conclusions following from these results are discussed. Although the present work is principally concerned with discrimination between equations of state, its results are pertinent to the more general problem of choosing a "best" analytical model (linear or nonlinear) to represent experimental results.

New absorption bands and isotopic studies of known transitions in CO, J. D. Simmons and S. G. Tilford, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 455-467 (Sept.-Oct. 1971).

Key words: Absorption spectrum; CO; electronic transitions; rotational analysis; vibrational analysis; vibrational and rotational constants.

Several new absorption bands of the $a'\,^3\Sigma^+ - X^1\Sigma^+$ and $e\,^3\Sigma^- - X^1\Sigma^+$ transitions in CO have been observed and analyzed. Vibrational levels of both the $a'\,^3\Sigma^+$ and $e\,^3\Sigma^-$ states are now known to within 0.4 eV of their dissociation limits. Isotopic bands of $^{13}C^{16}O$ in natural abundance have been analyzed for both transitions. The vibrational numbering of the $e\,^3\Sigma^-$ state must be increased by one unit. New bands of the $I^1\Sigma^- - X^1\Sigma^+$ and $D^1\Delta - X^1\Sigma^+$ transitions are also reported.

A study of line shape of CO infrared emission lines, J. A. Dowling, S. Silverman, W. S. Benedict, and J. W. Quinn, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 469-479 (Sept.-Oct. 1971).

Key words: Carbon monoxide; collision parameters; equivalent width; flame spectra; line shapes.

The shape of several vibration-rotation lines of CO emitted by a C_2H_2-O_2 flame was investigated. An equivalent width measurement was made using an absorption cell of room temperature CO as an analyzer. Analysis of the data showed that line shapes could be fitted to a Voigt function with shape parameters a between 1.0 and 1.5.

The collision widths of the flame lines, as determined by the shape parameters, are in essential agreement with earlier room temperature measurements. The extrapolation of the widths measured at room temperature to high temperature has been shown to be reliable within the uncertainty of this experiment (± 15%).

Ionization quantum yields and absorption coefficients of selected compounds at 58.4 and 73.6-74.4 nm, R. E. Rebbert and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 481-485 (Sept.-Oct. 1971).

Key words: Absorption coefficient; helium resonance radiation; hydrocarbons; inorganic molecules; ionization efficiency; ionization quantum yield; neon resonance radiation.

The ionization quantum yields and the extinction coefficients of a number of compounds have been determined at the wavelengths of the helium (58.4 nm) and neon (73.6-74.4 nm) resonance lamps. These are lamps with thin aluminum windows (100-200 nm) which we inserted in a glass cell backed by a second cell. Both cells are provided with parallel plate electrodes and separated from each other by an aluminum window. The ionization quantum yields are based on ionization efficiency of argon which is unity. Hydrogen, which has an ionization quantum yield of 0.94 and 1.00 at 73.6-74.4 and 58.4 nm respectively, was used as a secondary standard because it yielded better defined saturation ion current plateaus. The extinction coefficients were determined in both a double cell and a single cell arrangement. The agreement between the two measurements was excellent. In general an inert diluent was added to the gas of interest in order to improve the plateau of the saturation ion current. These results are compared with the literature values, which were mainly determined in windowless systems with monochromators.

Kinetic mass spectrometric investigation of the reactions of t-$C_4H_9^+$ ions with some simple polar molecules at thermal energies, L. Hellner and L. W. Sieck, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 487-493 (Sept.-Oct. 1971).

Key words: Ion molecule reactions; mass spectrometry; neopentane; photoionization; proton affinity; rate constants.

The interactions of t-$C_4H_9^+$ ions from neopentane with some simple polar molecules have been investigated in a high pressure photoionization mass spectrometer at thermal kinetic energies. Proton transfer was found to occur from t-$C_4H_9^+$ to acetone, ammonia, and the various methylamines, but not to molecules having estimated proton affinities < 195 kcal/mol (815 kJ/mol). Macroscopic thermal rate coefficients are reported for the various proton transfer reactions, all of which are on the order of 10^{-9} cm^3/molecule · second. The reaction

$$t\text{-}C_4H_9^+ + 2CH_3OH \rightarrow (CH_3OH)_2H^+ + C_4H_8$$

was found to occur, but not the analogous reaction with H_2O. On the basis of supplementary experiments, new limits are reported for the proton affinity of acetone. These are 203 ± 2 kcal/mol $<$ proton affinity of acetone < 207 kcal/mol.

Energy levels, wave functions, dipole and quadrupole transitions of trivalent gadolinium ions in sapphire, P. H. E. Meijer, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 5, 493-523 (Sept.-Oct. 1971).

Key words: Corundum; energy levels of Gd^{+++} in Al_2O_3; quadrupole transitions; spin Hamiltonian; transition probabilities; ultrasonic (paramagnetic) resonance; ultrasonic transition probabilities; wave functions of Gd^{+++}.

A computation is made of energy levels, wave functions and transition matrix elements of the Gd^{3+} ion in Al_2O_3. The crystal field parameters are taken from Geschwind and Remeika's paramagnetic resonance experiments. The transition probabilities are given for dipole radiation in three polarization directions. For ultrasonic work we give the real and imaginary parts of the five matrix elements of the quadrupole transition. From these one can easily deduce the transition probabilities in any given direction.

The magnetic field directions are described by the angles θ and ϕ, the polar and azimuthal angles with respect to the crystalline c axis. The values of θ go from 0 to $\pi/2$ in six steps and two values of π are chosen, 0 and 2 $\pi/3$ for which the variation is largest. The magnetic field strengths are from 0 to 0.6 tesla (6000 gauss); beyond this value the spin can be considered as "free." Some consideration is given to the analytical behavior of the energy versus field diagram for the direction $\theta = \phi = 0$.

November-December 1971

The accuracy of measurements of viscosity of liquids, R. S. Marvin, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 535-540 (Nov.-Dec. 1971).

Key words: Absolute measurement of viscosity; accuracy of viscosity measurement; calibration of viscometers; viscosity; uncertainty of viscosity measurements.

Most absolute measurements of viscosity have utilized capillary flow, and required semiempirical corrections amounting to several times their precision and estimated accuracy. The range of values found from these measurements and the possibility of unrecognized systematic errors make it impossible to base a realistic estimate of accuracy on the results of only one type of measurement. The results of two independent absolute measurements involving different types of flow, reported in the two accompanying papers, are summarized here. The estimated accuracy in each case is about 0.1 percent. The two results differ by 0.5 percent. It is suggested that we continue to base the calibration of relative viscometers on the value of 1.002 centipoise (cP) for the viscosity of water at 20 °C and one atmosphere. This provides a generally accepted base which limits comparability only by the precision of the measurements. However, whenever the true values of viscosity are required the limits of uncertainty including an estimate of systematic error should be taken as no better than ± 0.25 percent.

An absolute determination of viscosity using a torsional pendulum, H. S. White and E. A. Kearsley, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 541-551 (Nov.-Dec. 1971).

Key words: Absolute measurement; calibration; standard; torsional pendulum; viscosity.

An absolute measurement of the viscosity of di(2-ethylhexyl) sebacate with a torsional pendulum viscometer. The apparatus and calibration procedures are discussed and a detailed study of errors is made. The systematic error was estimated to be less than ± 0.07 percent and the variability was shown to be less than ± 0.07 percent. There is an unexplained difference of 0.3 to 0.4 percent between these measurements and measurements with a capillary instrument.

An absolute determination of viscosity using channel flow, R. W. Penn and E. A. Kearsley, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 553-560 (Nov.-Dec. 1971).

Key words: Absolute measurement; calculation of bounds; calibration; Poiseuille flow; standard; viscosity; viscous flow.

The viscosity of a sample of di(2-ethylhexyl) sebacate has been determined by measuring the pressure at taps along a closed channel containing the flowing liquid. By means of relative viscosity measurements in conventional capillary viscometers, we are able to express our results in terms of the viscosity of water at 20 °C. We find a value of 0.010008 poise. An appendix outlines the calculation of upper and lower bounds for the geometrical flow constant.

A new determination of the atomic weight of zinc, G. Marinenko, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 561-564 (Nov.-Dec. 1971).

Key words: Atomic weight; coulometry; zinc, atomic weight.

The atomic weight of zinc determined coulometrically for 5 metallic reference samples is 65.377 ± 0.003 where the uncertainty figure is the 95 percent confidence interval for the mean plus an allowance for the mean plus an allowance for known possible sources of systematic error.

High-speed (subsecond) measurement of heat capacity, electrical resistivity, and thermal radiation properties of niobium in the range 1500 to 2700 K, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 565-571 (Nov.-Dec. 1971).

Key words: Electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; niobium; thermal radiation properties; thermodynamics.

Measurements of heat capacity, electrical resistivity, hemispherical total emittance, and normal spectral emittance of niobium in the temperature range 1500 to 2700 K by a subsecond duration pulse heating technique are described. Results obtained on the above properties are reported and are compared with those in the literature. A sharp increase in heat capacity above 2000 K was observed. Electrical resistivity showed a negative departure from linearity in the curve of electrical resistivity against temperature. Estimated inaccuracy of measured properties is: 2 percent for heat capacity, 0.5 percent for electrical resistivity, and 3 percent for hemispherical total and normal spectral emittances.

Stable radical-anions derived from glyoxal *bis*(phenylhydrazones), A. J. Fatiadi, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 573-577 (Nov.-Dec. 1971).

Key words: Bis(phenylhydrazone); e.s.r.; glyoxal; methyl sulfoxide; oxygen; radical-anion.

A series of resonance-stabilized, hydrazyl radical-anions has been observed for the first time; they were prepared by an electron-transfer reaction involving treatment of glyoxal bis(phenylhydrazones) in methyl sulfoxide with a base and a trace of oxygen. The stability of these radical-anions appears to be dependent on the nature of the *para* substituents on the phenylhydrazine moiety.

Temperature dependence of photocurrents produced by x and gamma rays in silicon radiation detectors, K. Scharf and R. K. Mohr, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 579-589 (Nov.-Dec. 1971).

Key words: Gamma rays; photocurrents; radiation; radiation detector; radiation dosimetry; silicon radiation detector; temperature dependence; x rays.

The temperature dependence of dc photocurrents produced by x and gamma rays in silicon radiation detectors of the *n-p*, *p-i-n*, and surface-barrier type was investigated in a temperature range

between 20 and 50 °C. Photodiode photocurrents, assumed as being equal to the *generated* currents I_g, showed a positive temperature dependence in all detectors investigated. Their temperature coefficient at 25 °C varied between +0.004 per °C and +0.002 per °C. The temperature dependence of short-circuit currents I_{sc} measured by a compensation method, was positive and nearly linear for *n-p* type detectors but nonlinear and negative for *p-i-n* and surface-barrier type detectors. It is shown, that this different behavior of individual detectors is due to the influence of the strongly temperature-dependent junction current I_j which under the short-circuit mode is drained off the generated current I_g. The junction current is a function of the internal series resistance R_s and the junction resistance R_j of the irradiated detector ($I_j = I_{sc}\, R_s/R_j$). With increasing resistance ratio R_s/R_j, the current ratio I_j/I_g increases and the temperature coefficient α_{sc} of the short-circuit current decreases. Temperature coefficients $(\alpha_{sc})_{25}$ measured in the different detectors at 25 °C and a current density 6×10^{-7} A/cm² decreased with increasing resistance ratio from +0.004 per °C to −0.005 per °C. Resistance ratios R_s/R_j of the detectors investigated ranged between 0.01 and 0.24 approximately. Thus, $(\alpha_{sc})_{25}$ measured in an individual detector can be changed by changing its *effective* series resistance. A decrease of $(\alpha_{sc})_{25}$ with increasing I_{sc} was observed in detectors with larger resistance ratios. This was apparently due to the voltage dependence of R_j at higher junction voltages produced by larger short-circuit currents.

Isomerization processes in ions of the empirical formula $C_4H_8^+$, S. G. Lias, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 591-605 (Nov.-Dec. 1971).

Key words: Butene; cyclobutane; ion structure; isomerization; methylcyclopropane; photoionization; photolysis; radiolysis.

Ions of the formula $C_4H_8^+$ have been generated with different initial energies by ionizing ethylene ($C_2H_4^+ + C_2H_4 \rightarrow C_4H_8^+$, where the $C_4H_8^+$ ion is formed with an initial energy of > 11.51 eV), cyclobutane (initial energy of $C_4H_8^+$, > 10.84 eV), methylcyclopropane (> 10.15 eV), 1-C_4H_8 (> 9.58 eV), and *i*-C_4H_8 (> 9.06 eV) with 11.6-11.8 eV photons, and in some cases also with 10 eV photons and with gamma radiation. The structures of the ions have been determined from the structures of the C_4H_8 products formed in charge transfer reaction between the ions and charge acceptors such as dimethylamine and nitric oxide, as well as from the structures of the butanes formed in D_2^- transfer reactions with methylcyclopentane-d_{12} ($C_4H_8^+ + C_6D_{12} \rightarrow C_4H_8D_2 + C_6D_{10}^+$).

At low pressures the $C_4H_8^+$ ions initially formed in ethylene, cyclobutane, and methylcyclopropane isomerize to the thermodynamically most stable configurations, *i*-$C_4H_8^+$ and 2-$C_4H_8^+$. The 2-$C_4H_8^+$ structure predominates in all the experiments. As the pressure is raised, the *i*-$C_4H_8^+$ ion yield diminishes as that of 2-$C_4H_8^+$ increases, indicating that when the precursor of the *i*-$C_4H_8^+$ ion is collisionally deactivated, it ends up as 2-$C_4H_8^+$. At high pressures, 1-$C_4H_8^+$ ions are intercepted; their yield increases with increasing pressure, indicating that 1-$C_4H_8^+$ is an intermediate which isomerizes further unless it is collisionally deactivated. The 1-$C_4H_8^+$ ion formed in methylcyclopropane (initial energy > 10.15 eV) is more easily deactivated than that formed in cyclobutane (initial energy > 10.84 eV). That the isomerization of the 1-$C_4H_8^+$ ion to lower energy structures such as *i*-$C_4H_8^+$ and 2-$C_4H_8^+$ requires excess internal energy is demonstrated by the fact that in the photolysis with 10 eV photons, a negligible amount of isomerization is observed, but with 11.6-11.8 eV photons, more than half of the 1-$C_4H_8^+$ ions isomerize to the 2-$C_4H_8^+$ structure at a pressure of 2 torr. Isomerization of the low energy *i*-$C_4H_8^+$ ions formed in the photolysis of *i*-C_4H_8 to other structures is relatively unimportant at 11.6-11.8 eV.

Taking the ratio *i*-$C_4H_8^+$/2-$C_4H_8^+$ as an indicator of the amount of energy removed by collisions from the intermediate $C_4H_8^+$ species under conditions where only *i*- and 2-$C_4H_8^+$ ions are intercepted, it is shown that the efficiency of energy transfer from the ions to helium, hydrogen, neon, krypton, xenon, nitrogen, and carbon dioxide is related to the polarizability of the added deactivator.

The photochemistry of propane at high photon energies (8.4-21.2 eV), R. E. Rebbert, S. G. Lias, and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **75A** (Phys. and Chem.), No. 6, 607-612 (Nov.-Dec. 1971).

Key words: Ion-molecule reaction; photoionization; propane; quantum yields; rare-gas resonance radiation; unimolecular dissociation.

Neon and helium resonance lamps, which deliver photons of 16.7-16.8 eV and 21.2 eV energy, respectively, have been used to photolyze C_3H_8, C_3D_8, C_3H_8-C_3D_8 (1:1) mixtures, and $CD_3CH_2CD_3$ and the results obtained at the two energies are compared. In particular, it is noted that although the quantum yield of ionization in propane is unity at 16.7-16.8 eV, when the energy is raised still further to 21.2 eV, the probability of ionization apparently diminishes to 0.93, an observation which suggests that at 21.2 eV, superexcited states may be reached whose dissociation into neutral fragments competes with ionization.

The quantum yields of the lower hydrocarbon products formed in the presence of a radical scavenger in C_3H_8 and C_3D_8 are reported, and are compared with quantum yields of products formed in the vacuum ultraviolet photolysis at lower energies. (Quantum yields of products formed at 8.4 eV and 10.0 eV are reported here for the first time.) Acetylene is formed as a product in the decomposition of the neutral excited propane molecule, and its yield increases in importance with increasing energy; at 16.7-16.8 eV, where all product formation can be traced to ionic processes, acetylene is formed in negligible yields. It is concluded that ionic processes in propane do not lead to the formation of acetylene, and the observation of this product in radiolytic systems may be a reliable indicator of the relative importance of neutral excited molecule decomposition processes.

From the results obtained with the C_3H_8-C_3D_8 (1:1) mixture, and with $CD_3CH_2CD_3$, details of the ion-molecule reaction mechanisms and the unimolecular decomposition of the propane ion are derived.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 76A, JANUARY-DECEMBER 1972

January-February 1972

The absorption spectra of krypton and xenon in the wavelength range 330-600 Å, K. Codling and R. P. Madden, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 1-12 (Jan.-Feb. 1972).

Key words: Autoionization; far ultraviolet; krypton; photoionization; resonances; xenon.

A total of 153 krypton resonances in the spectral region 330-500 Å and 253 xenon resonances in the spectral region 375-600 Å are reported. A detailed listing of the resonances is given, with wavelength and line shape information. The analysis of the spectra is very incomplete and will require detailed theoretical calculation to significantly improve it. In Kr, 45 resonances and in Xe, 56 resonances have been grouped into probable Rydberg series, for which classifications are suggested. The resonances are due, in the main, to either the excitation of the inner subshell "*s*" electron ($s^2p^6 \rightarrow sp^6np$) or to the excitation of two of the outer "*p*" electrons simultaneously ($s^2p^6 \rightarrow s^2p^4nln'l'$). These high-lying excited states autoionize, resulting in resonances with window-, asymmetric-, or absorption-type profiles. Where possible, comparisons are made with previous work.

A reference calorimeter for laser energy measurements, E. D. West, W. E. Case, A. L. Rasmussen, and L. B. Schmidt, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 13-26 (Jan.-Feb. 1972).

Key words: Calorimetry; laser; laser calorimetry; laser energy measurement; laser power measurement.

Principles and detailed procedures are described for measuring laser energy and power in terms of electrical energy based on votage, resistance, and frequency standards. The construction of a small isoperibol calorimeter used for the measurements is described. The calorimeter will accommodate 0.01 to 20 J and 4×10^{-5} to 1 W cw and is limited to a maximum pulse intensity of 0.1 J/cm². The standard deviation of comparison measurements using two calorimeters and a beam splitter is 0.08 percent when the smaller energy input is not less than 0.3 J. The estimated limits of systematic error for one calorimeter are ±1.0 percent of the laser energy measured by the calorimeter.

Accurate calculations of properties of the two-tube electrostatic lens. I. Improved digital methods for the precise calculation of electric fields and trajectories, S. Natali, D. Di Chio, and C. E. Kuyatt, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 27-35 (Jan.-Feb. 1972).

Key words: Calculation of electric fields; calculation of electron trajectories; electron lens; nine-point relaxation formulas; predictor-corrector method; two-tube electrostatic lens.

Digital methods of high precision have been developed for the calculation of electric fields and trajectories in electrostatic lenses and a computer program was written to apply these methods to the two-tube lens. The increased precision results from the use of nine-point formulas in the relaxation calculation of potentials in place of previously used five-point formulas and from the use of an improved predictor-corrector method for the calculation of trajectories. Trajectories obtained with these methods are sufficiently precise to determine third-order aberration coefficients.

Dielectric constant of compressed gaseous and liquid oxygen, B. A. Younglove, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 37-40 (Jan.-Feb. 1972).

Key words: Clausius-Mossotti function; dielectric constant; oxygen.

The dielectric constants of compressed gaseous and liquid oxygen were measured on ten isotherms at temperatures between 100 and 300 K and on the saturated liquid boundary at temperatures between 55 and 154 K. Densities ranged from 0.06 to 1.30 g/cm³ at pressures up to 33 MN/m². The dielectric constant measurements were combined with accurate density data to compute the Clausius-Mossotti (CM) function, $(\epsilon-1)/(\epsilon+2)\rho$. The CM function for oxygen decreases with density from a value of 0.1236 cm³/g at the low density limit to 0.1219 cm³/g near the triple point.

Thermal analysis of calcium sulfate dihydrate and supposed α and β forms of calcium sulfate hemihydrate from 25 to 500 °C, J. R. Clifton, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 41-49 (Jan.-Feb. 1972).

Key words: α- and β-$CaSO_4 \cdot 1/2H_2O$; $CaSO_4 \cdot 2H_2O$; differential scanning calorimetry; differential thermal analysis; thermogravimetry.

Thermal studies were carried out on $CaSO_4 \cdot 2H_2O$ and the supposed α and β forms of $CaSO_4 \cdot 1/2H_2O$ in the region of 25 to 500 °C using differential thermal analysis, thermogravimetry, and differential scanning calorimetry methods.

Two large endothermic effects and a smaller exothermic effect were found in the differential thermogram of $CaSO_4 \cdot 2H_2O$ while a single endothermic as well as an exothermic effect were found in the thermograms of the supposed α and β forms of $CaSO_4 \cdot 1/2H_2O$. However, the exotherm of α-$CaSO_4 \cdot 1/2H_2O$ had lower peak and first-break temperatures than that of the β-form. The peak and first-break temperatures of the endothermic effects of $CaSO_4 \cdot 2H_2O$ and α and B-$CaSO_4 \cdot 1/2H_2O$ and the exothermic effect of α-$CaSO_4 \cdot 1/2H_2O$ were pressure dependent, shifting to lower temperatures as the gaseous pressure within the DTA cell was decreased. The noted differences in the thermograms possibly are due to kinetic factors because of the differences in crystallinity of the supposed α- and β-$CaSO_4 \cdot 1/2H_2O$.

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

No differences in the supposed α and β forms of $CaSO_4 \cdot 1/2H_2O$ were detected by thermogravimetry and differential scanning calorimetry studies. The formulation of a two-step dissociative process in the complete dehydration of $CaSO_4 \cdot 2H_2O$ was supported by the results of the thermogravimetry study.

Modulus of natural rubber cross-linked by dicumyl peroxide. I. Experimental observations, L. A. Wood, G. W. Bullman, and G. E. Decker, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 1, 51-59 (Jan.-Feb. 1972).

Key words: Creep; cross-linking; dicumyl peroxide; glass transition; indentation measurements; rubber, natural.

Natural rubber mixed with varying amounts of dicumyl peroxide was cross-linked by heating 120 min at 149 °C. The quantitative measure of cross-linking was taken as the amount *fp* of decomposed dicumyl peroxide, the product of *p*, the number of parts added per hundred of rubber and *f* the fraction decomposed during the time of cure. The shear creep modulus *G* was calculated from measurements of the indentation of a flat rubber sheet by a rigid sphere. The glass transition temperature T_g, was raised about 1.2 °C for each part of decomposed dicumyl peroxide. Above $(T_g + 12)$ the modulus-temperature relations were linear with a slope that increased with increasing cross-linking. The creep rate was negligible except near the glass transition and at low values of *fp*. Values of *G*, read from these plots at seven temperatures, were plotted as a function of *fp*. The linearity of the two plots permits the derivation of the general relation: $G = S(fp + B)T + H(fp + B) + A$ where *A*, *B*, *H*, and *S* are constants. The lines representing *G* as a function of *fp* at each temperature all intersected near the point, $fp = 0.45$ phr, $G = 2.70$ Mdyn cm^{-2} (0.270 MN m^{-2}). The constants were evaluated as $A = 2.70$ Mdyn cm^{-2}, $B = -0.45$ phr, $S = 5.925 \times 10^{-3}$ Mdyn cm^{-2} (phr)$^{-1}$K^{-1} and $H = 0.0684$ (Mdyn cm^{-2}) (phr)$^{-1}$. This equation represented satisfactorily all the data obtained at temperatures from − 50 to + 100 °C for values of *fp* from about 1 to 24 phr.

March-April 1972

Guidelines for the reporting of numerical data and experimental procedures, D. Garvin, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 67-70 (Mar.-Apr. 1972).

Key words: Chemistry; experimental procedures; numerical data; physics.

General recommendations are made about the reporting of data and experimental procedures. These are intended as instructions to authors of papers in which quantitative physical and chemical data are reported. There is included a bibliography of standards documents and more detailed guidelines.

A study of equilibrium in argon arcs, J. B. Shumaker and C. H. Popenoe, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 71-76 (Mar.-Apr. 1972).

Key words: Argon arcs; argon transition probabilities; equilibrium; LTE.

The intensities of the 7147 Å Ar I and 4806 Å Ar II lines obtained from wall-stabilized arcs at pressures of 0.2 to 5 atm are presented in an Olsen-Richter diagram. Departures from equilibrium are evident at electron densities below 5×10^{16} cm^{-3}. The assumption of equilibrium at higher electron densities leads to transition probabilities in fair agreement with lifetime measurements.

Rates of reaction of atomic oxygen III. Spiropentane, cyclopentane, cyclohexane, and cycloheptane, R. E. Huie and J. T. Herron, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 77-80 (Mar.-Apr. 1972).

Key words: Cycloheptane; cyclohexane; cyclopentane; oxygen; rate constants; spiropentane.

Rate constants have been measured from 307 to 652 K for the reactions of atomic oxygen (O^3P) with spiropentane, cyclopentane, cyclohexane, and cycloheptane. The derived Arrhenius parameters are $k(sp - C_5H_8) = 10^{13.60 \pm 0.10} \exp[(-2890 \pm 100)/T]$, $k(cy - C_5H_{10}) = 10^{14.10 \pm 0.09} \exp[(-2210 \pm 100)/T]$, $k(cy - C_6H_{12}) = 10^{14.35 \pm 0.09} \exp[(-2350 \pm 100)/T]$, and $(cy - C_7H_{14}) = 10^{14.46 \pm 0.13} \exp[(-2230 \pm 100)/T]$ all in units of cm^3 mol^{-1} s^{-1}.

Densities of compressed liquid methane, and the equation of state, R. D. Goodwin and R. Prydz, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 81-101 (Mar.-Apr. 1972).

Key words: Compressed liquid; densities; equation of state; methane; orthobaric densities.

Experimental *PVT* data for liquid methane are reported at densities from 1.8 times critical up to the freezing liquid, at temperatures from 91 to 245 K and pressures to 350 bar. A nonanalytic equation of state is adjusted to these and other *PVT* data from ideal gas states to the freezing liquid, at temperatures from the triple point to 400 K.

Spin-relaxation effects on the EPR spectrum of gaseous hydrogen atoms, R. L. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 103-113 (Mar.-Apr. 1972).

Key words: Electron spin resonance; hydrogen atoms; spin-exchange; spin-relaxation.

A theoretical analysis is presented of the relaxation processes which lead to the magnetization of gaseous hydrogen atoms in a strong magnetic field. Experiments are described which demonstrate that the spin-lattice relaxation time in a pure H_2 carrier can be of the order of 10 ms. From the effects of traces of O_2 on the hydrogen atom EPR spectrum, a H-O_2 spin-exchange collision cross section of $(8.0 \pm 2.5) \times 10^{-16}$ cm^2 was derived.

Photoionization of $C_4H_8^+$ isomers. Unimolecular and bimolecular reactions of the $C_4H_8^+$ ions, L. W. Sieck, S. G. Lias, L. Hellner, and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 115-124 (Mar.-Apr. 1972).

Key words: C_4H_8 isomers; collisional stabilization; isomerization; photoionization; rate constants; vapor phase.

1-Butene, *cis*-2-butene, isobutene and methylcyclopropane have been photoionized with the resonance lines of krypton (10.0 − 10.6 eV) and argon (11.6 − 11.8 eV). We have determined that the internally excited 1-$C_4H_8^+$ ion and, to a much lesser extent, the *i*-$C_4H_8^+$ ion isomerizes to the 2-$C_4H_8^+$ structure. In both cases the extent of isomerization increases, approximately by a factor of ten when the photon energy is increased from 10 to 11.7 eV. An inert gas, neon, quenches the isomerization of the *i*-$C_4H_8^+$ ion and, to a much lesser extent, that of the 1-$C_4H_8^+$ ion.

The unimolecular fragmentation of the $C_4H_8^+$ isomeric ions has been examined at 11.6 − 11.8 eV. In this energy range the dissociative lifetime of *i*-$C_4H_8^+$ was found to be at least 5×10^{-6} s, and collisional quenching of the dissociative process is already noticeable at pressures in the 10^{-3} torr range.

The rate coefficients for the reaction $C_4H_8^+$ (thermal) + C_4H_8 → $(C_8H_{18}^+)^*$ occurring in the isomeric C_4H_8 systems have been determined under conditions where the structure of the reacting $C_4H_8^+$ ion is established. The values in cm^3/molecule · second are 1-C_4H_8 − $6.0 \pm 0.5 \times 10^{-10}$, *cis*-2-$C_4H_8$ − $0.37 \pm 0.1 \times 10^{-10}$, *i*-$C_4H_8$ − $5.4 \pm 0.4 \times 10^{-10}$. At pressure below 10^{-3} torr, the internally excited $(C_8H_{16}^+)^*$ produced in the reaction dissociates along various channels with relative probabilities de-

pending upon the structure of both the ionic and neutral reactant. Above 10^{-3} torr collisional quenching of $(C_8H_{16}^+)^*$ is noted.

Theoretical investigation of the odd configurations of Ni II, Y. Shadmi and E. Caspi, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 125-136 (Mar.-Apr. 1972).

Key words: Energy levels; *g*-factors; nickel; parameters, theory.

Two groups of odd levels in Ni II were investigated: those belonging to the complex $3d^84p + 3d^74s4p + 3d^85p$ and those belonging to the configuration of $3d^84f$. In the first group the calculated positions of the levels were fit to the positions of the 174 observed levels with an rms error of 133 cm^{-1}. The fit for the second group was based on 60 observed levels and had an rms error of 25 cm^{-1}. The predictions of this investigation helped in the discovery of many of the observed levels.

The characterization of linear polyethylene SRM 1475. I. Introduction, C. A. J. Hoeve, H. L. Wagner, and P. H. Verdier, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 137-138 (Mar.-Apr. 1972).

Key words: Fractionation; linear polyethylene; molecular weight; molecular weight distribution; National Bureau of Standards; pellet variability; standard reference material.

The National Bureau of Standards has issued a linear polyethylene standard reference material, SRM 1475. In this report a general description of the sample is given, and the characterization work described in the subsequent reports is outlined. Some pellet-to-pellet variability was found and estimated.

The characterization of linear polyethylene SRM 1475. II. Determination of total methyl content by infrared spectrophotometry, J. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 141-142 (Mar.-Apr. 1972).

Key words: Infrared; linear polyethylene; methyl; methylene; number average molecular weight; spectra; spectrophotometry.

An ASTM method was used to determine the methyl content of linear polyethylene SRM 1475 by measuring the absorbance at 1378 cm^{-1} (7.25 nm) of methyl groups on compensated infrared spectra. The methyl content of this polymer was found to be 0.15 methyls per 100 carbon atoms. Considering the methyls to be polymer end groups, the number average molecular weight computed approximates that determined by gel permeation chromatography within the experimental error. These values indicate that the polymer is essentially free of branching.

The characterization of linear polyethylene SRM 1475. III. Density determination, J. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 143-144 (Mar.-Apr. 1972).

Key words: Crystallization; degree of crystallinity; density; linear polyethylene; polymer; recrystallization.

The density of SRM 1475 at 23 °C was determined by ASTM method D 1505-67 on samples prepared by Procedure A of ASTM method D 1928-68, with the result 0.9784 g/cm^3.

The characterization of linear polyethylene SRM 1475. IV. Melt flow rate, J. R. Maurey, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 145-146 (Mar.-Apr. 1972).

Key words: Extrusion plastometer; load; melt flow rate; orifice; orifice die; preliminary extrudate; test extrudate.

The melt flow rate of SRM 1475 was determined to be 2.07 g/10 min at 190 °C under a load of 325 g by a method similar to procedure A of ASTM method D 1238-65T. This value is the average of determinations on 42 samples with a standard deviation of a single measurement of 0.040 g/10 min, and a range of 1.991 g/10 min to 2.132 g/10 min.

The characterization of linear polyethylene SRM 1475. V. Solution viscosity measurements, R. G. Christensen, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 147-149 (Mar.-Apr. 1972).

Key words: Decalin; limiting viscosity number; linear polyethylene; solution viscosity; viscometer; 1-chloronaphthalene; 1,2,4-trichlorobenzene.

The limiting viscosity numbers of linear polyethylene SRM 1475 were determined at 130 °C in 1,2,4-trichlorobenzene, 1-chloronaphthalene, and decalin. Technique, including use of a novel solution transfer method, is described.

The characterization of linear polyethylene SRM 1475. VI. Preparation of calibrating fractions, R. G. Christensen, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 149-150 (Mar.-Apr. 1972).

Key words: Column extraction fractionation; fractionation; linear polyethylene.

Fractions for use in calibrating a gel permeation chromatograph were prepared by a Desreux column extraction method. The construction and operation of the fractionating system are described.

The characterization of linear polyethylene SRM 1475. VII. Differential refractive index of polyethylene solutions, H. L. Wagner, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 151-155 (Mar.-Apr. 1972).

Key words: Differential refractive index; *dn/dc*; refractive index; refractometer; 1-chloronaphthalene; 1,2,4-trichlorobenzene.

The value of *dn/dc* for polyethylene in 1-chloronaphthalene at 135 °C, required for the determination of molecular weight by light scattering, was found to vary with molecular weight. Similar changes were found in 1,2,4-trichlorobenzene, the gel permeation chromatograph solvent. The absolute value of *dn/dc* decreases by about 2 percent as the polymer molecular weight increases from 12,000 to 110,000.

The characterization of linear polyethylene SRM 1475. VIII. Light-scattering studies on polyethylenes in 1-chloronaphthalene, L. J. Frolen, G. S. Ross, A. M. Wims, and P. H. Verdier, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 156-160 (Mar.-Apr. 1972).

Key words: End-to-end distance; light scattering; linear polyethylene; M_w; polyethylene fractions; second virial coefficient; solution properties.

Light-scattering measurements have been made on a series of linear polyethylene fractions and a linear polyethylene standard reference material (SRM 1475). All measurements were made in 1-chloronaphthalene at 135 °C, and over an angular range from 45 to 135°. The data were analyzed to obtain the weight average molecular weights, second virial coefficients and root-mean square end-to-end distances.

The characterization of linear polyethylene SRM 1475. IX. Number average molecular weight of fractions by membrane osmometry, J. E. Brown and P. H. Verdier, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 2, 161-163 (Mar.-Apr. 1972).

Key words: Concentration dependence; linear polyethylene; membrane; number average molecular weight; osmometer; osmotic pressure; virial coefficient.

The number average molecular weights of a series of fractions of linear polyethylene have been determined using a high speed membrane osmometer. The M_n values of the fractions, which were prepared by an elution technique, were used in GPC calibration and subsequent characterization of linear polyethylene SRM 1475. The molecular weights, measurement techniques, and the precision of the measurements are presented.

The characterization of linear polyethylene SRM 1475. X. Gel permeation chromatography, G. Ross and L. Frolen, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 2, 163-170 (Mar.-Apr. 1972).

Key words: Gel permeation chromatography (GPC); linear polyethylene; molecular weight distribution (MWD); number average; weight average.

The determination of the integral molecular weight distribution *(MWD)* of the linear polyethylene sample (SRM 1475) by means of gel permeation chromatography (GPC) is described. Both the experimental and mathematical details of column calibration and sample analysis are included.

May-June 1972

Thermodynamics of standard cells of the saturated cadmium sulfate type, W. J. Hamer, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 3, 185-205 (May-June 1972).

Key words: Emfs of standard cells; emf-temperature coefficients of standard cells; standard potential of standard cells; thermodynamics of standard cells.

This paper gives data on the thermodynamic functions of standard cells of the saturated cadmium sulfate type, as obtained from calorimetric and equilibrium data at 25 °C or from the electromotive forces (emfs) and emf-temperature coefficients of the cell for the temperature range of 0 to 43.6 °C. The functions considered are the changes in Gibbs energy, enthalpy, entropy and heat capacity for the cell reaction. The electromotive forces are expressed on the V_{69} volt and the t_{68} temperature scale. Results are expressed on the SI and for comparisons with literature data in terms of the defined thermochemical calorie. The effect of expressing the emf-temperature coefficient as a function of temperature in different ways on the values for the changes in entropy and heat capacity for the cell reaction is discussed. Finally, the observed emf of the standard cell at 25 °C is compared with emfs calculated from various values reported for the standard potentials of the cadmium-amalgam and mercury-mercurous sulfate electrodes and the activity coefficient of cadmium sulfate in saturated aqueous solution.

An improved state equation in the vicinity of the critical point, O. B. Verbeke, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 3, 207-211 (May-June 1972).

Key words: Compressibility; critical point; equation of state; fluid; helium; low temperature; methane; scaling law; specific heat; xenon.

An improved state equation for the vicinity of the critical point is proposed. An analysis of the experimental data on helium and xenon has been carried out in order to investigate the influence of the number of constants in the equation and the $P\rho T$ range on the critical constants T_c and ρ_c and on the critical exponents α, β, γ, and δ. No such influence has been detected. The model for the critical point, recently proposed by Widom, has been checked regarding its consequences for the rectilinear diameter. No definite confirmation but indications for its correctness have been found.

Dilute solution theory of polymer crystal growth: fractionation effects, I. C. Sanchez and E. A. DiMarzio, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 3, 213-223 (May-June 1972).

Key words: Cilia; dissolution temperature; fractionation; rate constant; undercooling.

A nonequilibrium (kinetic) theory of polymer molecular weight (MW) fractionation is formulated and applied to binary and multicomponent polyethylenes crystallized from unstirred xylene solutions. High MW components crystallize more readily than do low MW components. This fractionation effect is enhanced as the crystallization temperature is raised. At low crystallization temperatures (high undercoolings) the polymer tends to fractionate according to the volume fraction distribution of its MW components and thus, the number average MW of the crystal that is formed is approximately equal to the weight average MW of the polymer in solution. It is shown that MW fractionation does not depend on the details of nucleation, but rather on the rates for post-nucleation crystal growth. The effects of MW polydispersity on crystalline properties is considered and in particular it is shown that polydispersity tends to mask the intrinsic dependence of crystal thickness on MW. The variables which govern and influence fractionation are also discussed.

The formation of curved polymer crystals: poly(4-methylpentene-1), F. Khoury and J. D. Barnes, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 3, 225-252 (May-June 1972).

Key words: Chain-folded; crystal, curved; electron microscopy; lamellar; optical microscopy; poly(4-methylpentene-1); polymer; solution-grown.

An optical and electron microscopical study is described of the habits exhibited by poly(4-methylpentene-1) crystals (Modification 1 tetragonal unit cell) grown at temperatures between 50 and 90 °C from 0.1 percent solutions of the polymer in equivolume mixtures of xylene and amyl acetate. A distinct trend in the effect of crystallization temperature (supercooling) on the habits of the crystals is illustrated and discussed. The lamellar crystals formed in that temperature range are all the more pronouncedly curved the lower the crystallization temperature. To indicate but the extremes in this trend, the crystals varied from essentially planar ones whose constitutent square shaped chain-folded lamellae (bounded laterally by {100} faces and up to 20 μm on a side) are four-sectored and only very slightly buckled as previously indicated by Bassett et al., to distinctly curved four-fold symmetrical hollow bowl shaped ones having a radius of curvature of about 2.5 μm and in which the surface of the curved multilayered wall of which they are constituted changes in orientation through 180° from the base (pole) to the periphery. In contrast with the four-sectored character of the lamellae in the aforementioned essentially planar crystals, the constituent lamellae in all the distinctly dished and bowl-like crystals formed in the temperature range 50 to 90 °C are multisectored, their lateral development being characterized by the formation at their periphery during growth of successive arrays of {100} microfaceted sectored outgrowths. The reasons why the lamellar crystals of poly(4-methylpentene-1) are all the more pronouncedly curved the lower the crystallization temperature are explored and discussed. Conjectures concerning the origins of this phenomena are advanced in the form of a working "model."

Photoionization of propylene, cyclopropane, and ethylene. The effect of internal energy on the bimolecular reactions of $C_2H_4^+$ and $C_3H_6^+$, L. W. Sieck and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 3, 253-262 (May-June 1972).

Key words: Collisional stabilization; hydrocarbons; ion-molecule reactions; photoionization; rate constants; structures of ions.

The ion-molecule chemistry occurring in photoionized ethylene, propylene and cyclopropane has been investigated in the NBS high pressure mass spectrometer. Emphasis has been placed on determining the overall effect of internal excitation on the absolute rate coefficients for the various reactions. This was accomplished by comparing the behavior found when ionization was induced by photon absorption at the ionization threshold with that found at higher photon energies. The values for the absolute rate coefficients for the formation of excited compound ions at various photon energies were as follows (units of 10^{-10} cm^3/molecule · s); $C_2H_4^+$, 9.6 (10.6 eV photons); 8.5 (11.7 eV photons); $C_3H_6^+$, 8.4 (10.0 eV photons); 6.8 (11.7 eV photons); $C_3D_6^+$, 7.8 (10.0 eV photons), 6.1 (11.7 eV photons); *c*-$C_3H_6^+$ and *c*-$C_3D_6^+$, 2.2 (10.0 eV photons); 2.2 (11.7 eV photons). The distributions of product ions obtained from the unimolecular decomposition of the compound ion in each system have also been determined at various photon energies, and considerable variation has been observed. In general, the variations are similar to those found elsewhere when the kinetic energy of the reactant ion is increased. The bimolecular reactions of the $C_6D_{12}^+$ compound ion obtained from $C_3D_6^+$ have been investigated at higher pressures, and separate experiments involving isotopically labeled ethylenes have provided new information concerning the nature of the compound ion in that system. Results obtained from other laboratories are discussed in some detail, and in most cases the differences found for the same system are explicable in terms of the energy content (internal and/or kinetic) of the reactant ion.

Low temperature thermocouples: KP, "normal" silver, and copper versus *Au*-0.02 at% Fe and *Au*-0.07 at% Fe, L. L. Sparks and R. L. Powell, *J. Res. Nat. Bur. Stand.* (*U.S.*), **76A** (Phys. and Chem.), No. 3, 263-283 (May-June 1972).

Key words: Cryogenics; gold alloy; liquid helium; liquid hydrogen; liquid nitrogen; thermocouples.

The Seebeck thermoelectric voltages of two dilute alloys of iron in gold, *Au* 0.02 at% Fe and *Au*-0.07 at% Fe, have been determined with respect to KP (a particular Ni-Cr alloy), "normal" silver, and copper in the temperature range from 4 to 280 K. The power series representation of these data, along with the calculated Seebeck coefficients and derivatives of the Seebeck coefficients, have been extrapolated to 0 K and are presented as a function of temperature. In addition to these reference data, seven different *Au*-0.07 at % Fe alloys were thermoelectrically intercompared in order to determine the variability in wires from different melts and from different manufacturers. The largest deviation found amounted to about 9 percent of the output of a KP versus *Au*-0.07 at% Fe thermocouple pair between 4 and 20 K. A more typical variation for this temperature range was 2 to 4 percent. Initial indications are that the reference data can be adjusted satisfactorily with data from spot calibrations on particular wires. The effect of heat treatment is illustrated by comparing our results to Rosenbaum's data for annealed and unannealed specimens of both *Au*-Fe alloys.

Infrared spectra of cerium (Ce I and Ce II) between 0.8 and 2.4 μm, J. Verges, C. H. Corliss, and W. C. Martin, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 3, 285-304 (May-June 1972).

Key words: Ce I and II; cerium spectra; infrared spectra; spectra; wavelengths.

The cerium spectrum emitted by an electrodeless lamp has been observed with a SISAM spectrometer in the region from 0.82 to 2.42 μm. Of the 2076 lines observed, about 1100 lines have been classified as transitions in the energy level system of Ce I and 400 lines in Ce II. The average deviation between the observed wave numbers and those calculated from the two energy levels is ± 0.023 cm^{-1}.

July-August 1972

The EMF-temperature coefficient of "acid" standard cells of the saturated cadmium sulfate type from 15 to 40 °C, W. J. Hamer, A. Skapars, and B. F. Field, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 4, 321-328 (July-Aug. 1972).

Key words: Effect of acid on standard cells; EMF-temperature coefficients of standard cells; entropy changes in standard cells; heat-capacity changes in standard cells; standard cells.

This paper gives the results of new measurements of the effect of temperature on the electromotive force of standard cells of the saturated cadmium sulfate type. Measurements were made over the temperature range of 15 to 40 °C. Twelve cells of NBS manufacture and 24 cells supplied by two different commercial manufacturers were used in the studies. Final results were analyzed by the method of least squares using computer programs. The relation between EMF and temperature for NBS, company 1, and company 2 cells was found to be given, respectively, by:

$$E_t = E_{20°C} - [40.44(t-20) + 0.921(t-20)^2 - 0.00866(t-20)^3] \times 10^{-6} \text{V},$$

$$E_t = E_{20°C} - [40.14(t-20) + 0.888(t-20)^2 - 0.00668(t-20)^3] \times 10^{-6} \text{V},$$

$$E_t = E_{20°C} - [39.28(t-20) + 0.986(t-20)^2 - 0.00943(t-20)^3] \times 10^{-6} \text{V}.$$

Values for the entropy and heat-capacity changes for the cell reaction in "acid" standard cells are also given.

Pulse radiolysis of neopentane in the gas phase, R. E. Rebbert and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 4, 329-336 (July-Aug. 1972).

Key words: Electron scavengers; gas phase; ion-molecule reactions; neopentane; neutralization; pulse radiolysis.

The pulse radiolysis of gaseous neopentane has been investigated in the absence and presence of electron scavengers (SF_6, CD_3I, CCl_4). Deuterium labeling experiments show that the stable product molecules can be accounted for by (a) radical combination reactions involving mainly CH_3 and H; (b) hydride ion transfer reactions involving $C_2H_3^+$, $C_2H_5^+$, and $C_3H_5^+$; (c) neutralization reactions of $C_4H_9^+$ and $C_5H_{11}^+$; and (d) unimolecular dissociation of the parent ion ($C_5H_{12}^+$) and of electronically excited neopentane. Neutralization of the *t*-$C_4H_9^+$ ion, which is the major positive ion in the system, occurs as follows: (a) *t*-$C_4H_9^+ + e \rightarrow$ *i*-$C_4H_8 + H$ and (b) *t*-$C_4H_9^+ + e \rightarrow 2CH_3 + C_3H_6$. It is shown that $C_5H_{11}^+$ produced in hydride ion transfer reaction $C_nH_m^+ +$ neo-$C_5H_{12} \rightarrow C_nH_{m+1} + C_5H_{11}^+$ (where $C_nH_m^+ = C_2H_3^+$, $C_2H_5^+$, and $C_3H_5^+$) rearranges to the $CH_3C^+(CH_3)CH_2CH_3$ structure prior to neutralization. A detailed accounting of all products produced in the unimolecular and bimolecular reactions led to the conclusion that the ratio of neutral electronically excited molecules to parent ions (N_{ex}/N_+) is 0.28.

Anatomy and thermal history of laser self-focusing damage tracks in glass, W. Haller and J. H. Simmons, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 4, 337-345 (July-Aug. 1972).

Key words: Glass; laser damage; self-focusing.

Laser induced self-focusing damage tracks in glass are analyzed. The damaged regions consist of long cylinders of altered refractive index, containing occasional bubbles and partly surrounded by arrays of small cracks. An analysis of the refractive index change in the subfracture damage tracks and the presence of bubbles leads to estimates of a minimum temperature reached by heating of the glass in the tracks. A calculation of minimum stresses developed during laser-beam heating gives a good account of the orientation of the observed cracks.

Normal emissivity of an isothermal, diffusely reflecting cylindrical cavity (with top) as a function of inside radius, W. B. Fussell, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 4, 347-349 (July-Aug. 1972).

Key words: Cavity; cylindrical cavity; diffusely reflecting; emissivity; normal emissivity; radiation; reflectance.

The normal emissivity of an isothermal cylindrical cavity (with top), with a diffusely reflecting interior of reflectivity much less than 1, is calculated approximately as a function of the inside radius of the cylinder by the DeVos method. The calculation is analytical, and considers the singly and doubly reflected radiation escaping from the cavity aperture. The results of the analysis indicate that, for cylinders whose length-to-lid aperture ratio is much larger than 1: (a), for a given cylinder length and lid aperture, the configuration with the inside diameter approximately 0.64 the length has the *smallest* normal emissivity; (b), as the inside diameter increases or decreases from the configuration of smallest normal emissivity, the normal emissivity *increases* monotonically.

Lattice vibrations of antiparallel chain sheet structures, B. M. Fanconi, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 4, 351-359 (July-Aug. 1972).

Key words: Antiparallel chain sheet structures; honeycomb lattice; lattice vibrations.

Methods are developed for calculating the normal coordinate vibrations of isolated helical homopolymers and of the antiparallel sheet structures formed by some helical polymers in the solid state. The dynamical equations are expressed in Cartesian displacement coordinates starting from an internal coordinate harmonic force field. As an example of the method, the dynamical equations of the honeycomb lattice are derived.

September-October 1972

High accuracy spectrophotometry at the National Physical Laboratory, F. J. J. Clarke, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 5, 375-403 (Sept.-Oct. 1972).

Key words: High accuracy spectrophotometry; photoelectronic linearity; reflectance; transmittance.

The techniques and equipment used at the National Physical Laboratory (NPL) to achieve high accuracy spectrophotometric measurements are described and discussed. The emphasis at NPL has always been on the determination of systematic components of error and their elimination or correction rather than on the attainment of mere precision, which is largely a matter of variance and resolution. The scales of regular transmittance, diffuse transmittance, total transmittance of scattering samples, regular reflectance, diffuse reflectance, total reflectance and radiance factor are determined, maintained, and made available in practical form to industry by combined use of a reference NPL manual spectrophotometer and commercial recording spectrophotometers.

The presentation will concentrate on transmittance measurements made with the reference instrument, which is designed specifically to allow separate investigation of the various possible sources of systematic error, processes that are not practicable with commercial spectrophotometers. The investigation of the linearity of the complete photoelectronic system has always been a key factor, and double-aperture devices have been used consistently at NPL for over 40 years to monitor the performance of this instrument and its predecessors. Besides instrumentation, the procurement of material standards of suitable quality is a major limitation of the art, and the types in use at NPL are described, including the recently developed Ceramic Colour Standards.

An accurate spectrophotometer for measuring the transmittance of solid and liquid materials, R. Mavrodineanu, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 5, 405-425 (Sept.-Oct. 1972).

Key words: Absorbance; automation of accurate spectrophotometer; instrumentation, spectrophotometric; spectrophotometry, high accuracy; standard reference material in spectrophotometry; transmittance.

The optical transmittance of solids and liquids as well as the molar absorptivity of various chemical species are parameters of fundamental significance in characterizing these materials. Meaningful transmittance data can be obtained only when the measurements are performed with well-known accuracy and precision. To perform such measurements, a high accuracy spectrophotometer was designed and assembled at NBS, Analytical Chemistry Division, and will be described in this paper. This single-beam instrument is composed of a constant radiation source, a monochromator, a sample carriage, an integrating sphere-photomultiplier assembly followed by appropriate electronics, and a read out system consisting of a digital voltmeter and a computer data acquisition and handling provision. The accuracy of transmittance measurements is determined by the light-addition principle used in conjunction with a two-aperture arrangement. The spectrophotometer can be used in manual or automatic modes of operation. A detailed discussion of the data obtained with this instrument, used in both modes, will be presented together with its application to the certification of solid and liquid Standard Reference Materials for checking the photometric scales of conventional spectrophotometers.

Absolute spectroradiometric measurements, G. A. W. Rutgers, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 5, 427-436 (Sept.-Oct. 1972).

Key words: Absolute spectroradiometry; absolute standard source of radiation; calibrated photodetector.

There are two general methods for measuring a quantity of radiation emitted by a source. One can compare it with the radiation emitted by a standard source or one can measure the radiation with a detector calibrated in absolute units. When using the latter method, one must know the spectral transmittance factor of the optical components between source and detector.

In the present paper, a survey will be given of the standard sources available for spectroradiometry: cavity radiator, tungsten strip lamp, anode of the carbon arc, xenon arc and cascade arc. Several types of detectors such as the absolute bolometer and thermopile, with their properties, will be discussed.

Accurate measurements of and corrections for nonlinearities in radiometers, C. L. Sanders, *J. Res. Nat. Bur. Stand. (U.S.)*, **76A** (Phys. and Chem.), No. 5, 437-453 (Sept.-Oct. 1972).

Key words: Nonlinearity; photocell linearity; photometric accuracy; radiation addition method.

The methods described in the literature for accurately measuring photocell linearity are surveyed and assessed. The effects of not measuring photocell linearity under the conditions used in the final apparatus are considered. Some of the conditions necessary for accurate assessment of the nonlinearity under working conditions are specified. The use of the NRC "Photocell Linearity Tester" to measure and correct for the nonlinearity of various receivers is described.

Physical parameters in high-accuracy spectrophotometry, K. D. Mielenz, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 455-467 (Sept.-Oct. 1972).

Key words: High accuracy spectrophotometry, physical parameters; linearity test of photodetector; spectrophotometry, high accuracy.

The measured apparent transmittance T_A of a filter or liquid sample depends on the beam geometry in the spectrophotometer. For focused light incident upon the sample, T_A is different for systems having different f-numbers, and also depends on the state of polarization of the light. These effects are eliminated when the incident light is collimated; in this case T_A approaches the "true" transmittance T of the sample. Both modes of operation suffer from stray light and interference effects. The former may be reduced significantly by using mirror rather than lens optics, and the latter by suitable choice of the monochromator slit width. A new spectrophotometer based upon the above-mentioned design principles is described. The photometric precision of this instrument is shot-noise limited, permitting measurements to better than 10^{-4} transmittance units.

The double-aperture method of testing detector linearity to this level of precision is discussed. The conventional method of finding the nonlinearity correction can be replaced by a curve-fitting procedure giving better precision. Data on detector nonlinearity, and its dependence on wavelength, are presented.

Liquid absorbance standards, R. W. Burke, E. R. Deardorff, and O. Menis, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 469-482 (Sept.-Oct. 1972).

Key words: Absorptivity data; liquid absorbance standards; Standard Reference Materials.

Errors in the measurement of the absorbances of liquid filters result from instrumental and chemical uncertainties. This paper presents a systematic study of these variables on the absorbances of selected filters. Three types of liquid filters are discussed. These are (1) individual solutions of high purity compounds, (2) composite mixtures, and (3) aqueous solutions of organic dyes. The accuracy of the absorptivity data is established using NBS-calibrated glass filters. The magnitude of the errors arising from spectral bandpass, beam geometry, stray light, internal multiple reflections, and refractive index are delineated. Finally, as a practical outgrowth of this study, the development and issuance of NBS Standard Reference Material 931, Liquid Absorbance Standards for Ultraviolet and Visible Spectrophotometry, is described.

Accurate measurement of molar absorptivities, R. W. Burnett, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 483-489 (Sept.-Oct. 1972).

Key words: Molar absorptivity in clinical chemistry; random errors in molar absorptivity; systematic errors in molar absorptivity.

The key to accurate measurement of molar absorptivities is a thorough understanding of the sources of error which appear throughout the measurement procedure. Sources of determinant error will be listed with comments on estimating their magnitude and eliminating them where possible. Sources of random error will be discussed as well as the propagation of both random and determinant errors. There is discussion of the need for accurate values of molar absorptivities using examples from clinical chemistry. Finally, the proper use of accurate absorptivity values in the clinical chemistry laboratory will be considered. Here, emphasis is on the need for a quality assurance system which includes routine checks on such things as wavelength calibration and photometric accuracy of spectrophotometers, calibration of analytical balances, and quality of incoming reagents.

Problems associated with the need for standardization in clinical spectrophotometric and fluorometric measurements, J. R. Penton, G. M. Widdowson, and G. Z. Williams, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 491-498 (Sept.-Oct. 1972).

Key words: Clinical standards; standardization, spectrofluorometric; standardization, spectrophotometric; standard reference materials.

There is a growing demand in clinical chemistry for analyses to be performed in a manner allowing comparisons of results among laboratories and, from time to time, in the same laboratory. Reliable comparability requires adequate procedures of standardization for spectrophotometric and fluorometric instruments and methods. Problems with chemical and instrumental standardization are discussed.

For assays where the substance to be measured is available in suitable form, primary chemical standardization is justifiably popular. Relatively unsophisticated instrumentation can be used to compare measurements of unknown samples with such standards. Because primary standards meeting all necessary criteria are not available for many assays of clinical significance, standardization must depend on precision and accuracy of the instrumentation used, and on accurately compiled values of chemical-optical properties for the materials of interest. The task of compilation is outside the capability of the routine laboratory and should be provided by a reliable central agency. If an individual laboratory is to use the agency's compiled values, that laboratory must have available precise, accurate and reasonably inexpensive instrumentation along with reliable absorbance, fluorescence, and wavelength calibration standards.

The role of spectrophotometric standards in the clinical chemistry laboratory, R. N. Rand, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 499-508 (Sept.-Oct. 1972).

Key words: Clinical spectrophotometry, accuracy, precision; optical cuvettes; spectrophotometric standards, clinical.

It is obvious that erroneous data reported to a physician may adversely affect patient welfare. Currently, acceptable limits of accuracy and precision are poorly defined. It should be recognized, however, that the spectrophotometric measurement step in an appropriate analytical procedure is critical and inapparent error may occur. Spectrophotometric measurements, both manual and automated, are extensively used in the clinical chemistry laboratory. At least 1,000,000 such measurements per day on rather diverse equipment are made in this country; yet, few standards exist. Results of intra-lab surveys suggest that performance could be improved. The various ways in which spectrophotometry is used will be illustrated and a discussion of possible errors resulting from nonstandardized instrumentation will follow. There is pressing need for well defined and easily usable standards for wavelength, photometric accuracy, photometric linearity, stray light, as well as NBS specifications for optical cuvettes.

Spectrophotometric standards, W. H. Venable, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 509-510 (Sept.-Oct. 1972).

Key words: Photometric accuracy; standards, spectrophotometric.

To be useful, spectrophotometric measurements must be believable and practical. The basic standard for any believable spectrophotometric measurements is the ability to accurately compare fluxes of radiation within the framework of a well-defined geometry. The emphasis in the program proposed for the Institute for Basic Standards is to develop such ability over the broadest range of spectrophotometric measurements. Establishing such a basis will enable the National Bureau of Standards to render real assistance to those who deal with the problem of making practical measurements.

An alternative to accurate pyrometry in distinguishing concurrent vaporization reactions. Postulated results using the vaporization of gold in analyzing the vaporization of beryllium oxide in water vapor, T. B. Douglas, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 511-515 (Sept.-Oct. 1972).

Key words: Beryllia hydrates (gases); contaminants; gold; pyrometry; reference vaporization; temperature consistency; thermodynamic parameters (estimated).

For the transpiration determination of vaporization properties whose interconsistency is critical, the simultaneous vaporization of a reference substance such as uncontaminated gold is suggested as an alternative to accurate pyrometry. Calculations suggest that gold would be superior to all but the most accurate pyrometry in the temperature range 1700 to 2300 K. An application to seeking unreported gaseous hydrates of beryllia is illustrated by calculations based on estimated thermodynamic parameters.

The determination of iron, titanium, and nickel in Apollo 14 samples by cathode ray polarography, E. J. Maienthal, *J Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 517-520 (Sept.-Oct. 1972).

Key words: Analyses of iron, titanium, nickel; Apollo 14 lunar samples; differential cathode ray polarography.

Methods have been developed and applied to the determination of iron, titanium, and nickel in Apollo 14 fine soil and rock by differential cathode ray polarography on the same sample. A 5 mg sample was sufficient for the determination of all 3 elements. Iron and titanium were determined either directly or after cupferron separation. Nickel was determined after dimethylglyoxime separation.

The Stark splitting of millimeter wave transitions of water, Y. Beers and G. P. Klein, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 5, 521-528 (Sept.-Oct. 1972).

Key words: Millimeter waves; Stark effect; water.

This paper first discusses the technique of making Stark measurements at millimeter wavelengths. The details of correcting for residual overlap between the lines, the effects of modulation, and of the field inhomogeneity are discussed. Finally the measured frequencies and the empirical Stark coefficients for one H_2O and one D_2O and five HDO lines between 85 and 250 GHz are given. The final analysis of the data to give values of the dipole moment will be given in another paper.

November-December 1972

Absolute spectrofluorometry, W. H. Melhuish, *J. Res. Nat. Bur. Stand. (U.S.),* **76A,** (Phys. and Chem.), No. 6, 547-560 (Nov.-Dec. 1972).

Key words: Actinometers; calibration of spectrofluorometers; detectors, absolute; fluorescence spectra, corrected; quantum counters; spectrofluorometers, design; spectrofluorometry, absolute; standard lamps; standards, fluorescence; thermopiles.

The last 10 years has seen the increasing publication of the emission spectra of organic, inorganic and metal-chelate compounds, but there is no agreed method of presentation of such spectra. In the few cases where corrected emission spectra have been published, there is often no mention of the units used for the intensity coordinate or the method used for correcting spectra. A method of reporting absolute fluorescence spectra originally put forward in 1962 will be reexamined and improved. The two best known methods for calibrating spectrometers for absolute spectrofluorometry: (a) standard tungsten lamp, (b) quantum counter method, will be critically examined, and the limitations and possible improvements in accuracy will be proposed. The criteria for an emission standard will be examined and the use of emission standards for calibrating spectrofluorometers discussed. It is suggested that the distribution of emission standards to laboratories measuring corrected fluorescence spectra and the analysis and publication of the results should be done in the near future.

Absolute quantum efficiencies, G. A. Crosby, J. N. Demas, and J. B. Callis, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 561–577 (Nov.-Dec. 1972).

Key words: Calorimetry in quantum yields; laser, use in quantum yields; photodetectors in quantum yields; quantum efficiencies.

Recent developments in several areas of chemistry, laser technology, photodetector instrumentation, and calorimetry are surveyed, and their probable impact on the measurement of quantum yields is assessed. Chemical developments include: (a) synthesis and design of new luminescent molecules that could possibly serve as standards, (b) application of improved separation techniques to provide samples of extreme purity, and (c) advances in photochemistry that portend the development of wide-range chemical actinometers. The potential use of lasers in quantum yield measurements and their advantages over conventional sources for application in both optical and calorimetric techniques are pointed out. New methods of quantum yield measurements, based on the novel characteristics of laser pump sources, are suggested, including the feasibility of measuring yields under time-resolved conditions and of employing internal standards. The possible lifting of wavelength restrictions on both laser sources and detector devices and the implications of these developments for extending the spectral range of quantum yield measurements are discussed. The current status of calorimetry for determining yields is surveyed, and the impact of recent technology on the feasibility of developing calorimetric methods competitive with optical methods is assessed.

Phosphorimetry, J. D. Winefordner, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 579-592 (Nov.-Dec. 1972).

Key words: Aqueous solvents in phosphorimetry; phosphorimetry; rotating capillary cell; solvents for phosphorimetry.

Phosphorimetry in the past has received limited use because the precision of reproducibility was inadequate, there were solvent limitations, and preparation of test specimens was difficult and time consuming. Detection limits have now been lowered by more than two orders of magnitude by using a rotating capillary

sample cell, a more stable excitation-source power supply, and aqueous solvents. These steps have also increased precision by more than an order of magnitude. Considerable reduction in time and effort of sampling and measurements has been effected compared to phosphorimetric measurements made with standard procedures and commercial equipment. Twenty microliters of aqueous solution is all that is required to fill a quartz capillary cell by capillary action. Capillary cells filled with aqueous solutions do not crack when cooled to 77 K or when returned to room temperature. Rotation of the sample cell minimizes effects due to cell orientation and thus improves precision. Reduction of background phosphorescence results in improved accuracy of analysis. A study was made of the influence of methanol-water mixtures and of sodium-halide aqueous solutions on the magnitude of phosphorescence signals from several substances and of the effect on signal-to-noise ratios. The optimum solvent system for many phosphorimetric measurements is discussed. Analytical results are given for several organic substances measured by phosphorimetry at 77 K. These results are compared with those from previous studies by older methods.

Measurements of absolute values in biochemical fluorescence spectroscopy, R. F. Chen, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 593-606 (Nov.-Dec. 1972).

Key words: Absolute fluorometry; absolute fluorometry in biochemistry; standard reference materials in fluorometry.

Fluorescence spectroscopy is an important tool of the biochemist studying the structure and interactions of proteins and nucleic acids. The four basic quantities to measure accurately are: (1) spectra (corrected excitation and emission), (2) quantum yields (Q), (3) fluorescence decay characteristics, and (4) polarization. Commercially available instruments, with little modification, can be used to obtain these measurements, but the biochemist in this field is very dependent on the accuracy of measurements of substances he uses as standards. Confusion arises from disagreement between reported values for standards which may be used to calibrate a detector system to obtain quantum yields, or to set up lifetime and polarization photometers. For instance, the protein chemist is fond of using tryptophan and quinine as quantum yield standards, but Q for tryptophan has been variously reported as 0.13 and 0.20, and Q values for quinine bisulfate range from 0.4 to 0.7. The biochemist should also be aware of the problems inherent in the use of commercially available instruments in absolute measurements, as well as the special complications arising in complex biochemical systems where the fluorescence is heterogeneous.

Newer fluorometric methods for the analysis of biologically important compounds, G. G. Guilbault, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 607-612 (Nov.-Dec. 1972).

Key words: Enzymes, fluorometric analysis; fluorometry of enzymes; fluorometry of substrates; silicone pad; solid surface fluorometry.

Newer fluorometric methods for the analysis of biologically important compounds will be discussed: enzymes such as LDH, alkaline phosphatase, lipase and cholinesterase, and substrates such as glucose, urea and uric acid. These methods are based on the production of fluorescence initiated by an enzymic reaction.

New reagentless fluorescence methods will be described for enzymes and substrates. These methods are highly precise (1%), fast (less than 1 minute) and involve no preparation of reagents. These methods, as adapted to clinical laboratory procedures, will be discussed.

Inorganic ions in glasses and polycrystalline pellets as fluorescence standard reference materials, R. Reisfeld, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 613-635 (Nov.-Dec. 1972).

Key words: Fluorescence standards, inorganic ions; glass standards in fluorescence; rare-earth-doped glasses.

The absorption and fluorescence of inorganic glasses and polycrystalline disks doped by heavy metal ions is discussed, and their use as fluorescence standards is evaluated. The advantages of the glass standards over other media are summarized.

The glass standards are divided into two groups: (1) glasses doped by trivalent rare earths such as Gd^{3+}, Tb^{3+}, Eu^{3+}, Sm^{3+}, and Tm^{3+} which have narrow band optical spectra as a result of intraconfigurational transitions, and (2) glasses and polycrystalline disks doped by ions such as Tl^{+}, Pb^{2+}, Ce^{3+}, and Cu^{+} which have broad spectral bands since the optical spectra originate from interconfigurationally allowed transitions. Optical and physical parameters, including matrix effects, quantum efficiencies, decay characteristics, Stokes' shifts and spin-orbit versus orbit-lattice interactions due to the different transitions will be discussed.

Group (1) glasses are suitable for use as standards where a narrow well-defined fluorescence range is required, and group (2) glasses are suitable for use as standards whenever a substance with a wide range of fluorescence is measured. Special emphasis will be placed on energy transfer between donor and acceptor ions.

Development of a new fluorescent reagent and its application to the automated assay of amino acids and peptides at the picomole level, S. Udenfriend, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 637-640 (Nov.-Dec. 1972).

Key words: Fluorometry, amino acids; fluorometry, peptides; picomole fluorometry.

Methods for the assay of amino acids and peptides are most important in elucidating the structure of proteins and peptides. In many important areas of research such as in endocrinology, neurobiology, and genetics, methods are needed with sensitivity higher than is available with the widely used colorimetric ninhydrin procedure. A short while ago, we noted that all primary amines react with ninhydrin and phenylacetaldehyde to give a ternary product which is highly fluorescent. The chemistry of that reaction has now been elucidated and the conditions have been modified and improved so that essentially quantitative yields of fluorescent products are formed with all primary amines. The reaction has been automated and is being used as the detecting system for chromatography of amino acids, peptides and amines in the 10 to 100 picomole range. Problems concerning the fluorescence instrumentation and the isolation and chromatography of these compounds in the picomole range will be discussed.

Considerations on organic compounds in solution and inorganic ions in glasses as fluorescent standard reference materials, R. A. Velapoldi, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 641-654 (Nov.-Dec. 1972).

Key words: Emission spectra; excitation spectra; fluorescence; fluorescence standards; glass standards; quinine derivatives; rare earths; relative quantum efficiencies; solution standards.

The use of various organic compounds in solution and inorganic ions in glasses has been investigated as possible fluorescence Standard Reference Materials. Emphasis was placed on measuring physical and chemical parameters such as stability, reproducibilities of absorbance and fluorescence measurements, relative quantum efficiencies as a function of excitation wavelength, etc., for quinine derivatives and selected or-

ganic compounds. A brief discussion is included on the use of rare earth and non-rare earth inorganic ions in glasses as standards.

Ion-molecule reactions in isopropanol: Implications for its radiolysis, R. Gorden, Jr., and L. W. Sieck, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 655-659 (Nov.-Dec. 1972).

Key words: Gas-phase kinetics; ion-molecule reactions; mass spectrometry; photoionization; proton affinity; radiolysis.

The photoionization of isopropanol (*i*-PrOH) at 11.7 eV has been investigated in the NBS high pressure photoionization mass spectrometer over the pressure range 0.1 to approximately 200 millitorr. The major primary ion, CH_3CHOH^+, reacts with a total rate coefficient of $1.1 \pm 0.1 \times 10^{-9}$ cm^3/molecule · s to yield mainly (*i*-PrOH)H^+ and $CH_3(i\text{-}C_3H_7)COH^+$. At pressures in excess of a few millitorr consecutive reactions of (*i*-PrOH)H^+ and $CH_3(i\text{-}C_3H_7)COH^+$ were also detected, including the overall dehydration process

$$(i\text{-PrOH})H^+ + i\text{-PrOH} \rightarrow H_2O + (i\text{-}C_3H_7)_2OH^+$$

These data are interpreted in light of a recent radiolysis study, and a thermal cationic chain mechanism for production of $(i\text{-}C_3H_7)_2O$ consistent with those results is proposed. The value for the proton affinity of SF_6 is also discussed in some detail.

Excitation of $O_2{}^1\Delta_g$ by electron impact, P. S. Julienne and M. Krauss, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 661-663 (Nov.-Dec. 1972).

Key words: Ab initio Gaussian wave functions; electron impact excitation; exchange amplitude; $O_2{}^1\Delta_g$ state; Ochkur-Rudge approximation.

The total and differential cross sections as a function of energy were calculated for electron impact excitation of the $O_2{}^1\Delta_g$ state for the ground $^3\Sigma_g^-$ state. The Ochkur-Rudge approximation was used for the exchange amplitude, which was calculated using Hartree-Fock wave functions with a Gaussian basis; there is good agreement with the experimental total cross section except near threshold.

Vibrational and electronic oscillator strengths of LiO, M. Marchetti, P. S. Julienne, and M. Krauss, *J. Res. Nat. Bur. Stand. (U.S.),* **76A** (Phys. and Chem.), No. 6, 665-668 (Nov.-Dec. 1972)

Key words: $A^2\Sigma$; electronic transition probabilities; Hartree-Fock; LiO; vibrational transition probabilities; $X^2\Pi$.

Electronic energies and wave functions of ground and excited states of LiO are calculated in the Hartree-Fock approximation. The vibrational oscillator strengths of the $X^2\Pi$ and $A^2\Sigma^+$ valence states are calculated for v=0 to 1 and 1 to 2 transitions. Electronic oscillator strengths are also presented for transitions to the quantum number of two Li Rydbergs. Reasons are presented to support the use of the Hartree-Fock approximation.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 77A, JANUARY-DECEMBER 1973

January-February 1973

Spectrum and energy levels of neutral thulium, J. Sugar and W. F. Meggers, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 1, 1-43 (Jan.-Feb. 1973).

Key words: Energy levels; spectrum; thulium; wavelengths.

A new set of measurements of the spectrum of neutral thulium covering the range of 2513 Å to 11750 Å is given. The light source utilized for the observations was a microwave-excited thulium-iodide lamp. Second spectrum lines were recognized by comparing the output of this lamp with that of a 6A sliding spark. The results of Zeeman effect studies of these lines are included. Analysis of these new data led to the discovery of 348 new energy levels and provided revised values for the 142 already published. Measured Landé g factors are given for most of the levels.

Simultaneous measurement of specific heat, electrical resistivity, and hemispherical total emittance of niobium-1 (wt.%) zirconium alloy in the range 1500 to 2700 K by a transient (subsecond) technique, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 1, 45-48 (Jan.-Feb. 1973).

Key words: Electrical resistivity; emittance; high-speed measurements; high temperature; niobium-zirconium alloy; specific heat; thermodynamics.

Simultaneous measurements of specific heat, electrical resistivity, and hemispherical total emittance of niobium-1 (wt.%) zirconium alloy in the temperature range 1500 to 2700 K by a subsecond duration pulse heating technique are described. Estimated inaccuracy of measured properties are: 3 percent for specific heat and hemispherical total emittance, and 0.5 percent for electrical resistivity. Properties of the alloy are compared with the properties of pure niobium. It was found that specific heat and emittance of the alloy were approximately 0.5 percent and 1.5 percent, respectively, higher than those of pure niobium. Electrical resistivity of the alloy was 0.5 percent lower than that of pure niobium. Like niobium, the alloy showed a negative departure from linearity in the curve of electrical resistivity versus temperature.

Theory of disclinations: II. Continuous and discrete disclinations in anisotropic elasticity, R. deWit, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 1, 49-100 (Jan.-Feb. 1973).

Key words: Burgers vector; continuum mechanics; defect; dipole; disclination; dislocation; distortion; Green's tensor; incompatibility; loop; plasticity; strain; Volterra.

A general theory of stationary disclinations for a linearly elastic, infinitely extended, homogeneous body is developed. Dislocation theory is extended in three different ways to include disclinations, i.e., from continuous distributions, discrete lines, and continuous distributions of infinitesimal loops. This leads to three independent definitions of the disclinations, which can be uniquely related to each other. These interrelationships clarify Anthony and Mura's approaches to disclination theory, which at first appear to diverge from the present theory. Mura's "plastic distortion" and "plastic rotation" are identified as the dislocation and disclination loop densities. The elastic strain and bend-twist are derived as closed integrals in terms of the defect densities, and shown to be state quantities. The theory reduces to classical dislocation theory when the disclinations vanish. For every discrete disclination line, it is always possible to find a "dislocation model," which is a dislocation wall terminating on the line that gives exactly the same elastic strain and stress.

Photochemistry of methane in the photoionization region, R. E. Rebbert and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 1, 101-107 (Jan.-Feb. 1973).

Key words: Ion-molecule reaction; ion pair yield; methane; photochemistry; photoionization; quantum yields.

Methane was irradiated with microwave operated helium (21.2 eV) and neon (16.7–16.8 eV) resonance lamps which were separated from the reaction vessel by an aluminum window. The quantum yields of the stable end products have been determined at methane pressures ranging from 1 to 20 torr. Over this pressure range the abundances of the primary ions, determined through various diagnostic experiments, are within experimental error the same at 21.2 eV as at 16.7–16.8 eV [$(CH_4^+ \simeq CH_3^+ \simeq 0.5$, $CH_2^+ \leq 0.02)$, and are in good agreement with the primary mass spectra obtained in a photoionization mass spectrometer under collision free conditions ($P < 10^{-5}$ torr). The $C_2H_5^+$ which is formed by the reaction: $CH_3^+ + CH_4 \rightarrow C_2H_5^+ H_2$ loses a proton by an undetermined mechanism to give C_2H_4 as a product.

There is no evidence for the formation of neutral fragments such as H_2, C, CH or CH_2 at 16.7–16.8 eV. The fact that the ionization quantum is equal to unity in this energy range accounts for the absence of these intermediates. At 21.2 eV where ($\Phi_{ionization} = 0.95$) there is concrete evidence for the formation of carbon atoms ($\Phi(C) \geq 0.002$).

In an attempt to demonstrate the usefulness of enclosed neon and helium resonance light sources in the ion-molecule kinetic studies, the relative probabilities of transfer of H^- over D^- from various partially deuterium labeled hydrocarbons in $C_2H_5^+$ (or $C_2D_5^+$) has been determined.

The results presented in this article resolve the existing disagreements between previous helium resonance photolysis studies on CH_4.

Radiolysis of methane. Formation of acetylene, R. E. Rebbert and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 1, 109-114 (Jan.-Feb. 1973).

Key words: Acetylene formation; electron scavenger; ion

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

pair yields; methane; pulse radiolysis; vacuum ultraviolet photolysis.

The ^{60}Co-gamma radiolysis (at 200 to 2000 torr) and the pulse radiolysis (100 to 760 torr) of methane has been investigated with the specific purpose of elucidating the mode of formation of acetylene. The following two reactions account for the formation of acetylene in the pulse radiolysis:

$$C_2H_5^+ + e \rightarrow C_2H_2 + H_2 + H \qquad \text{I}$$

$$C(^1S \text{ or } ^1D) + CH_4 \rightarrow C_2H_2 + H_2. \qquad \text{II}$$

Addition of SF_6 as an electron scavenger eliminates reaction I as a source of acetylene, but increases the yield of ethylene through the occurrence of a reaction such as:

$$C_2H_5^+ + SF_6^- \rightarrow C_2H_4 + HF + SF_5.$$

In the low dose rate ^{60}Co-gamma radiolysis of $CH_4 - NO$ mixtures, reaction II is the only mode for formation of acetylene. The $C(^1S$ or $^1D)$ atoms which undergo reaction II are formed in the gamma radiolysis and pulse radiolysis, as well as in the 10 and 11.6 – 11.8 eV photolyses, through the dissociation process:

$$CH_4^* \rightarrow C + 2H_2.$$

In the gamma radiolysis, the $C_2H_5^+$ ion apparently is intercepted by accumulated products before undergoing homogeneous neutralization process 1. In the 16.7 – 16.8 and 21.2 eV photolyses, evidence is presented that the ions do not undergo homogeneous neutralization.

The enhancement of water vapor in carbon dioxide-free air at 30, 40, and 50 °C, R. W. Hyland and A. Wexler, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 1, 115-131 (Jan.-Feb. 1973).

Key words: Concentration of saturated water vapor in air; enhancement factor; moist air; moisture content of saturated air; saturated air; solubility of water vapor in air; water vapor.

The enhancement of water vapor in compressed atmospheric air was measured at 30, 40, and 50 °C over respective pressure ranges of 10 to 35 bars, 15 to 60 bars, and 10 to 100 bars. The data for each isotherm were fitted by the method of least squares to an empirical smoothing equation of the form $\ln f = a + bP$ where f is the enhancement factor, P is the total (absolute) pressure and a and b are constants. A detailed error analysis, necessary for the eventual use of the data in humidity standards work, shows that the calculated (predicted) values of f have an estimated limit of systematic bias of ± 0.07 percent and a maximum observed standard deviation of a predicted value of ± 0.2 percent.

The second interaction (cross) virial coefficient for moist air, R. W. Hyland and A. Wexler, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 1, 133-147 (Jan.-Feb. 1973).

Key words: Interaction virial coefficients; moist air; second virial coefficient; virial coefficients; water vapor.

The results of calculations of the second interaction (cross) virial coefficient B_{aw} for water vapor and air, based on enhancement data obtained at NBS at 30, 40, and 50 °C, are presented. Comparisons are made with the results of calculations based on the enhancement data of Politzer and Strebel, Webster, and Goff et al. and with the results of the theoretical calculations of Mason and Monchick and of Chaddock. An empirical equation is given for interpolation and extrapolation.

The random (one standard deviation) uncertainty in the mean values of B_{aw}, arising from the scatter of previously obtained NBS values of the enhancement factor is estimated to range from 0.7 percent at 30 °C to 1.4 percent at 50 °C. The estimated systematic uncertainties range from 4 percent at 30 °C to 6 percent at 50 °C, respectively.

Solubility and surface properties of finely divided hydroxyapatite, Y. Avnimelech, E. C. Moreno, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 1, 149-155 (Jan.-Feb. 1973).

Key words: Bone mineral; calcium phosphate; hydroxyapatite; solubility product; surface.

Synthetic hydroxyapatite (OHAp), $Ca_5(PO_4)_3OH$, was prepared by slow addition of phosphoric acid to a boiling $Ca(OH)_2$ suspension. The solid, precipitated at a pH of about 12, was stabilized by prolonged boiling. The Ca/P ratio of the product was 1.69 ± 0.04 and it had a specific surface area of 26 m^2/g.

Samples of OHAp were equilibrated with phosphoric acid solutions. Within the pH range studied, 5 to 7, the solubility product, $(Ca)^5(PO_4)^3(OH)$, was found to be $6.3 \pm 2.1 \times 10^{-59}$ at 25 °C.

Substantial deviations of the overall dissolution reaction from OHAp stoichiometry were observed and are attributed to non-stoichiometric reactions occurring at the surface. A linear dependence of excessive phosphorus on the surface with decrease in pH was found. Estimated on the extent of deviation from stoichiometry caused by the surface reaction are given.

Pyrolysis of anionic and thermally prepared polystyrenes, L. A. Wall, S. Straus, R. E. Florin, and L. J. Fetters, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 1, 157-170 (Jan.-Feb. 1973).

Key words: Anionic polystyrene; molecular weight distributions; molecular weights; thermal polystyrene; polymers; polystyrene degradation; pyrolysis; thermolysis.

The changes in molecular weights, their distributions, and initial rates have been measured, for a series of polystyrenes prepared by thermal and anionic procedures. The information obtained and previous results can be explained to a very large extent by a kinetic chain decomposition comprised of competing end and random initiation, depropagation, intra- and intermolecular transfer and termination by combination.

Modulus of natural rubber cross-linked by dicumyl peroxide. II. Comparison with theory, L. A. Wood, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 1, 171-177 (Jan.-Feb. 1973).

Key words: Cross-linking of rubber; dicumyl peroxide; elasticity theory of rubber; entropy component; gel point; modulus of rubber; rubber elasticity; statistical theory of rubber elasticity; thermodynamics of rubber elasticity.

Thermodynamics and molecular considerations are applied to an examination of the equation $G = S(fp + B)T + H(fp + B) + A = 5.925 \times 10^{-3}(fp - 0.45)T + 0.0684(fp - 0.45) + 2.70$, found experimentally in Part I. G is the shear modulus in Mdyn cm^{-2} at a temperature T for natural rubber cross-linked by adding p parts of dicumyl peroxide per hundred of rubber (phr) and heating until a fraction f of the peroxide is decomposed. G^*, the energy component of the modulus, is $H(fp + B) + A$. The ratio G^*/G decreases from 1.00 at the gel point ($fp = 0.45$ phr) to 0.5 near 2 phr and to 0.09 at 23.8 phr. The modulus G is related to ν_e, the number of moles of effective sub-chains per cm^3, by the equation $G - G^* = \nu_e RT$ where R is the gas constant. If each molecule of decomposed dicumyl peroxide of molecular weight M_d produces one cross-link in the rubber of specific volume $\bar{v}_r$, then

it is predicted that $S = 2R(100M_d\bar{v}_r)^{-1} = 5.5535 \times 10^{-3}$ Mdyn cm^{-2} phr^{-1} K^{-1}, as compared with the experimental value 5.925×10^{-3}. Theory gives no prediction of the values of A, or of H. The gel point may be located experimentally as the point where the slope of the modulus-temperature relation is zero. The value of G at the gel point is the energy component G^*. The experimental value of fp at the gel point permits a calculation of the molecular weight of the rubber before cross-linking as 193,000. The results afford a very satisfactory confirmation of the essential validity of the statistical theory of rubber elasticity in its simplest form, if due regard is paid to G^*, the energy component of the modulus.

March-April 1973

An adiabatic solution calorimeter and measurements of a standard reaction for solution calorimetry, E. J. Prosen and M. V. Kilday, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 2, 179-203 (Mar.-Apr. 1973).

Key words: Adiabatic solution calorimeter; enthalpy of reaction of H_2SO_4 in aqueous NaOH; H_2SO_4, enthalpy of reaction in NaOH(aq); heat of reaction of H_2SO_4 in aqueous NaOH; heat of solution of H_2SO_4 in aqueous NaOH; solution calorimetry; thermochemistry.

This paper discusses in detail the design, construction, and performance of the vacuum jacketed, adiabatic solution calorimeter which was used for the work in the certification of two NBS Standard Reference Materials for solution calorimetry. As a test for the calorimetric precision the following enthalpies of reaction were measured (referred to the mass or moles of $H_2SO_4 \cdot 8H_2O$):

$$H_2SO_4 \cdot 8H_2O + 2.36\,(NaOH \cdot 2620\,H_2O) = (Na_2SO_4 \cdot 0.36\,NaOH \cdot 6193\,H_2O)_{soln}$$

$$\Delta H_r(298.15\text{ K}) = -590.692 \pm 0.101\ J \cdot g^{-1}$$

$$= -34{,}194 \pm 5.9\ \text{cal} \cdot \text{mol}^{-1}$$

$$H_2SO_4 \cdot 8H_2O + 2.6\,(NaOH \cdot 714\,H_2O) = (Na_2SO_4 \cdot 0.6\,NaOH \cdot 1866\,H_2O)_{soln}$$

$$\Delta H_r(298.15\text{ K}) = -590.828 \pm 0.193\ J \cdot g^{-1}$$

$$= -34{,}203.4 \pm 11.1\ \text{cal} \cdot \text{mol}^{-1}$$

The enthalpy of solution of low quartz (α-quartz) in aqueous hydrofluoric acid, M. V. Kilday and E. J. Prosen, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 2, 205-215 (Mar.-Apr. 1973).

Key words: Enthalpy of soln, SiO_2; heat of soln, SiO_2(c); quartz, soln in HF(aq); reference material, soln calorimetry; SiO_2(c), soln in HF(aq); thermochemistry.

An adiabatic solution calorimeter was used to measure the enthalpy of solution of the NBS Standard Reference Material No. 1654 (α-quartz or low quartz) for use as a reference standard for HF solution calorimetry. The enthalpy of solution of this material at a concentration of 5 grams in 1000 cm^3 of 24.4 weight percent HF(aq) is

$$-\Delta H_{soln}(353.15\text{ K}) = 2362.2 \pm 1.1\ J \cdot g^{-1}.$$

This value also applies to the enthalpy of solution of pure low quartz within the uncertainty limits given. The enthalpy of solution of quartz (in $J \cdot g^{-1}$) as a function of the temperature, T, of reaction in 24.4 weight percent HF in the range 298 to 358 K, is

$$-\Delta H_{soln}(T) = 2275.0 + 1.586\,(T - 298.15).$$

Thus, the average ΔCp for the reaction over the range, 298 to 358 K, is $-1.586 \pm 0.025\ J \cdot g^{-1} \cdot K^{-1}$. As a function of the concentration of HF solution in the range, 18 to 30 weight percent.

$$-\Delta H_{soln}(353.15\text{ K}) = 2362.10 + 1.429\,(\text{wt\%HF} - 24.40) + 0.069\,(\text{wt\%HF} - 24.40)^2.$$

From measurements of the enthalpies of solution of several samples of quartz and fused silica, the enthalpy difference between low quartz and silica glass at 298.15 K was determined to be $162.2 \pm 4.9\ J \cdot g^{-1}$ (2.330 ± 0.070 kcal $\cdot$ mol^{-1}).

Enthalpies of solution of BeO(c) in HF(aq) and in HCl(aq), M. V. Kilday, E. J. Prosen, and D. D. Wagman, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 2, 217-225 (Mar.-Apr. 1973).

Key words: BeO(c), enthalpy of soln in HF(aq); BeO(c), enthalpy of soln in HCl(aq); BeO(c), enthalpy of reaction in HF(aq); beryllium oxide; enthalpy of solution; heat of solution; thermochemistry.

An adiabatic solution calorimeter was used to measure the enthalpies of the following reactions:

$$BeO(c) + [96\ HF + 338\ H_2O]\ (l) \rightarrow [BeF_2 + 94\ HF + 339\ H_2O](l)$$

$$\Delta H \text{ at } 298.15\text{ K} = -101.30 \pm 0.20\ \text{kJ} \cdot \text{mol}^{-1}$$

$$BeO(c) + [48\ HCl + 333\ H_2O]\ (l) \rightarrow [BeCl_2 + 46\ HCl + 334\ H_2O](l)$$

$$\Delta H \text{ at } 352.58\text{ K} = -54.19 \pm 0.22\ \text{kJ} \cdot \text{mol}^{-1}$$

$$\Delta H \text{ at } 298.15\text{ K} = -53.0 \pm 2.0\ \text{kJ} \cdot \text{mol}^{-1}$$

ΔCp is $12.5 \pm 2.8\ J \cdot \text{mol}^{-1} \cdot K^{-1}$ for the first reaction in the range 298 to 325 K.

The enthalpies of formation of BeO(c) and BeF_2(c), V. B. Parker, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 2, 227-235 (Mar.-Apr. 1973).

Key words: BeF_2(c); BeO(c); beryllium fluoride; beryllium oxide; enthalpies of formation; $\Delta H f°_{298.15K}$ [BeF_2(c)]; $\Delta H f°_{298.15K}$ [BeO(c)]; thermochemistry.

Two of the key compounds in the evaluation and synthesis of a consistent set of thermodynamic values for the Be compounds are BeO(c) and BeF_2(c). The available measurements on the enthalpies of formation of these two compounds are presented with a detailed outline of the approach used to select the "best" values. $\Delta H f°_{298.15K}$ [BeO(c)] $= -145.7 \pm 0.6$ kcal $\cdot$ mol^{-1} (-609.6 ± 2.5 kJ $\cdot$ mol^{-1}) and $\Delta H f°_{298.15K}$ [BeF_2(c, quartz)] $= -245.4 \pm 0.8$ kcal $\cdot$ mol^{+1} (-1026.8 ± 3.3 kJ $\cdot$ mol^{-1}).

Vapor pressure and heat of sublimation of tungsten, E. R. Plante and A. B. Sessoms, *J. Res. Nat. Bur. Stand. (U.S.),* **77A** (Phys. and Chem.), No. 2, 237-242 (Mar.-Apr. 1973).

Key words: Heat of sublimation; Langmuir vaporization; rate of vaporization; tungsten; vapor pressure.

The vapor pressure of tungsten was measured by the Langmuir method in the temperature range 2600 to 3100 K using a vacuum microbalance. Four series of data gave concordant results and three of the four series gave second and third law heats of sublimation in excellent agreement. A vapor pressure equation representing the data is $\log P(\text{atm}) = -45385/T + 7.871$, based on our mean third law heat and tabulated entropies at 2800 K. The mean third law heat of sublimation at 298.15 K is 205.52 ± 1.1 kcal mol^{-1} (859.90 ± 4.6 kJ mol^{-1}) where the uncertainty is an overall estimated error. Rates of vaporization are about 1/2 those previously accepted for tungsten.

Gas phase far ultraviolet photolysis and radiolysis of vinyl

chloride, P. Ausloos, R. E. Rebbert, and M. H. J. Wijnen, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 2, 243-248 (Mar.-Apr. 1973).

Key words: Gas phase; photolysis; quantum yield; radiolysis; vinyl chloride; vinyl radical.

Quantum yields of the major products formed in the far ultraviolet photolysis of CH_2CDCl (C_2H_2, C_2HD, C_2H_3D, $C_2H_2D_2$, and 1,3-$C_4H_4D_2$) have been determined at 147 nm (8.4 eV), 123.6 nm (10.0 eV), and 104.8-106.7 nm (11.6-11.8 eV). The quantum yield of the stable vinyl radicals which can be unambiguously ascribed to the primary process ($CH_2CDCl + h\nu \rightarrow CH_2CD + Cl$) is 0.3 and 0.05 at 147 and 123.6 nm, respectively. The sharp decrease in the yield of vinyl radicals with the increase in energy of the incident photon beam is in part attributed to the decomposition of internally excited vinyl radicals to give acetylene as a product. At 147 nm, the combined yield of acetylene plus vinyl radicals is 0.95 ± 0.05. At the shorter wavelengths, approximately one acetylene molecule is formed per electronically excited vinyl chloride molecule. It is concluded that the dissociative process: $C_2H_3Cl^* \rightarrow C_2H_2 + H + Cl$, occurring via a C_2H_3 or C_2H_2Cl intermediate adequately accounts for the reactive neutral species formed at higher photon energies. Isotopic labeling experiments show that the hydrogen atoms are detached from both positions of the parent molecule. Ethylene which is a product over the entire wavelength range is in part formed via the reaction: $H^* + C_2H_3Cl \rightarrow C_2H_4 + Cl$, where H^* represents a translationally excited hydrogen atom. The $C_2H_2DCl^+$ ions formed at 104.8-106.7 nm with a quantum yield of 0.47 do not contribute to the formation of acetylene or vinyl radicals. In the gas phase radiolysis of vinyl chloride, acetylene ($G \sim 1.5$) is mainly formed in the dissociation of neutral electronically excited vinyl chloride molecules. From this value, we may estimate that the ratio of neutral excited molecules formation to ionization in the radiolysis of vinyl chloride is 0.39. Vinyl ions, which are also produced ($G \sim 0.28$-0.35) react mainly by addition to vinyl chloride.

Pulse radiolysis of methane, R. E. Rebbert, S. G. Lias, and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 2, 249-257 (Mar.-Apr. 1973).

Key words: Electron scavengers; gas phase; ion-molecule reactions; methane; neutralization; pulse radiolysis.

The pulse radiolysis of methane has been studied in the absence and presence of electron scavengers such as SF_6 and CD_3I and positive ion scavengers such as i-C_4D_{10} in order to define the role of the intermediates H, C, CH, CH_2, CH_3,CH_5^+, and $C_2H_5^+$ in product formation. The dose rate was varied from 0.68 to 15.2×10^{19} eV/g-s, the dose (number of pulses) was varied, and the duration of the pulse was changed from 3 ns to 100 ns. The variation of the yields of the ethylene and ethane products with dose is explained by the reaction of H-atoms with accumulated ethylene product. The fast reacting C, CH, and $^1CH_2$ species insert into methane to form acetylene, ethylene, and ethane products, but all of the reactions of these species cannot be completely specified since they may originate in upper electronic states, whose reactions with methane are unknown. Product formation by the slow reacting $^3CH_2$ and CH_3 radicals is also examined; for instance, evidence is presented for the occurrence of the reaction: $^3CH_2 + CH_3 \rightarrow C_2H_4 + H$. Results indicate that the ions CH_5^+ and $C_2H_5^+$ undergo neutralization mainly through the processes

$$CH_5^+ + e \rightarrow CH_4 + H$$

$$C_2H_5^+ + e \rightarrow (C_2H_4)^* + H \rightarrow C_2H_2 + H + H_2(2H).$$

When i-C_4D_{10} is added, a fraction of the CH_5^+ and $C_2H_5^+$ react with the additive rather than undergo neutralization. A calculation demonstrates that the fraction of ions undergoing reaction with a given concentration of i-C_4D_{10} can be correctly predicted by assuming that the rate constant for neutralization of CH_5^+ and $C_2H_2^+$ is the same as that determined recently for the t-butyl ion.

Relation of vitron theory to 2-layer-liquid immiscibility in binary silicate and borate glass melts, L. W. Tilton, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 2, 259-272 (Mar.-Apr. 1973).

Key words: Binary borates; binary silicates; boron glass; glass; homogenization of glass melts; immiscible glass melts; immiscibility gaps; silica glass; structure of glass; vitron theory.

Silica-rich and boron-rich binary glasses resemble clathrates in having host cavities in which modifier oxides may be inclosed without stress as inactive guests until the cavities are approximately filled. Additional modification results in stress both in the holes of the matrix and the cavities of vitrons. Then the structure begins to disintegrate and mixing takes place. The required mole-percent modification is expressed by an equation of the form

$$100_{r_h} = \frac{100(A-\alpha)\cdot q/5}{(L-\delta-\alpha)+(A-\alpha)\cdot q/5}$$

where A and α are the diameters of vitron cavity and matrix hole, respectively, L is the linear extent of a modifier, and q the proportion of glass-maker that forms vitrons. Computations for 66 glasses have been made to constitute a unified system covering approximately the gamut of typical modifiers.

The identity of parameters A and α for silicates and borates leads to the suggestion that the vitron structure in boric-oxide glass is the regular icosahedron of 20 triangular faces to accommodate a neutral molecule of $(B_4O_6)_5$. Regular octahedra of $(B_4O_6)_2$, if present in the matrix, would provide matrix holes of approximately α in diameter.

May-June 1973

The International Practical Temperature Scale of 1968 in the region 13.81 K to 90.188 K as maintained at the National Bureau of Standards, G. T. Furukawa, J. L. Riddle, and W. R. Bigge, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 309-332 (May-June 1973).

Key words: International Practical Temperature Scale; NBS-IPTS-68; NBS-1955 provisional scale; platinum resistance thermometer.

The reproducibility of the International Practical Temperature Scale of 1968 (IPTS-68) in the region of 13.81 K to 90.188 K using standard platinum resistance thermometers is discussed. The effect of errors above 0 °C on the calibration between 13 and 90 K is analyzed. Calibrations resulting from least squares and "fixed point" treatment of the data are compared. The results show that in general the NBS-IPTS-68 temperature scale maintained at the National Bureau of Standards (NBS) by reference standard platinum resistance thermometers is transferred to thermometers calibrated at the NBS within a few tenths of a mK between about 20 and 90.188 K and within about ± 1 mK between 13.81 and 20 K. Agreements within a few mK are shown between the observed values of temperatures, employing platinum resistance thermometers calibrated in terms of the NBS-IPTS-68 scale, and the values of temperatures of the fixed points in the region 13.81 to 90.188 K given in the text of the IPTS-68.

Radiance temperature of niobium at its melting point, A. Cezair-

liyan, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 333-339 (May-June 1973).

Key words: High-speed measurements; high temperature; melting; niobium; radiance temperature; surface roughness.

A subsecond duration pulse heating method is used to investigate variations in the radiance temperature (at 650 nm) of niobium near and at its melting point. Measurements were made on several specimens with different surface conditions. The results do not indicate any dependence of radiance temperature (at the melting point) on initial surface conditions. The average radiance temperature (at 650 nm) at the melting point for twelve different niobium specimens is 2425 K on the International Practical Temperature Scale of 1968, with an average absolute deviation of 0.6 K and a maximum deviation of 1.2 K.

An experimental search for gaseous reactivity between AlF_3 and HF near 1200 K, T. B. Douglas and R. F. Krause, Jr., *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 341-342 (May-June 1973).

Key words: Aluminum fluoride; aluminum hydrofluorides; equilibrium constant; hydrogen fluoride; stability limits; transpiration measurements.

Using an accurate transpiration method, AlF_3 was sublimed near 1200 K into argon containing 0, 0.02, and 0.76 atm of HF, but no reaction between AlF_3 and the HF was detected within the precision (about 1%). Two alternative structures of $HAlF_4$ are postulated. An upper bound for extent of reaction corresponds to $\Delta H°_{298} > -33$ kcal (-138 kJ) for AlF_3 (g) + HF (g) = $HAlF_4$ (g); this indicates a far lower stability of $HAlF_4$ (g) than that of $LiAlF_4$ (g) or $NaAlF_4$ (g) when formed similarly.

A numerical solution of the integral equation describing a photometric integrating sphere, R. L. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 343-351 (May-June 1973).

Key words: Integrating sphere; photometry.

A photometric integrating sphere containing a single disk-shaped baffle and a point source with an arbitrary angular intensity distribution is described by an integral equation. Numerical solutions of this equation are presented for several different source distributions. The errors involved in comparing the various sources are evaluated as a function of baffle size and position.

Crystallization of random copolymers, I. C. Sanchez and R. K. Eby, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 353-358 (May-June 1973).

Key words: Copolymers; crystallization; growth rate; lamella thickness; melting temperature.

A theory of crystallization is formulated for random copolymers which crystallize with the noncrystallizable co-units incorporated into the crystalline lattice as defects. The appropriate melting point equation and other associated thermodynamic properties are derived for this model as a function of crystal thickness and comonomer concentration. The formation of lamellar type morphology is assumed to be a kinetically determined phenomena and nucleation theory is utilized accordingly. The isothermal lamella thickness is predicted to increase in a definitive manner as the noncrystallizable comonomer concentration X increases, while the associated isothermal growth rate is predicted to decrease. The variation of lamella thickness with X when the copolymer is quenched or cooled at a uniform rate is also qualitatively predicted. Under these conditions lamella thickness decreases with increasing X, which is in accord with previous experimental observations on random copolymers of tetrafluorethylene and hexafluoropropylene as well as other random copolymers. Theory also suggests how the surface free energy parameters σ_e and σ can be determined from isothermal crystallization experiments for a series of random copolymers of varying composition.

Theory of disclinations: III. Continuous and discrete disclinations in isotropic elasticity, R. deWit, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 359-368 (May-June 1973).

Key words: Burgers vector; continuum mechanics; defect; disclination; dislocation; distortion; Green's tensor; incompatibility; plasticity; strain.

A general theory of stationary disclinations is developed for a linearly elastic, infinitely extended, homogeneous, isotropic body. It is shown to be a special case of the anisotropic theory. Integral expressions are derived for the total displacement, elastic strain and bend-twist, and stress. Both continuous distributions and discrete lines are treated.

Compressive fatigue coaxing in composites, C. A. Berg and M. Salama, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 3, 369-373 (May-June 1973).

Key words: Coaxing; composites; compressive fatigue; fatigue.

Compressive fatigue experiments on unidirectional fiber reinforced composites, of both fiberglass and graphite fiber, reveal that compressive fatigue damage takes place by crack extension directly transverse to the fibers. It is also found that specimens which are first subjected to a few hundred thousand cycles of compressive fatigue at low stress levels, and then subjected to compressive fatigue at high stress levels, will survive longer at high stress levels than specimens which are placed under high compressive fatigue stresses from the outset. The increase of fatigue life at high compressive stress levels can be quite large; increases of fatigue life by as much as a factor of five were observed. The phenomenon of prolonging fatigue life at high stress levels by first "running in" a specimen at low stress levels is called coaxing, and is directly opposite to the often reported cumulative damage phenomena observed in tensile fatigue of composites. A possible mechanism for coaxing in compressive fatigue of composites is offered, and practical applications of the effect are suggested.

July-August 1973

The thermodynamic kelvin temperature scale from 273.15 K to 415 K, L. A. Guildner and R. E. Edsinger, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 383-389 (July-Aug. 1973).

Key words: Gas thermometry; International Practical Temperature Scale of 1968; sorption; steam point; temperature standards; Thermodynamic Kelvin Temperature Scale.

The investigation of the effects of sorption in a gas thermometer used to realize the Thermodynamic Kelvin Temperature Scale has been continued. By eliminating sorbable material more completely from the gas thermometer, we attained higher gas purity. So little contaminant remained that further cleanup produced no significant effect on the values of thermodynamic temperatures measured between 0 °C and 142 °C. The results are presented by giving the differences between the values on the thermodynamic scale and the International Practical Temperature Scale of 1968. The value of the steam point was determined to be 99.970 °C(therm) with an uncertainty of ± 3.5 mK at the 99 percent confidence level (based on 3 times the estimate of the standard deviation).

An alumina standard reference material for resonance frequency and dynamic elastic moduli measurement. II. Characteristic values for use from 25 °C to 1000 °C, R. W. Dickson and E. Schreiber, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 391-394 (July-Aug. 1973).

Key words: Alumina; elastic modulus; resonance frequency; shear modulus; standard reference material; Young's modulus.

The temperature dependence of Young's modulus and the shear modulus of polycrystalline alumina is given over the range of 25 to 1000 °C. Results are expressed in terms of the dimensionless ratio: modulus value at temperature divided by modulus value at 25 °C. The results are intended for use with Standard Reference Material No. 718 which is intended for calibration of apparatus used to determine elastic moduli of solids by a resonance technique. The worst agreement is 9.5×10^{-4} for the flexure and 19.1×10^{-4} for the torsion, between any two individual measurements, and we recommend these as the minimum acceptable limits in using the standards.

Heat capacities of polyethylene from 2 to 360 K. I. Standard samples of linear and branched polyethylene whole polymer, S. S. Chang and A. B. Bestul, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 395-405 (July-Aug. 1973).

Key words: Branched polyethylene; calorimetry; glass transition; heat capacity; linear polyethylene; polyethylene; thermal analysis; thermodynamic properties.

Heat capacities of two well characterized polyethylene samples have been measured from 2 to 360 K in a precision vacuum adiabatic calorimeter. The two samples are derived from the same stocks from which NBS standard reference materials (SRM) 1475 and 1476 for linear and branched polyethylene whole polymers, respectively, were established. Both samples have been studied in the conditions as received. The branched polyethylene sample has also been studied following various thermal treatments in the calorimeter. The effect of thermal history on the behavior of branched polyethylene has also been studied by differential scanning calorimetry.

The quasi-harmonic approximation and a generalized Grüneisen equation of state, F. I. Mopsik, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 406-409 (July-Aug. 1973).

Key words: Crystal equation of state; frequency distribution; Grüneisen constant; Grüneisen equation of state; quasi-harmonic approximation; thermal expansion.

The validity of the Grüneisen equation of state for a solid having a continuous distribution of frequencies is investigated. It is shown that one cannot generally replace $\partial S/\partial V$ with the heat capacity multiplied by appropriate Grüneisen constants. A model frequency distribution is used to show the difference that can arise.

Valence resonance states of N_2^-, M. Krauss and D. Neumann, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 411-412 (July-Aug. 1973).

Key words: Electron scattering resonance; excited states N_2; excited states N^-; inelastic scatter; N_2^-; valence excited states.

Resonance valence excited states of N_2^- are calculated and used to interpret resonant excitation of the A and B states of N_2 by electron impact.

Internal electric fields near isolated defects in ionic crystals, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 413-417 (July-Aug. 1973).

Key words: Electric fields; *F* centers; Gaussian function; Holtsmark function; isolated defects.

Integral representations for three distributions of internal electric fields near isolated defects in ionic crystals are given. These three distributions are the Gaussian distribution for electric fields associated with phonons, and two Holtsmark type distributions for electric fields associated with charged impurities when the Jahn-Teller effect is small and when it is large. Numerical values for the distributions and for the averages of squared-dipole matrix elements over them are tabulated in the conclusion.

Wavelengths and energy levels of the second spectrum of cerium (Ce II), C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 4, 419-546 (July-Aug. 1973).

Key words: Cerium; Ce II; energy levels; spectrum; wavelengths.

The second spectrum of cerium (Ce II) has been compiled in the wavelength region between 2500 Å and 24 000 Å. Of the 11 000 lines in the list, about 7500 are now classified as transitions between 192 odd levels and 288 even levels. The odd levels arise from 5 configurations ($4f5d^2$, $4f5d6s$, $4f6s^2$, $4f^26p$, and $4f^3$) and the even levels from 7 configurations ($4f^26s$, $4f^25d$, $4f5d6p$, $4f6s6p$, $5d^3$, $5d^26s$, and $5d6s^2$). The known levels extend up to only 52 000 cm^{-1} although the ionization potential is known to be 35 000 cm^{-1} higher.

September-October 1973

Enthalpies of precipitation of silver halides; entropy of the aqueous silver ion, D. D. Wagman and M. V. Kilday, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 569-579 (Sept.-Oct. 1973).

Key words: AgBr; AgCl; AgI; $AgNO_3$; enthalpy of dilution; enthalpy of precipitation; enthalpy of solution; entropy; heat of reaction; KBr; KCl; solution calorimetry; thermochemistry.

The enthalpies of precipitation of silver halides and the enthalpies of solution of $AgNO_3$, KCl, and KBr in H_2O were measured in an adiabatic solution calorimeter.

From the enthalpy measurements of KCl(c) and KBr(c) in $AgNO_3$(aq), and of $AgNO_3$(c) in KCl(aq), in KBr(aq), and in KI(aq), we calculated (in kJ · mol^{-1}) − 65,724, − 84,826, and − 111,124 for $\Delta H°$pptn(298.15 K) for the averages of the chloride, bromide, and iodide reactions, respectively.

A reevaluation of the data for the enthalpy of solution of $AgNO_3$(c) has resulted in our selected best value,

$$\Delta H°(\infty)(298.15\ \text{K}) = 22.730 + 0.084\ \text{kJ} \cdot \text{mol}^{-1}$$

$$= 5.433 \pm 0.020\ \text{kcal} \cdot \text{mol}^{-1}$$

A table of enthalpies of dilution of $AgNO_3$(aq) is also given.

The average standard entropy for the aqueous silver ion at 298.15 K is found to be

$$S°[Ag^+(aq)] = 73.42 \pm 0.20\ \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$$

$$= 17.55 \pm 0.05\ \text{cal} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}.$$

Enthalpies of reaction of tris(hydroxymethyl)aminomethane in HCl(aq) and in NaOH(aq), E. J. Prosen and M. V. Kilday, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 581-597 (Sept.-Oct. 1973).

Key words: Enthalpy of reaction; heat of solution; solution

Key words: calorimetry; standard reference material; THAM; TRIS; tris(hydroxymethyl)aminomethane; thermochemistry.

The enthalpy of reaction of tris(hydroxymethyl)-aminomethane, NBS Standard Reference Material 724a, measured in an adiabatic solution calorimeter at 298.15 K in 0.1 *N* HCl solution is -245.76 ± 0.26 J · g^{-1}, and in 0.0500 *N* NaOH solution is 141.80 ± 0.19 J · g^{-1}. The conditions applicable and the factors included in the overall uncertainties are discussed in detail. For the reaction in 0.1 *N* HCl in the range, 293 to 303 K, $\Delta Cp = 1.435 \pm 0.023$ J · g^{-1} · K^{-1}, and in 0.0500 *N* NaOH in the range, 295 to 303 K, $\Delta Cp = 1.025 \pm 0.025$ J · g^{-1} · K^{-1}.

Possible sources of error in measurements of the reactions are discussed. A summary of other enthalpy measurements of the reaction in 0.1 *N* HCl is given.

The enthalpy of reaction of tris(hydroxymethyl)aminomethane with hydrochloric acid, A. P. Brunetti, E. J. Prosen, and R. N. Goldberg, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 599-606 (Sept.-Oct. 1973).

Key words: Enthalpy of reaction; solution calorimetry; standard reference material; tris(hydroxymethyl)-aminomethane; thermochemistry.

The enthalpy of reaction of tris(hydroxymethyl)aminomethane with 0.1 *N* HCl has been measured using an isoperibol solution calorimeter, employing a modified quartz thermometer and an automatic digital data acquisition system. The enthalpy value obtained at 298.15 K is 245.93 ± 0.26 J · g^{-1}. Particular attention was given to possible sources of systematic error in the electrical calibrations.

Theory of disclinations: IV. Straight disclinations, R. deWit, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 607-658 (Sept.-Oct. 1973).

Key words: Burgers vector; continuum mechanics; defect; dipole; disclination; dislocation; distortion; Green's tensor; incompatibility; loop; plasticity; strain; Volterra.

The general theory of disclinations developed earlier is applied to the special case of a straight disclination line. First the geometrical fields are found, such as the defect loop densities which correspond to Mura's new concepts of "plastic distortion" and "plastic rotation," the basic plastic fields (strain and bend-twist), the defect densities (dislocation and disclination), the characteristic vectors (Burgers and Frank), and the incompatibility. Then the static fields are found for the isotropic case, such as the displacement, total distortion, basic elastic fields, and the stress. It is shown that the disclination axis is moved by adding a dislocation to the disclination line. All these special results for the straight disclination line are shown to satisfy the general equations of the theory. As corollaries the following topics are also treated:

1. The finite and infinitesimal straight disclination dipole, which can be biaxial or uniaxial. It resembles the straight dislocation line.

2. The dislocation models of the straight disclination line and of the finite disclination dipole. They are terminating dislocation walls (tilt and twist).

3. The compensated disclination line and the bent dislocation wall.

4. Finally we show analytically a special case of a dislocation ending on a disclination.

Optical properties of *U* centers in alkali halides and alkaline earth fluorides, H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 659-665 (Sept.-Oct. 1973).

Key words: BaF_2; CaF_2; ionic polarization; KCl; Mollwo-Ivey relations; NaCl; point-ion potential; SrF_2; *U* centers.

The two-electron orbitals for the *U* center have been computed numerically from the Hartree-Fock-Slater (HFS) equations in the point-ion lattice potential. The lattice relaxation of the nearest-neighbor ions is included in the model. The five lowest-lying *U*-center states for NaCl, KCl, CdF_2, CaF_2, SrF_2, and BaF_2 are given. The low-lying singlet states have the following order for increasing values of the energy; $^1S(1s,1s)$, $^1P(1s,2p)$, and $^1S(1s,2p)$. The energy levels for the triplet states $^3S(1s,2s)$, and $^3P(1s,2p)$ lie between the energy levels for the $^1S(1s,1s)$ and $^1P(1s,2p)$ states. The ordering of the triplet states depends upon the host crystal and the lattice relaxation. The predictions based upon the numerical HFS wave functions are compared with the predictions based upon past variational wave functions and with experiment.

Air flow rate as a test for gage block wringing, L. A. Guildner, R. L. Anderson, and R. E. Edsinger, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 667-670 (Sept.-Oct. 1973).

Key words: End length standards; gage blocks; joining; wringing; wring test.

Gage blocks can be joined by "wringing" to produce a vacuum-tight joint. Hoke gage blocks have square gaging surfaces with a central hole connecting them. The quality of the joints between blocks can be tested by measuring the vacuum leak rates through the joints into the central hole. When two Hoke blocks are in contact at one edge but tilted at an angle ϕ, the vacuum leak rate into a chamber of 22 cm^3 produces a rate of pressure increase which can be represented by the following polynomial:

$$dp/dt = 0.42\,\phi^2 + 0.022\,\phi^3 \ \mu\text{m Hg/min},$$

where ϕ is in μrad. Hoke blocks in suitable condition to be joined by wringing can also be joined by alining them and evacuating the joint through the center hole.

Low frost-point humidity generator, L. Greenspan, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 5, 671-677 (Sept.-Oct. 1973).

Key words: Calibration; frost-point; generator; humidity; water vapor.

A low frost-point humidity generator has been developed at NBS to provide a capability for calibration, testing and research at very low levels of water vapor content in such gases as atmospheric air, carbon dioxide and nitrogen. The generator produces frost points from − 30 to − 100 °C at ambient pressures from 500 to 200,000 pascals (0.005 to 2 atm.). This is equivalent to mixing ratios of 4×10^{-6} to 51 grams of water vapor per kilogram of dry air and to vapor pressures of 1.4×10^{-3} to 38 pascals. The generated test gas can be fed to a test chamber with independent temperature control between + 25 and − 100 °C. The uncertainty of the frost point in the test chamber is estimated not to exceed 0.05 deg C. Intercomparisons with a frost-point hygrometer as well as two gravimetric checks gave results which in all cases agreed to within 0.2 deg C in frost-point temperature.

November-December 1973

Absolute isotopic abundance ratio and atomic weight of a reference sample of rhenium, J. W. Gramlich, T. J. Murphy, E. L. Garner, and W. R. Shields, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 691-698 (Nov.-Dec. 1973).

Key words: Absolute ratio; atomic weight; isotopic abundance; rhenium.

An absolute value has been obtained for the isotopic abundance ratio of a reference sample of rhenium, using surface emission mass spectrometry. Samples of known isotopic composition, prepared from nearly isotopically pure separated rhenium isotopes, were used to calibrate the mass spectrometers. The resulting absolute $^{185}Re/^{187}Re$ ratio is 0.59738 ± 0.00039, which yields atom percents of $^{185}Re = 37.398 \pm 0.016$ and $^{187}Re = 62.602 \pm 0.016$. The atomic weight calculated from this isotopic composition is 186.20679 ± 0.00031. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for the effects of known sources of possible systematic error.

Reflection correction for high-accuracy transmittance measurements on filter glasses, K. D. Mielenz and R. Mavrodineanu, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 699-703 (Nov.-Dec. 1973).

Key words: Correction for reflections; reflections, multiple; spectrophotometry, high accuracy; systematic bias in spectrophotometry; transmittance, correction.

Multiple reflections in the sample compartment of a spectrophotometer constitute a source of systematic bias in transmittance measurements on filter glasses. This bias may be removed by applying a numerical correction obtained from measurements on tilted samples in polarized light. For a high-accuracy spectrophotometer, this correction was found to be of the order of several 10^{-4} transmittance units, independent of polarization, but slightly wavelength-dependent.

Temperature-pressure phase relationships in niobium pentoxide, J. L. Waring, R. S. Roth, and H. S. Parker, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 705-711 (Nov.-Dec. 1973).

Key words: Niobium pentoxide; phase relationships; pressure; temperature.

A pressure-temperature (P-T) section of the phase equilibrium diagram for Nb_2O_5 has been determined. Four single phase regions, H-Nb_2O_5, B-Nb_2O_5, and two L-Nb_2O_5 areas, were characterized by x-ray powder diffraction data. The superstructure of L-Nb_2O_5 was indexed on the basis of similarities to the known superstructures of L-Ta_2O_5 and confirmed with single crystal electron diffraction data. The correct unit cell is orthorhombic with $a = 6.168$, $b = 29.312$, $c = 3.938$ Å, with the b axis 8 times the subcell (8×3.664 Å).

Nuclear magnetic resonance of ^{113}Cd and ^{199}Hg in Cd-Mg and Cd-Hg solid solutions, V. V. Zhukov, I. D. Weisman, and L. H. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 713-723 (Nov.-Dec. 1973).

Key words: Anisotropic; Cd; Cd-Hg; internal Mg oxidation; isotropic; Knight shift.

The current theoretical and experimental situation with respect to Knight shifts and bulk susceptibility of Cd in pure Cd and in Cd-Mg and Cd-Hg alloys is reviewed. New experimental isotropic and anisotropic Knight shift data on ^{113}Cd in Cd-Mg and Cd-Hg alloys and on ^{199}Hg in Cd-Hg alloys are presented. The behavior of the ^{199}Hg sites is found to be remarkably similar to that of the ^{113}Cd site in the Cd-Hg alloys. However the ratio of isotropic Knight shift of ^{199}Hg to ^{113}Cd is somewhat greater than the ratio of ^{199}Hg to ^{113}Cd atomic hyperfine fields suggesting that there is more local electronic "s" character at the Fermi surface in the alloy than in the pure metals. This is consistent with the theoretical picture of Cd in which phonon scattering induced by increasing temperature or alloying smears and weakens the lattice potential which in turn leads to a more "s" like Fermi surface.

Further, the ^{113}Cd Knight shift is found to be a useful tool for monitoring the phase segregation that occurs in Cd-Mg due to internal oxidation and for determining the concentrations of solutes such as Hg and Mg in Cd-Hg and Cd-Mg alloys.

The pair correlation function in liquid ^4He, R. D. Mountain and H. J. Raveché, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 725-731 (Nov.–Dec. 1973).

Key words: Ground state wave function; liquid ^4He; neutron diffraction data; pair correlation function; short range behavior; structure factor; superfluid transition.

The pair correlation function obtained from the neutron diffraction data of Mozer, De Graaf, and Le Neindre, is given for liquid ^4He at several thermodynamic states above and below the superfluid transition. A method for smoothly and accurately extrapolating the pair function into the limit of zero internuclear separation is considered. The pair function is computed from an approximation integral equation for the ground state wave function and compared to the experimental results.

Molecular basis of flame inhibition, J. W. Hastie, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 733-754 (Nov.-Dec. 1973).

Key words: Fire retardants; flame inhibition; flames.

The role played by inorganic chemical additives in fire retardancy and flame inhibition is considered. Particular attention is given to the molecular level aspects of commercially important systems containing compounds of antimony, halogens, and phosphorus. The flame inhibiting function of metal containing additives is also discussed.

The effect of temperature and pressure on the refractive index of some oxide glasses, R. M. Waxler and G. W. Cleek, *J. Res. Nat. Bur. Stand. (U.S.)*, **77A** (Phys. and Chem.), No. 6, 755-763 (Nov.-Dec. 1973).

Key words: Interferometry; light scattering; oxide glasses; polarizability; pressure; refractive index; temperature coefficient of refractive index; thermal expansion.

The change in refractive index with temperature has been determined for some oxide glasses from about – 200 to 700 °C. The change in refractive index with applied hydrostatic pressure has been determined at room temperature from a pressure of 10^5 to 10^8 Pa. All measurements were made using the yellow spectral line of helium. A calcium aluminate glass, an aluminum magnesium phosphate glass, a binary barium borate glass and a multicomponent germanate glass were studied, as were four commercial specimens of fused silica. From the data at room temperature, it has been possible to calculate the change in electronic polarizability with temperature at constant volume. This parameter has been found to be very high for the glasses as compared to crystals, and this agrees with the results of earlier research on silica-based optical glasses. Furthermore, over the entire temperature range, the change of refractive index with temperature is shown to be due predominantly to the temperature dependence at constant volume of the electronic polarizability. The relevance of the data to the molecular scattering of light in glasses is discussed.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 78A, JANUARY–DECEMBER 1974

January-February 1974

Thermophysical measurements on iron above 1500 K using a transient (subsecond) technique, A. Cezairliyan and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 1-4 (Jan.-Feb. 1974).

Key words: electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; iron; melting point; phase transformation; thermodynamics; thermophysical properties.

Simultaneous measurements of heat capacity, electrical resistivity and hemispherical total emittance of iron (99.9% pure) in the temperature range 1500 to 1800 K, and the melting point of iron by a subsecond duration, transient technique are described. The measurements indicate increases in heat capacity and electrical resistivity as the result of the solid-solid phase transformation ($\gamma \rightarrow \delta$) in iron. The measured value of the hemispherical total emittance at 1720 K is 0.33. The average of the results of two experiments yield a value of 1808 K for the melting point of iron. Estimated inaccuracies of measured properties are: 3 percent for heat capacity and emittance, 1 percent for electrical resistivity, and 5 K for the melting point.

Measurement of melting point, normal spectral emittance (at melting point) and electrical resistivity (near melting point) of some refractory alloys, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 5–8 (Jan.–Feb. 1974).

Key words: alloys; electrical resistivity; high temperature; melting point; normal spectral emittance; refractory materials; thermophysics.

A subsecond duration pulse heating method is used to measure the melting point, normal spectral emittance (at the melting point, corresponding to 650 nm), and electrical resistivity (near the melting point) of the following refractory alloys: 90 Ta-10W, 99 Nb-1 Zr, and 80 Nb-10 Ta-10 W (numbers indicate nominal composition in percentage by weight). The melting point and the normal spectral emittance are: 3286 ± 15 K and 0.396 for 90 Ta-10 W, 2737 ± 10 K and 0.351 for 99 Nb-1 Zr, and 2814 ± 10 K and 0.333 for 80 Nb-10 Ta-10 W. The inaccuracy of the normal spectral emittance and electrical resistivity results is estimated to be 3 percent and 0.5 percent, respectively.

Comparative density measurements for solid specimens weighing a few milligrams, A. D. Franklin and J. R. Donaldson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 9-13 (Jan.-Feb. 1974).

Key words: CaF_2; density; measurement technique; Si; tungsten wires.

A density comparison technique previously described has been used to compare the densities of tungsten wires weighing about 1.3 mg to within a few percent error. For larger, less dense specimens the expected random error of a few parts in 10^4 was confirmed by comparing the known densities of Si and CaF_2.

A density scale based on solid objects, H. A. Bowman, R. M. Schoonover, and C. L. Carroll, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 13-40 (Jan.-Feb. 1974).

Key words: density standard; hydrostatic weighing; perfect sphere; silicon; spherical interferometer; spherical volume; volume standard.

We have determined the density of four pieces of single crystal silicon in terms of universally accepted standards of mass and length. These four objects will be used as a working density standard to which all future density work in the United States will be referred. Using these crystals as standards, NBS can calibrate other objects as density standards for associated laboratories.

The work was accomplished with the assistance of an interferometer, developed especially for the task, which measures the diameter of commercially available steel balls. From measured diameters ball volumes are calculated. The volumetric information contained in the balls is transferred to the silicon crystals in a newly designed hydrostatic weighing experiment.

We have made three independent density determinations on each of the four crystals, and the presently accepted values of the density of each crystal is the average of the three determinations. The random component of uncertainty (3 standard deviations) of these four averages is 0.7 ppm. The systematic error is estimated to be about 0.7 ppm.

Geometrical considerations in the measurement of the volume of an approximate sphere, D. P. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 41-48 (Jan.-Feb. 1974).

Key words: asphericity correction; density; spherical harmonics; volume of ball.

Expressions are derived for the volume of an approximate sphere in terms of measured breadth, the distance between parallel planes tangent to opposite sides. The difference in volume of a ball and a true sphere of the same average breadth is shown to be of second order, and much smaller than the random and systematic errors in the measurements of the dimension. Thus, a ball commercially available at moderate cost can be used for absolute density measurements of high accuracy. Similar expressions are given for the area of an approximate circle.

Note on diffusion of vapor into flowing gas, D. P. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 49-51 (Jan.-Feb. 1974).

Key words: diffusion; equilibrium; evaporation; humidity; humidity generator; laminar flow; saturation; water vapor.

The theory of diffusion of vapor between the walls of a tube and a stream of gas is applied to a generator of known humidities. The rate of approach to equilibrium is evaluated for gas velocities in the laminar flow range. The effect of pressure drop is examined.

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

Theoretical analysis of miscibility gaps in the alkali-borates, P. B. Macedo, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 1, 53-59 (Jan.-Feb. 1974).

Key words: glass; immiscibility; phase separation; thermodynamics of solutions.

A thermodynamic approach based on the regular solution concept is applied to the description of miscibility gap boundaries in the alkali-borate systems. It is suggested that in each system the structural units which control the entropy of mixing are the stoichiometric compounds at the apparent limit of the alkali-rich edge of the gap, and a complex boron trioxide structure. (The former is inferred by the shape of the gap, and the latter is chosen to fit the regular mixing equation.) The same boron trioxide complex is used for all the systems analyzed. The physical implications of this analysis are discussed.

March-April 1974

The formation of curved polymer crystals: Polyoxymethylene, F. Khoury and J. D. Barnes, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 95-127 (Mar.-Apr. 1974).

Key words: chain-folded; crystal; curved; electron microscopy; optical microscopy; polymer; polyoxymethylene; solution grown.

An optical and electron microscopical study is presented of the habits exhibited by chain-folded polyoxymethylene crystals grown from hot 0.02 percent solutions of the polymer in orthodichlorobenzene when these solutions are cooled to temperatures (T_c) between 140 and 80 °C inclusive. In contrast with the lamellar crystals formed in the $T_c = 140$ and 120 °C preparations, which crystals were six-sectored and nearly planar, the crystals formed below $T_c = 120$ °C exhibited multisectored dendritic habits and were all the more pronouncedly curved the lower the temperature at which they grew. The most pronouncedly curved crystals which were observed were hollow bowl shaped dentrites having a radius of curvature of $\sim 2\mu$m which were formed in the 80 °C preparations. The possible origins of why the lamellar crystals of polyoxymethylene were all the more pronouncedly curved the lower the crystallization temperature are considered in the light of conjectures which have been previously advanced concerning the formation of curved crystals of poly(4-methylpentene-1). Among the features which are discussed is the role played by the bulkiness of the chain folds.

Solid-phase behavior of several long-chain *n*-paraffins, esters, and a ketone, P. K. Sullivan, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 131-141 (Mar.-Apr. 1974).

Key words: dielectric loss; *n*-paraffins; phase transitions; x-ray scattering.

The long-spacings of the compounds methyl stearate, ethyl stearate, *n*-butyl stearate, 2-nonadecanone, *n*-eicosane, *n*-hexatriacontane and *n*-tetratetracontane have been examined as a function of temperature by means of low-angle x-ray diffraction. The intensity of the long-spacing was also determined versus temperature. The effect of annealing temperature and time was examined by means of the DSC. Dielectric loss was studied in two crystalline phases of *n*-butyl stearate.

Simultaneous measurements of heat capacity, electrical resistivity, and hemispherical total emittance by a pulse heating technique: Vanadium, 1500 to 2100 K, A. Cezairliyan, F. Righini, and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 143-147 (Mar.-Apr. 1974).

Key words: electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; thermodynamics; thermophysics; vanadium.

Simultaneous measurements of heat capacity, electrical resistivity, and hemispherical total emittance of vanadium in the temperature range 1500 to 2100 K by a subsecond duration, pulse heating technique are described. The results are expressed by the relations:

$$c_p = 56.34 - 3.839 \times 10^{-2}\, T + 1.563 \times 10^{-5}\, T^2$$

$$\rho = 8.794 + 6.282 \times 10^{-2}\, T - 6.804 \times 10^{-6}\, T^2$$

where c_p is in J · mol^{-1} · K^{-1}, ρ is in $10^{-8}\,\Omega \cdot$ m, and T is in K. The values for the hemispherical total emittance are: 0.313 at 1900 K and 0.332 at 2000 K. Estimated inaccuracies of the measured properties are: 3 percent for heat capacity, 0.5 percent for electrical resistivity and 5 percent for hemispherical total emittance.

The shape of idealized grain boundaries, S. R. Coriell, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 149-150 (Mar.-Apr. 1974).

Key words: boundary shape; curvature; grain boundary.

Mullins has treated a two-dimensional model of grain boundary motion in which each point on the boundary moves toward its center of curvature with a speed proportional to its curvature. For boundaries which preserve shape under uniform magnification, an integral representation of the boundary shape is found. We then obtain several analytic results from approximate evaluations of the integral.

Reactions of fluorocarbon ions in C_2F_6. Implications for the radiolysis, L. W. Sieck, R. Gorden, Jr., and P. Ausloos, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 151-156 (Mar.-Apr. 1974).

Key words: fluorocarbons; heats of formation; ion-molecule reactions; mass spectrometry; photoionization; rate constants.

Reactions of the fragment ions formed in the photoionization of C_2F_6, Xe-C_2F_6, and Kr-C_2F_6 mixtures have been investigated in the NBS photoionization mass spectrometer using both helium (21.2 eV) and neon (16.66-16.84 eV) resonance radiation. Contrary to previously held views, it is shown that CF_3^+ ions having no internal excitation energy undergo the F^- transfer reaction:

$$CF_3^+ + C_2F_6 \rightarrow CF_4 + C_2F_5^+. \qquad (a)$$

A rate constant of $4 \pm 1 \times 10^{-11}$ cm^3/molecule − s is determined for reaction (a) at pressures below 10^{-2} torr. On the basis of the collision rate for these reactants, it can be estimated that, on the average, each CF_3^+ ion undergoes 16 unreactive collisions before undergoing reaction (a). Therefore, from the facts that (1) in pure C_2F_6, all CF_3^+ ions undergo reaction (a) at high pressures, and (2) CF_3^+ ions formed by charge transfer from Xe^+ ions with a maximum of 8.4 kJ/Mol (2kcal/mol) excess energy undergo reaction (a), one must conclude that reaction (a) is either thermoneutral or exothermic for ground state CF_3^+ ions. Therefore, the earlier estimate for $\Delta H_f(C_2F_5^+)$ of ~ 33 kJ/mol (8 kcal/mol) must be revised downward: $\Delta H_f(C_2F_5^+) \leq 3.8$ kJ/mol (0.9 kcal/mol).

The $C_2F_5^+$ ion is unreactive towards C_2F_6, but does react with alkanes through the H^- transfer reaction:

$$C_2F_5^+ + RH \rightarrow C_2F_5H + R^+. \qquad (b)$$

It is suggested that the CF_4 observed in previous gas and liquid phase radiolysis studies of C_2F_6-O_2 mixtures can be entirely ascribed to reaction (a). Small concentrations of impurities or accumulated products will react with the $C_2F_5^+$ ions under normal low dose rate radiolysis conditions.

A simple technique for the generation of dilute mixtures of pollutant gases, W. Tsang, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 2, 157-162 (Mar.-Apr. 1974).

Key words: acetaldehyde; acrolein; air pollution; calibration; decomposition; formaldehyde; reactive gases.

The pyrolysis of compounds whose decomposition produces equal numbers of reactive and stable molecules provides a simple quantitative means of generating dilute mixtures of formaldehyde, acetaldehyde and acrolein. The requirements with respect to the thermal stability of such "parent" compounds are discussed and the possible extentions to other reactive gas systems are considered.

Energy levels and classified lines in the second spectrum of thorium (Th II), R. Zalubas and C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 2, 163-246 (Mar.-Apr. 1974).

Key words: energy levels of Th II; g-values of Th II; spectrum of Th II; Th II spectrum; thorium; wavelengths of Th II.

The analysis of Th II has been extended with improved observations of the spectrum between 2000 and 25 000 Å. About 6500 lines are classified as transitions between 199 odd levels and 271 even levels. Of the 192 levels expected from the six odd configurations $5f(6d+7s)^2$ and $(6d+7s)^2 7p$, 188 are now known. In the even level system, all but one of the 37 levels of the three $(6d+7s)^3$ configurations are known. Of the 268 levels predicted for the configurations $5f^2 7s + 5f7s7p + 5f6d7p + 5f^2 6d$, 235 are now known. The identifications are based on the theoretical calculations by N. Minsky. New Zeeman effect observations have increased the number of levels with known g-values to 406 out of 470 known levels. The classifications will be useful in establishing secondary standards of wavelength.

Proposed secondary wavelength standards and line classifications in thorium spectra between 0.9 and 3 μm, A. Giacchetti, J. Blaise, C. H. Corliss, and R. Zalubas, *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 2, 247-281 (Mar.-Apr. 1974).

Key words: classified lines of Th I and Th II; Fourier transform spectra of Th; infrared spectra of Th; spectra of Th; Th I and Th II; thorium spectra; wavelengths of Th.

The spectrum of thorium as emitted by an electrodeless lamp has been recorded by Connes and collaborators by means of Fourier Transform Spectroscopy in the region 0.9 to 3 μm. Of the 3100 lines observed, about 1900 are classified as transitions in the energy level system of Th I and 412 in Th II. Since the average deviation between the observed and calculated wave numbers is less than 0.002 cm^{-1}, the observed wavelengths are suitable for use as standard wavelengths.

May-June 1974

Photoionization of CO_2-CO-O_2 mixtures. Formation and reactions of ion clusters, L. W. Sieck and R. Gorden, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 3, 315-322 (May-June 1974).

Key words: CO; CO_2; ion-molecule reactions; O_2; photoionization; radiolysis; rate constants.

Various mixtures containing combinations of CO_2, O_2, or CO have been photoionized at 16.7 and 21.2 eV at pressures up to 1.5 torr in the NBS high pressure photoionization mass spectrometer. In CO_2-CO mixtures the interactions of CO_2^+ ions eventually lead to the formation of $(CO)_2^+$ and $[(CO)_2 \cdot CO_2]^+$ cluster ions, while photoionization of CO_2-CO-O_2 mixtures yields mainly oxygen-containing clusters at higher pressures. The investigation of O_2-CO mixtures also revealed reactions between O_4^+ and CO. The role of impurity reactions involving H_2O is considered in some detail, and the implications of all of these data to the vapor phase radiolysis of CO_2 is discussed.

Analysis of low temperature viscosity data for three NBS standard glasses, A. Napolitano, J. H. Simmons, D. H. Blackburn, and R. E. Chidester, *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 3, 323-329 (May-June 1974).

Key words: beam-bending; fiber-elongation; Fulcher equation; glass viscosity; standard reference material; viscosity; viscosity standard.

The low temperature viscosities of three glasses established as viscosity standards at the National Bureau of Standards are reported. The data overlap results which appear on the published certificates between 10^9 and 10^{12} poise and present extensive measurements up to 10^{16} poise. The measurements were made using both the fiber-elongation and beam-bending methods. No evidence of an Arrhenius behavior was found for any of the three glasses, even though the measurements covered a narrow range of temperatures. An analysis of the inherent measurement uncertainty associated with each method indicates that the fiber-elongation measurements are more precise than the beam-bending measurements. Analysis of the data and its uncertainty by the Fulcher Equation supports the conclusions of the error analysis.

***PVT* relationships for liquid and glassy poly(vinyl acetate),** J. E. McKinney, *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 3, 331-353 (May-June 1974).

Key words: density; dilatometer; entropy; glass transition; glass; liquid; polymer; poly(vinyl acetate); *PVT*; relaxation.

PVT measurements were made on liquid and glassy poly(vinyl acetate) over ranges of − 30 to 100 °C and 0 to 800 bar (gage pressure). The data were obtained by three different thermodynamic histories: (a) variable formation pressure, (b) constant formation pressure at one atmosphere, and (c) constant formation pressure at 800 bar. In all of these the glass was formed by isobaric cooling at 5 °C/h. The salient characteristics resulting from the different histories are the following. History (a) produces a glass of structure varying with formation pressure and, hence, does not necessarily give the proper thermodynamic properties of a "single physical substance." However, the liquid-glass intersection temperature, $T_g(P)$, is an important kinetic, or relaxational, property which approximates an isoviscous state. Accordingly, the values of dT_g/dP are in close agreement with those obtained from dynamic mechanical and dielectric time-temperature-pressure superposition. Constant formation histories (b) and (c) give proper thermodynamic properties of the glasses, but very little information with respect to kinetics. Increasing the pressure at which the glass is formed increases the density of the glass (at the given cooling rate) considerably in contrast to the entropy (from other work), which appears to be essentially independent of formation pressure.

A considerable part of the paper is definitional. The results are related to other *PVT*, dynamic mechanical, dielectric, and thermodynamic measurements. Interpretations are given in terms of both phenomenological and molecular models.

Correction and extension of van der Poel's method for calculating the shear modulus of a particulate composite, J. C. Smith, *J. Res. Nat. Bur. Stand. (U.S.),* **78A** (Phys. and Chem.), No. 3, 355-361 (May-June 1974).

Key words: bulk modulus; composite materials; elastic constants; filled polymers; mechanical properties; particulate composites; shear modulus; theory of elasticity.

Van der Poel's method (Rheol. Acta **1**, 198 (1958) for calculating the shear modulus of a particulate composite agrees well with experimental data, but its validity has been questioned, and it was applicable only to composites in which the matrix material is incompressible. These limitations are removed in this paper in which an error in the original derivation is corrected and the method generalized to apply to any matrix material. Calculations

using the corrected theory show that despite the error, a table of shear modulus values published with the original theory is sufficiently correct for most practical purposes. Applicability of the generalized method to the large class of composites having compressible matrices is discussed. Shear moduli calculated by the corrected and extended method are compared with corresponding values calculated by other methods currently used.

The formation of curved polymer crystals: Polychlorotrifluoroethylene, J. D. Barnes and F. Khoury, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 363-373 (May-June 1974).

Key words: crystal morphology; crystallization; electron microscopy; optical microscopy; polychlorotrifluoroethylene; solution crystallization.

The habits and fine structure of crystals of polychlorotrifluoroethylene (PCTFE) grown from dilute solution were studied as functions of crystallization temperature. The solvent used was a low molecular weight PCTFE oil. The simplest crystals found were monolayered chain folded lamellae formed at 110 °C. These lamellae are planar and possess an unusual texture characterized by the presence of fine channel-like voids in the interior of the crystals. These lamellae do not exhibit well-formed crystal faces but are disc-like in overall shape. At lower crystallization temperatures the crystals take the form of complex arrays of curved lamellae which are aggregated into, among others, watchglass-shaped or hollow spherical objects. The variation of the curvature of the crystals with crystallization temperature is discussed in the light of previous studies of the formation of curved crystals of poly(4-methylpenetene-1) and polyoxymethylene.

Enthalpy of formation of phosphorus pentachloride; derivation of the enthalpy of formation of aqueous orthophosphoric acid, R. H. Schumm, E. J. Prosen, and D. D. Wagman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 375-386 (May-June 1974).

Key words: enthalpy of formation; phosphoric acid; phosphorus pentachloride.

When chlorine (real gas, 980 mmHg) combines with white (α) phosphorus to form phosphorus pentachloride at 24.89 °C, 3986 $\pm$ 2.7 J of heat are liberated per gram of stoichiometrically equivalent $Mg_2P_2O_7$. This value was determined by a dead-ended flow system in an electrically calibrated isoperibol calorimeter. Correction was made for the formation of up to one mol percent PCl_3 in the products; no other impurities were found. From this value, the standard (25 °C, ideal gas) enthalpy of formation of PCl_5(c) is calculated to be $-$ 443.85 $\pm$ 0.30 kJ/mol, $-$ 106.08 $\pm$ 0.07 kcal/mol. When this figure is combined with a recent determination of the enthalpy of hydrolysis of PCl_5(c), the standard enthalpy of formation of H_3PO_4 (aq, 100 H_2O) is calculated to be $-$ 1296.5 $\pm$ 1.5 kJ/mol, in good agreement with two other values which involve the formation and hydrolysis of P_4O_{10} (hex). A "best value" is suggested: $\Delta Hf°$ (H_3PO_4, 100 H_2O) = $-$ 1295.8 $\pm$ 1.3 kJ/mol, $-$ 309.7 $\pm$ 0.3 kcal/mol.

Heat capacities of polyethylene from 2 to 360 K. II. Two high density linear polyethylene samples and thermodynamic properties of crystalline linear polyethylene, S. S. Chang, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 387-400 (May-June 1974).

Key words: amorphous polyethylene; calorimetry; crystalline polyethylene; extended chain crystals; glass transition temperature; heat capacity; linear polyethylene; polyethylene; thermodynamic properties.

Heat capacities of two high density linear polyethylene samples were measured from 2 to 360 K. By incorporating the results from the previous work of this series, thermodynamic properties of completely crystalline linear polyethylene may be estimated. C_p, $H - H_0$, S and $-(G - H_0)$ at 298.15 K for crystalline linear polyethylene are estimated to be 22.60 J K^{-1} mol^{-1}, 3544 J mol^{-1}, 23.02 J K^{-1} mol^{-1} and 3319 J mol^{-1}, respectively. Spontaneous adiabatic temperature drifts were observed in both samples near 240 K. These drifts may be attributed to the enthalpy relaxation phenomena occurring in the glass transformation region.

The specific heats, C_σ, and C_V, of compressed and liquefied methane, B. A. Younglove, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 401-410 (May-June 1974).

Key words: constant volume; heat capacity; liquid; saturated liquid; specific heat; methane.

The specific heats, C_σ, of saturated liquid methane have been measured at 66 temperatures in the temperature range 95-187 K. The specific heats at constant volume, C_V have been measured at 20 densities ranging from 0.8 to 2.8 times the critical density, at temperatures between 91 and 300 K, and at pressures to 330 bar (at 280 *PVT* states in all). The uncertainty of most of the measurements is estimated to be less than 0.5 percent, except near the critical point. These measurements were performed primarily to provide input data for accurate thermodynamic properties data calculations for liquid methane. They are believed to be the most comprehensive specific heat measurements available for pure compressed gaseous and liquid methane.

An improved procedure for synthesis of DL-4-hydroxy-3-methoxymandelic acid (DL-"vanillyl"-mandelic acid, VMA), A. J. Fatiadi and R. Schaffer, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 411-412 (May-June 1974).

Key words: alkaline condensation; glyoxylic acid; guaiacol; synthesis; vanillyl-mandelic acid; VMA.

An improved procedure for synthesis of DL-4-hydroxy-3-methoxymandelic acid (DL-vanillyl-mandelic acid, VMA) entails slow addition of an ice-cold, aqueous solution of glyoxylic acid to an ice-cold alkaline solution of guaiacol, with efficient mechanical stirring. This one-step condensation procedure provides VMA in 68-75 percent yield.

Single particle motions in liquids: Qualitative features of memory functions, R. D. Mountain, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 413-420 (May-June 1974).

Key words: depolarized Rayleigh scattering; ideal gas; incoherent neutron scattering; infrared absorption; liquid state; memory function; projection operator; Raman scattering; time correlation function.

Memory functions, which enter into the equations of motion for time correlation functions, are constructed from neutron scattering, infrared absorption and light scattering data involving single particle motions in liquids. The qualitative features of these memory functions are related to the shape of the corresponding time correlation functions. It is found that a negative portion to the memory function is indicative of a rapid loss of correlation in time while strong temporal correlations imply a memory function which does not go negative. The mathematical structure of a memory function is examined for the case of the ideal gas by expanding and evaluating the projection operator representation of the function. The resulting expression has a rich mathematical structure and can be expressed in a closed form only for its Laplace transform.

The infrared spectra of matrix isolated uranium oxide species, S. Abramowitz and N. Acquista, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 3, 421-424 (May-June 1974).

Key words: infrared spectra; mass spectrophotometry; matrix isolated; oxides of uranium.

The infrared spectra of matrix isolated products of the interaction of uranium and oxygen have been investigated at high temperatures. By use of collateral available data on the various uranium oxide species, plus employment of oxygen 16 and 18 isotopes, peak assignments were verified for many of the neutral metal oxide species.

July-August 1974

The glass transition temperature of monodispersed polystyrenes and their binary mixtures, L. A. Wall, Roestamsjah, and M. H. Aldridge, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 447-451 (July-Aug. 1974).

Key words: binary mixtures; glass transition temperature; monodispersed polystyrene.

Glass transition measurements on monodispersed polystyrenes of different molecular weight and their binary mixtures result in the following conclusions: (a) the effect of molecular weight on the glass transitions of monodispersed samples satisfies the Fox and Flory equation written as $T_g = T_{g\infty} - A/M_n$, with constant $A = 0.84 \times 10^{-5}$; (b) polymers of the same number average molecular weight with a broad distribution show lower glass transitions than the monodisperse; (c) the binary mixtures follow the Gordon-Taylor equation derived for copolymers, with constant k (experimental) 0.5.

A method of measuring the solubilities of hydrocarbons in aqueous solutions, R. L. Brown and S. P. Wasik, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 453-460 (July-Aug. 1974).

Key words: aqueous solutions; benzene solubility; hydrocarbons; partition coefficients; seawater.

An apparatus is described which measures the equilibrium distribution of a hydrocarbon between a gas phase and a liquid water phase. The method involves a multiple equilibration procedure which requires the analysis of only the gas phase. Gas-liquid chromatography was used for the hydrocarbon analysis because of its high sensitivity and selectivity. Supplemented by vapor pressure data, the observed distribution can be used to calculate the solubility of the hydrocarbon in the liquid phase. This was done for benzene, toluene, and ethylbenzene in distilled water over the temperature range 5 to 20 °C and in an artificial seawater over the temperature range 0 to 20 °C. The various factors affecting the accuracy of the results are discussed in detail.

Theoretical and experimental Compton scattering cross sections at 1.12 MeV in the case of strongly bound K-shell electrons, P. N. Baba Prasad and P. P. Kane, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 461-463 (July-Aug. 1974).

Key words: Compton scattering; differential cross section; electron binding; gamma rays; K-shell; photons.

Measurements are reported for the differential cross sections for Compton scattering of 1.12 MeV gamma rays by the K-shell electrons of tin, tantalum, gold, and thorium. A few discrepancies between approximate theoretical calculations and the experimental results for different energies are pointed out. The need for an exact relativistic calculation is indicated.

Standardization of ^{60}Co and ^{137}Cs gamma-ray beams in terms of exposure, T. P. Loftus and J. T. Weaver, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 465-476 (July-Aug. 1974).

Key words: cavity ionization chamber; exposure; gamma rays; ^{60}Co; ^{137}Cs; standards.

At the National Bureau of Standards (NBS), the exposure-rate standards for ^{60}Co and ^{137}Cs gamma rays were based for a number of years on a weighted average of measurements using a cylindrical ionization chamber and a group of small spherical chambers. Complex setup conditions for the cylindrical chamber, differences between the cylindrical and spherical chamber data, and recognition that the institution of this weighted average exposure-rate standard increased the difference between free-air-chamber and cavity-chamber measurements, led to the development of new spherical chambers. All correction factors for exposure-rate measurements were investigated and updated. Excellent agreement was achieved between independent exposure-rate measurements for six spherical chambers and, as of May 1, 1972, the exposure standards were reduced 0.7 percent for ^{60}Co and 0.6 percent for ^{137}Cs gamma rays. Recalculation of correction factors since that time indicates that the standard ^{137}Cs should be further reduced by 0.2 percent, and this adjustment was made on July 1, 1974.

The uncertainties associated with each of the quantities entering into the determination of exposure rate were tabulated and the overall uncertainty of the exposure rates used for instrument calibrations at NBS was found to be about 0.7 percent for addition in quadrature.

Investigation of freezing temperatures of National Bureau of Standards aluminum standards, G. T. Furukawa, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 477-495 (July-Aug. 1974).

Key words: A-C bridge; aluminum; aluminum point; fixed point; freezing point; IPTS-68; platinum resistance thermometer.

The design of a high-precision furnace for investigating the freezing points of metals up to 700 °C or higher is described. The freezing points of aluminum samples of nominally 99.999 percent purity from two batches were compared in terms of the ratio $R(\mathrm{Al})/R\mathrm{TP})$, the ratio of the resistance of the platinum resistance thermometer at the aluminum freezing point to that at the triple point of water. The average standard deviation of measurements of the ratio $R(\mathrm{Al})/R\mathrm{TP})$ obtained on six specimens corresponds to ± 0.40 mK, while the average standard deviations of $R(\mathrm{Al})$ and $R(\mathrm{TP})$ correspond to ± 0.17 mK and ± 0.14 mK, respectively. (The variations in the measurements of $R(\mathrm{TP})$ are amplified by 3.4 in the ratio $R(\mathrm{Al})/R(\mathrm{TP})$.) The spread of the mean $R(\mathrm{Al})/R(\mathrm{TP})$ obtained for five out of the six specimens corresponds to 0.51 mK; the deviation of the mean $R(\mathrm{Al})/R(\mathrm{TP})$ of the sixth specimen from the mean $R(\mathrm{Al})/R(\mathrm{TP})$ of the five specimens corresponds to -1.31 mK. (The sixth specimen may have been contaminated during the assembly of the freezing-point cell or the original sample bar was inhomogeneous.) The results show that aluminum can provide a freezing point (near 660 °C) that is at least as reproducible as the freezing point of antimony (near 631 °C).

Prediction of the viscosities of "soda-lime" silica glasses, K. C. Lyon, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 497-504 (July-Aug. 1974).

Key words: composition; Fulcher equation; glasses; soda-lime glasses; viscosity.

Published data are used to develop factors for predicting the viscosity-temperature relationship from the compositions of "soda-lime" type silicate glasses at specific temperatures in the range of 600 to 1300 °C. The effects of Na_2O, K_2O, CaO, MgO, Al_2O_3 and their interactions are evaluated. The influence of minor amounts of BaO, B_2O_3, Li_2O, and F_2, in the temperature range of 700 to 1300 °C, is estimated.

The system NaCl-$AlCl_3$, E. M. Levin, J. F. Kinney, R. D. Wells, and J. T. Benedict, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 505-507 (July-Aug. 1974).

Key words: immiscibility; $NaAlCl_4$; phase equilibrium; system $AlCl_3$-NaCl; system NaCl-$AlCl_3$.

The system NaCl-$AlCl_3$ has been restudied by DTA, visual observation, and x-ray diffraction powder techniques for identification of crystalline phases. It was confirmed that the system contains one intermediate compound $NaAlCl_4$ with an incongruent mp of 153 ± 0.5 °C and a region of liquid immiscibility extending from 80.25 to 99.6 mol percent $AlCl_3$ at 191.3 °C, the monotectic temperature.

Simultaneous measurements of heat capacity, electrical resistivity and hemispherical total emittance by a pulse heating technique: zirconium, 1500 to 2100 K, A. Cezairliyan and F. Righini, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 509-514 (July-Aug. 1974).

Key words: electrical resistivity; emittance; heat capacity; high-speed measurements; high temperature; thermodynamics; thermophysical properties; zirconium.

Simultaneous measurements of heat capacity, electrical resistivity and hemispherical total emittance of zirconium in the temperature range 1500 to 2100 K by a subsecond duration, pulse heating technique are described. The results are expressed by the relations:

$$C_p = 36.65 - 1.435 \times 10^{-2} T + 6.624 \times 10^{-6} T^2$$

$$\rho = 87.95 + 1.946 \times 10^{-2} T$$

$$\epsilon = 0.2031 + 6.362 \times 10^{-5} T$$

where C_p is in $J \cdot mol^{-1} \cdot K^{-1}$, ρ is in 1^{-8} $\Omega \cdot m$, and T is in K. Estimated inaccuracies of the measured properties are: 3 percent for heat capacity, 2 percent for electrical resistivity and 5 percent for hemispherical total emittance.

Measured enthalpy and derived thermodynamic properties of crystalline and liquid potassium chloride, KCl, from 273 to 1174 K, T. B. Douglas and A. W. Harman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 4, 515-529 (July-Aug. 1974).

Key words: heat of fusion; high-temperature drop calorimetry; lattice vacancies; muriate of potash; potassium chloride; sylvite; thermodynamic properties.

The enthalpy of KCl relative to that at 273.15 K was precisely measured by drop calorimetry from 273 to 1174 K, and smooth thermodynamic functions were derived for this temperature range. The heat capacities found for the crystalline phase join smoothly the most precise published data for lower temperatures; those for the liquid phase are temperature-independent within the precision of measurement over the 120° range covered. It is concluded that the broad exponential upturn of the heat-capacity curve below the melting point, if attributed to lattice vacancies, indicates a predominance of large vacancy clusters.

September-October 1974

Spectrum of doubly ionized praseodymium from 2107 Å to 10716 Å, J. Sugar, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 555-593 (Sept.-Oct. 1974).

Key words: line classifications; praseodymium; Pr III; spectrum.

Wavelengths, relative intensity estimates, and classifications of the spectral lines of doubly ionized praseodymium (Pr III) in the range of 2107 to 10716 Å are given. About 4400 lines are included of which some 2500 are classified.

A heat-loss-compensated calorimeter: Theory, design, and performance, S. R. Domen and P. J. Lamperti, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 595-610 (Sept.-Oct. 1974).

Key words: absorbed dose; calorimeter; heat-loss-compensation; thermal gradients.

A new type of 3-body calorimeter for measuring absorbed dose produced by ionizing radiation is described in detail. All three bodies rise in temperature during irradiation, and the heat absorbed by the central core is measured by standard means. Only the central core is heated during electrical calibration, but the increased heat losses are compensated by measuring most of the heat lost to the surrounding jacket and automatically adding it to the heat retained by the core. The third body is a massive, thermally-floating shield, whose presence reduces the heat losses during irradiation, with a consequent increase in sensitivity and stability. A mathematical description of the calorimeter behavior is presented, along with a discussion of control and operation technique. In particular it is shown how this 3-body calorimeter can be calibrated as a 1-body calorimeter, with large heat losses, or as a 2-body calorimeter, in the quasi-adiabatic mode. This calorimeter design decreases the effects of thermal gradients and at the same time provides the means to test for these effects. The results of these tests show that for this particular model, systematic errors caused by thermal gradients, during electrical measurements, are no larger than 0.1 percent. Errors in comparing an electrical run with an irradiation may be somewhat larger because of different temperature gradient within the system. It is also pointed out that the general design of this calorimeter is not restricted to measuring absorbed dose but can be applied to calorimetry in general.

The enthalpies of combustion and formation of linear polyethylene, P. L. Splitstone and W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 611-616 (Sept.-Oct. 1974).

Key words: enthalpy; heat of combustion; heat of crystallization; heat of formation; polymer; standard reference polymer.

The enthalpies of combustion and formation of two samples of linear polyethylene which differ only in the degree of crystallinity have been determined in an oxygen bomb calorimeter. For the two samples the degree of crystallinity, the enthalpy of combustion at 298.15 K, and the enthalpy of formation at 298.15 K, were respectively: 72 percent, -651.16 ± 0.12 $kJ \cdot mol^{-1}$, -28.18 ± 0.13 $kJ \cdot mol^{-1}$ for the less crystalline sample; and 96 percent, -650.27 ± 0.12 $kJ \cdot mol^{-1}$ and -29.08 ± 0.12 $kJ \cdot mol^{-1}$ for the more crystalline sample. The values are per mole of CH_2. Uncertainties listed are estimates of accuracy of approximate 95 percent confidence limits. The results of previous determinations by other investigators are discussed briefly.

High pressure measurements of density, velocity of sound, and bulk moduli of pentane and 2-methylbutane and their mixtures, J. C. Houck, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 617-622 (Sept.-Oct. 1974).

Key words: bulk modulus; compressibility; density; dilatometric measurements; high pressure; liquids; 2-methylbutane; pentane; ultrasonics.

Dilatometric and ultrasonic measurements were made on mixtures of pentane and 2-methylbutane to give density, relative volume, isothermal bulk modulus, velocity of sound, and adiabatic bulk modulus to pressure of 24 kilobars (2.4×10^9 N/m^2).

Long-time creep in a pure-gum rubber vulcanizate: Influence of humidity and atmospheric oxygen, L. A. Wood, G. W. Bullman, and F. L. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 623-629 (Sept.-Oct. 1974).

Key words: compliance of rubber; creep, long-time, in rubber; humidity, effect of, on creep of rubber; modulus of rubber, effect of humidity; oxygen, influence of, on creep of rubber; rubber, natural, creep; time, effect of, on compliance of rubber.

Long-time creep of natural rubber cured with a sulfur-accelerator recipe containing no filler can be conveniently represented by a plot of $(E - E_1)/E_1 = \Delta E/E_1$ with a double-abscissa scale showing log t and t. E is the elongation at any time t, after application of the load, and E_1 its value at unit time. Experimental data conform to the equation

$$\Delta E/E_1 = A \log t + B(t - 1)$$

except for a more rapid rise preceding rupture. The constants A and B can be evaluated from only three observations—at the longest time (about 70 days), at one minute, and at an intermediate time. $\Delta E/E_1$ is approximately linear with log t when t is less than $0.1(A/B)$ and approximately linear with t when t is greater than $4.343(A/B)$. The observed modulus was about 1.4 MPa and A was about 2.4 percent/(unit log t) when the atmosphere was a vacuum, dry N_2, or dry air. The modulus was lowered very slightly and A became about 4 percent/(unit log t) when the air was saturated with water. B was raised from about 2×10^{-5} percent/min to about 20×10^{-5} percent/min when the vacuum or dry N_2 was replaced by dry air and to about 50×10^{-5} percent/min when the air was saturated with moisture. A is considered to be related to physical relaxation, while B corresponds to a chemical reaction, probably oxidative degradation.

Adaptation of a high-accuracy spectrophotometer for ultraviolet work, K. D. Mielenz, R. Mavrodineanu, and E. D. Cehelnik, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 5, 631-636 (Sept.-Oct. 1974).

Key words: averaging sphere; deuterium arc lamp; fluorescent wavelength converter; grating; spectrophotometry; standard reference materials; ultraviolet; UV achromats; visible.

A high-accuracy spectrophotometer, originally designed for work at visible wavelengths, was modified to permit measurements in the ultraviolet without degradation of its original performance. This was accomplished by equipping the spectrophotometer with a stable deuterium arc source, a highly efficient averaging sphere with fluorescent wavelength converter, a new grating, and achromatic sample-compartment optics. The modified spectrophotometer will be used for the development of new Standard Reference Materials, as well as for materials research, in the region between 200 and 300 nm.

November-December 1974

Solubility of β-$Ca_3(PO_4)_2$ in the system $Ca(OH)_2$-H_3PO_4-H_2O at 5, 15, 25, and 37 °C, T. M. Gregory, E. C. Moreno, J. M. Patel, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 6, 667-674 (Nov.-Dec. 1974).

Key words: beta-tricalcium phosphate, preparation; solubility, solubility product, stoichiometry of; dissolution, thermodynamics of; ion pairs; singular points; solubility isotherms; thermal coefficient of solubility.

Solubility isotherms of beta-tricalcium phosphate, β-$Ca_3(PO_4)_2$, prepared by heating mixtures of $CaCO_3$ and $CaHPO_4$ above 800 °C, were determined in the ternary system $Ca(OH)_2$-H_3PO_4-H_2O at 5, 15, 25, and 37 °C in the pH range 6.0-7.5 by equilibration with dilute H_3PO_4 solutions. The results indicate that β-$Ca_3(PO_4)_2$ has a negative thermal coefficient of solubility. The solubility product, K_s, was determined as a function of temperature by a generalized least-squares procedure; the resulting equation is

$$\log K_S = -45723.26/T + 287.4536 - 0.546763T;$$

the values of K_S and its dispersion at 25 and 37 °C are 1.20(0.056), and $0.283(0.011) \times 10^{-29}$. Thermodynamic functions for the dissolution of the salt at the four experimental temperatures are reported.

When treated as an adjustable constant, the Ca/P ratio in these β-$Ca_3(PO_4)_2$ solutions was found to have the value 1.514(0.010), confirming that the stoichiometry of the high temperature form of this salt is correctly indicated by the above formula.

Solubility of $CaHPO_4 \cdot 2H_2O$ in the quaternary system $Ca(OH)_2$ – H_3PO_4 – NaCl – H_2O at 25 °C, P. R. Patel, T. M. Gregory, and W. E. Brown, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 6, 675-681 (Nov.-Dec. 1974).

Key words: brushite; $CaHPO_4 \cdot 2H_2O$; $NaHPO_4^-$ ion pair; solubility product; system $Ca(OH)_2$ – H_3PO_4 – H_2O – NaCl.

Solubility of $CaHPO_4 \cdot 2H_2O$ was determined in the quaternary system $Ca(OH)_2$ – H_3PO_4 – NaCl – H_2O at 25 °C in the pH range 4.39-6.38; ionic strengths of the saturated solutions varied from 0.00485 to 0.545. Satisfactory constancy in the solubility product, $(K_{sp} = [Ca^{2+}] \cdot [HPO_4^{2-}] \cdot \gamma_{Ca^{2+}} \cdot \gamma_{HPO_4^{2-}} = 2.49 \pm 0.05 \times 10^{-7}$ mol^2 l^{-2}) was obtained when (i) the ion activity coefficients, γ_i, were calculated with the Debye-Hückel equation, $\log \gamma_i = -AZ_i^2 \sqrt{I}/(1 + B\alpha_i \sqrt{I}) + 0.0626I$ + the value 0.0626 for the coefficient in the linear term was derived from the solubility data by utilizing a statistical procedure, and (ii) formation of an ion pair $NaHPO_4^-$ was taken into account; a statistically derived value for the stability constant of this ion pair is 7.0 ± 2.41 — mol^{-1}. The ion pair $NaHPO_4^-$ appears to have significant concentrations in physiological fluids.

The enthalpies of combustion and formation of the monochlorobenzoic acids, W. H. Johnson and E. J. Prosen, *J. Res. Nat. Bur. Stand. (U.S.)*, **78A** (Phys. and Chem.), No. 6, 683-689 (Nov.-Dec. 1974).

Key words: combustion; enthalpy; formation; heat; isomerization; secondary standard.

The enthalpies of combustion of *o*-, *m*-, and *p*-chlorobenzoic acid have been determined in an adiabatic rotating-bomb calorimeter. The enthalpies of formation have been obtained by combination of the experimental data with the accepted values for the enthalpies of formation of water and for the formation and solution of hydrochloric acid. The results of other investigators are discussed briefly. The resulting values and their estimated 95 percent confidence limits are as follows:

	$\Delta Hc°$ (25 °C) kJ/mol	$\Delta Hf°$ (25 °C) kJ/mol
o-Chlorobenzoic Acid	−3087.67 ± 0.69	−404.83 ± 0.74
m-Chlorobenzoic Acid	−3067.91 ± 1.53	−424.59 ± 1.55
p-Chlorobenzoic Acid	−3064.34 ± 0.66	−428.16 ± 0.72

Where $\Delta Hc°$ corresponds to the process:

$$C_7H_5O_2Cl(c) + 7\ O_2(g) + 198\ H_2O(liq) \rightarrow 7\ CO_2(g) + [HCl + 200\ H_2O](liq).$$

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 79A, JANUARY-DECEMBER 1975

January-February 1975

Polarization effects on fluorescence measurements, E. D. Cehelnik, K. D. Mielenz, and R. A. Velapoldi, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 1, 1-15 (Jan.-Feb. 1975).

Key words: emission anisotropy; fluorescence; fluorescence quantum yield; fluorescence standards; fluorimetry; polarization; spectrofluorimetry; viewing angle.

Polarization effects on fluorescence measurements are a function of four independent variables. The first is F, the polarization ratio of the exciting light which reaches the sample. The second is r, the emission anisotropy of the sample, which is the polarization "response" of the sample to plane polarized exciting light. The third is G, the polarization ratio of the emission detection system, which is the ratio of the sensitivities of the detection system to vertically and horizontally polarized light. The fourth is α, the viewing angle, which is the angle between the direction of the propagation of the exciting light and the direction from which the emission is being detected.

The intensity and the degree of polarization of the fluorescence emission that the sample exhibits are functions of F, r, and α, while the actual readings obtained with a typical spectrofluorimeter are functions of all four variables, F, r, α, and G. A theoretical analysis is made taking all these factors into account, and proper mathematical models are developed for the different modes of operation in which a fluorimeter can be used. These are verified experimentally with data obtained for a sample which has a high degree of emission anisotropy (Nile Blue A Perchlorate in glycerol). A recently designed goniospectrofluorimeter was used. Calibration procedures are developed and recommendations are made for modes of operation and fluorescence standards.

The iron-neon hollow-cathode spectrum, H. M. Crosswhite, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 1, 17-69 (Jan.-Feb. 1975).

Key words: hollow cathode; iron; neon; wavelength standards.

Over 4000 wavelengths are listed between 1900 and 9000 Å for Fe I, Fe II, Ne I and Ne II lines measured in a hollow cathode discharge tube with iron electrodes and a neon gas filling. Photoelectric traces between 2400 and 5700 Å on a semiquantitative intensity scale are also included. For Fe I, energy values for 124 even and 240 odd levels have been computed. These have been used to calculate Ritz standards for most of the Fe I lines.

Equation of state for thermodynamic properties of fluids, R. D. Goodwin, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 1, 71-79 (Jan.-Feb. 1975).

Key words: coexistence boundary; critical point; ethane; equation of state; fluids; methane; orthobaric densities; specific heats; vapor pressures.

This equation of state was developed from PVT compressibility data on methane and ethane. The highly-constrained form originates on a given liquid-vapor coexistence boundary (described by equations for the vapor pressures and the orthobaric densities). It then requires only five least-squares coefficients, and ensures a qualitatively correct behavior of the $P(\rho, T)$ surface and of its derivatives, especially about the critical point. This nonanalytic equation yields a maximum in the specific heats $C_v(\rho, T)$ at the critical point.

Thermodynamic studies of the $\alpha \rightarrow \beta$ phase transformation in zirconium using a subsecond pulse heating technique, A. Cezairliyan and F. Righini, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 1, 81-84 (Jan.-Feb. 1975).

Key words: electrical resistivity; high-speed measurements; high temperature; solid-solid phase transformation; thermodynamics; zirconium.

Measurements of the temperature and energy of the $\alpha \rightarrow \beta$ phase transformation, and the electrical resistivity near and at the transformation point of zirconium using a subsecond duration pulse heating technique are described. The results yield 1147 K for the transformation temperature and 3980 J · mol^{-1} for the transformation energy. Electrical resistivity is found to decrease by 17 percent during the transformation. Estimated inaccuracies of the measured properties are: 10 K for the transformation temperature, 5 percent for the transformation energy, and 2 percent for the electrical resistivity.

March-April 1975

Thermal conductivity of gases. III. Some values of the thermal conductivities of argon, helium, and nitrogen from 0 °C to 75 °C at pressures of 1×10^5 to 2.5×10^7 pascals, L. A. Guildner, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 407-413 (Mar.-Apr. 1975).

Key words: excess thermal conductivity of N_2; thermal conductivity of Ar; thermal conductivity of He; thermal conductivity of N_2.

Accurate measurements of the thermal conductivities of Ar and He agree with the theoretical value of 2.5 $\phi \eta c_v$ (η = viscosity, c_v = specific heat capacity at constant volume, ϕ is a number slightly greater than 1 depending upon the intermolecular potential). Measurements of the thermal conductivities of N_2 at 9.6 and 75 °C as a function of pressure up to 2.53×10^7 Pa help to appraise the validity of other measurements of the thermal conductivities of dense gases. The excess conductivity of

[1] The various NBS publications series are grouped under subjeadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

nitrogen (the additional conductivity resulting from pressure) is shown to be a function of only the density of the nitrogen from 0 to 700 °C and pressures up to 1.3×10^8 Pa.

On the differential cross section for x-ray inelastic scattering, M. Kuriyama, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 415-417 (Mar.-Apr. 1975).

Key words: differential cross section; real metals; theory; x-ray inelastic scattering.

A formal formulation of the differential cross section for x-ray inelastic scattering is given for a real solid, in particular, in terms of the polarization propagator and the inverse dielectric function. The differential cross section is related to the causal functions of electron properties rather than those retarded functions.

Simplification of van der Poel's formula for the shear modulus of a particulate composite, J. C. Smith, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 419-423 (Mar.-Apr. 1975).

Key words: composite materials; elastic constants; filled polymers; mechanical properties; particulate composites; shear modulus; theory of elasticity.

The coefficients in van der Poel's equation for calculating the shear modulus of a particulate composite have been greatly simplified, making the calculation much less unwieldy. Approximate solutions of van der Poel's equation are also derived, and it is shown that one of the low order approximations is Kerner's equation, or Hashin and Shtrikman's equation for the highest lower bound. The Kerner approximation is often too low in value when the volume fraction of filler exceeds 0.2, but it can be used to provide further simplification in van der Poel's equation, or it can be used as a first approximation in a Newton's method of solution.

The enthalpies of combustion and formation of nicotinic acid and creatinine, W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 425-430 (Mar.-Apr. 1975).

Key words: calorimetry; combustion; creatinine; enthalpy; formation; heat; nicotinic acid.

The enthalpies of combustion of nicotinic acid and creatinine have been determined in an adiabatic rotating-bomb calorimeter. The enthalpies of formation have been obtained by combination of the experimental data with the accepted values for the enthalpies of formation of carbon dioxide and water. The results of other investigations on creatinine are discussed briefly. The resulting values and their estimated uncertainties are as follows:

	Nicotinic acid	*Creatinine*
$\Delta Hc°$(25 °C)	−2730.67±0.57 kJ/mol	−2334.53±0.86 kJ/mol
$\Delta Hf°$(25 °C)	−344.97±0.62 kJ/mol	−239.93±0.88 kJ/mol

Simultaneous measurements of specific heat, electrical resistivity, and hemispherical total emittance by a pulse heating technique: Hafnium-3 (wt. %) zirconium, 1500 to 2400 K, A. Cezairliyan and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 431-436 (Mar.-Apr. 1975).

Key words: electrical resistivity; emittance; hafnium; high-speed measurements; high temperatures; specific heat; thermodynamics.

Simultaneous measurements of specific heat, electrical resistivity and hemispherical total emittance of hafnium containing 3.12 weight percent zirconium in the temperature range 1500 to 2400 K by a subsecond duration, pulse heating technique are described. The measurements indicate decreases in specific heat (by about 13%) and in electrical resistivity (by about 8%) as the result of the $\alpha \rightarrow \beta$ transformation. Estimated inaccuracies of the measured properties are: 3 percent for specific heat, 1 percent for electrical resistivity and 5 percent for hemispherical total emittance.

Heat capacities of polyethylene III. One linear and one branched sample from 5 to 350 K, S-S. Chang, E. F. Westrum, Jr., and H. G. Carlson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 2, 437-441 (Mar.-Apr. 1975).

Key words: adiabatic calorimetry; branched polyethylene; calorimetry; cryogenic temperature; heat capacity; linear polyethylene; polyethylene; thermodynamic properties.

Heat capacities of two polyethylene samples, one linear with a density of 0.973 g cm^{-3} and one branched with a density of 0.91 g cm^{-3}, have been determined by adiabatic calorimetry from 5 to 360 K in a different experimental arrangement than employed for studies of other polyethylene samples in this series. The heat capacity behavior of these two samples confirms expectations for samples with corresponding densities.

May-June 1975

The enthalpies of combustion and formation of ortho- and parafluorobenzoic acid, W. H. Johnson and E. J. Prosen, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 3, 481-486 (May-June 1975).

Key words: combustion; enthalpy; formation; heat; isomerization; secondary standard.

The enthalpies of combustion and formation of one sample of ortho- and two samples of parafluorobenzoic acids have been determined by combustion in an oxygen-bomb calorimeter. The data obtained by other investigators are discussed briefly. The values obtained and their estimated uncertainties are as follows:

	o-Fluorobenzoic acid
$\Delta Hc°$ (25°C)	−3080.00±1.02 kJ/mol
$\Delta Hf°$ (25°C)	−568.52±1.10 kJ/mol
	p-Fluorobenzoic acid I
$\Delta Hc°$ (25°C)	−3062.97±0.70 kJ/mol
$\Delta Hf°$ (25°C)	−585.56±0.81 kJ/mol
	p-Fluorobenzoic acid II
$\Delta Hc°$ (25° C)	−3063.78±0.80 kJ/mol
$\Delta Hf°$ (25° C)	−584.74±0.90 kJ/mol

where $\Delta Hc°$ corresponds to the reaction:

$$C_7H_5O_2F(c) + 7\ O_2(g) + 48\ H_2O(liq) \rightarrow 7\ CO_2(g) + [HF + 50\ H_2O](liq).$$

The enthalpies of combustion and formation of acetanilide and urea, W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 3, 487-491 (May-June 1975).

Key words: combustion; enthalpy; formation; heat; secondary standard; thermochemical standard.

The enthalpies of combustion of acetanilide and urea have been determined in an oxygen-bomb calorimeter. The following values and their estimated uncertainties were obtained.

	Acetanilide	Urea
$\Delta Hc°$(25°C)	−4224.88±0.93kJ/mol	−631.78±0.16 kJ/mol
$\Delta Hf°$(25°C)	−209.40±1.00 kJ/mol	−333.39±0.17 kJ/mol

A comparison with previously reported data is given.

The enthalpies of combustion and formation of cholesterol [cholest-5-en-ol (3β)], W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 3, 493-496 (May-June 1975).

Key words: cholesterol; clinical standard; combustion, heat of; enthalpy; formation, heat of; reference material.

The enthalpy of combustion of cholesterol was measured in an adiabatic, rotating-bomb calorimeter capable of high precision with relatively small samples. The random error for the experimental measurements was 0.006 percent which may be compared with approximately 0.3 percent for prior investigations on this substance. The results obtained for the enthalpy of combustion and the derived enthalpy of formation together with the estimated overall uncertainties are:

$$\Delta Hc°(25\ °C) = -16524.0 \pm 3.9\ \text{kJ/mol}$$

$$\Delta Hf°(25\ °C) = -674.8 \pm 4.1\ \text{kJ/mol}$$

The results of prior investigations are discussed briefly.

The third spectrum of copper (Cu III), A. G. Shenstone, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 3, 497-521 (May-June 1975).

Key words: atomic energy levels; atomic spectrum; copper; doubly ionized copper; electron configuration; ionization potential; wavelengths.

An analysis of Cu III based on observations from 500 to 6900 Å is presented. The low structures $3d^9$ and $3d^84s$ are complete, including the rarely, if ever before, found $3d^8(^1S)4s\ ^2S$. The $3d^74s^2$ includes ^4F, ^2F, ^2G, and ^2H but the ^4P, ^2P, $a\ ^2D$, $b\ ^2D$ have eluded all attempts to find them. The ionization potential calculated from $4s$, $5s$, $6s\ ^4F_4 1/2$ is 296 980 cm^{-1} but by a comparison with Ni II which has a longer series an approximate value of 297 140 can be estimated. The $3d^84d$ group is complete, except for one level, as is $5d$ based on ^3F and ^1G, the other $5d$ groups being incomplete. $3d^8(^3F)4f$ is complete and 26 levels based on ^1D, ^3P, ^1G are known. $3d^8(^3F)5g$ is incomplete and a few levels based on ^1D and ^1G have been found. A discussion of the validity of the analysis of Cu IV by J. F. Schröder and Th. A. M. Van Kleef is given.

July-August 1975

Radiance temperature (at 653 nm) of iron at its melting point, A. Cezairliyan and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 4, 541-544 (July-Aug. 1975).

Key words: high-speed measurements; high temperature; iron; melting; normal spectral emittance; radiance temperature.

Radiance temperature (at 653 nm) of iron at its melting point was measured using a subsecond-duration pulse heating technique. Specimens in the form of strips with initially different surface roughnesses were used. The results do not indicate any dependence of radiance temperature (at the melting point) on initial surface or system operational conditions. The average radiance temperature (at 653 nm) at the melting point for 13 specimens is 1670 K on IPTS-68, with a standard deviation of 0.8 K and a maximum absolute deviation of 1.7 K. The total error in the radiance temperature is estimated to be not more than ± 6 K.

Precision measurements of the dimensional stability of four mirror materials, B. Justice, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 4, 545-550 (July-Aug. 1975).

Key words: dimensional stability; glass; glass-ceramic; interferometry.

There are several glasses and glass-ceramics available today which have low coefficients of thermal expansion—some near zero. For this reason they often serve as substrates for massive mirrors in orbit. In order for such a mirror to enjoy a lifetime of 5 years or more of diffraction-limited service, the substrate must be dimensionally stable and thereby preserve the original figure.

Early in 1967, it was decided that the National Bureau of Standards and Corning Glass Works would undertake a joint effort to measure the lengths of small samples of such materials over a period of years. These measurements were completed in 1971.

The average length changes in parts per million of the four materials selected are as follows:

Corning Code 9623 a glass ceramic − 0.30

Corning Code 7971 a titanium silicate − 0.37

Corning Code 7940 a vitreous silica − 0.47

Corning Code 9622 a glass-ceramic − 1.03.

A correlation for the second interaction virial coefficients and enhancement factors for moist air, R. W. Hyland, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 4, 551-560 (July-Aug. 1975).

Key words: enhancement factor; equation of state; interaction virial coefficients; moist air; saturated air; second virial coefficients; virial coefficients.

Experimental measurements of the enhancement factors for mixtures of water vapor and CO_2-free air have been made at − 20, − 10, and + 70 °C. The results, coupled with previous experimental enhancement data, have been used to calculate the second interaction virial coefficients, B_{aw}, for water vapor air mixtures from − 50 to + 90 °C. Within this temperature range, an error analysis shows that the uncertainties in B_{aw} are between 6 and 10 percent. The calculated B_{aw} values are used in deriving enhancement factors at 10 °C intervals for $-50 < t < 90$ °C, at varying pressure intervals from 0.25 to 100 bar. The associated uncertainties are shown as a function of pressure and temperature. The enhancement factors are extrapolated to − 80 °C.

The enthalpies of combustion and formation of thianthrene, W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 4, 561-564 (July-Aug. 1975).

Key words: combustion; enthalpy; formation; heat; secondary standard; sulfur compound; thianthrene.

The enthalpy of combustion of thianthrene (diphenylene disulfide) has been determined in an oxygen-bomb calorimeter. The enthalpy of formation has been derived using data from the available literature. The results obtained are as follows:

$$C_{12}H_8S_2(c) + 17\ O_2(g) + 228\ H_2O(liq) =$$

$$12\ CO_{2(g)} + 2[H_2SO_4 + 115\ H_2O]\ (liq).$$

$$\Delta H_c°(25\ °C) = -7253.27 \pm 1.40\ \text{kJ/mol}$$

$$(-1733.65 \pm 0.33\ \text{kcal/mol}).$$

$$\Delta Hf°(25\ °C) = 184.23 \pm 1.50\ \text{kJ/mol}\ (44.03 \pm 0.36\ \text{kcal/mol}).$$

A comparison is given of the results of this investigation with those of previous investigators.

Unbound water content from application of adsorption theory, W. V. Loebenstein, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 4, 565-576 (July-Aug. 1975).

Key words: adsorption; computer application; desorption;

dry weight determination; moisture content; surface area; water content; water vapor adsorption.

It is standard procedure to fit an applicable isotherm equation to water vapor adsorption data using the method of least squares in arriving at a value for the surface area accessible to the water molecule. The least squares technique has been extended in the present investigation to determine, in addition and simultaneously, a "best value" for the zero-humidity sample weight of the material. The application is equally valid for desorption insofar as the zero-humidity weight is concerned, although the derived value for "surface area" from desorption data will be over-estimated in the general case because of hysteresis. There is no limitation on the range of humidities since the method is not restricted to the BET equation (i.e., between 0.1 and 0.3 r.h.). In fact, good agreement with the zero-humidity points measured experimentally has been obtained even from drying curves in which the relative humidity has been confined to the region above 50 percent. An iterative method is employed in the calculations for which computer assistance is especially adaptable. Fortran IV programs are included in the appendix whose use requires no extensive computer experience. A fraction of a second in computer processing time is all that is required for each determination.

September-October 1975

Surface films on polyoxymethylene single crystals. J. E. Breedon and P. H. Geil, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 609-611 (Sept.-Oct. 1975).

Key words: adsorbed polymer; deformation; fold surface; gold decoration; polymer crystals; poly(oxymethylene); surface layer.

The deformation of single crystals of poly(oxymethylene) grown from 0.01 percent bromobenzene solution has been studied by deposition on a deformable substrate. Slight decoration of the crystal surfaces with gold prior to mechanical deformation of the composite reveals breaks in the gold which are displaced with respect to cracks in the underlying polymer crystals. These observations are interpreted to imply the existence of a very thin discrete film on the surface of the polymer crystals which can slip during deformation. Such a film might arise from polymer molecules adsorbed on the crystal surface.

On the origin of the amorphous component in polymer single crystals and the nature of the fold surface. J. D. Hoffman and G. T. Davis, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 613-617 (Sept.-Oct. 1975).

Key words: adsorbed layer; amorphous component; fold surface; polymer crystals; regular folds.

A model for the surface of folded-chain polymer single crystals is presented in which the "amorphous" phase is composed of polymer molecules physically adsorbed on surface sites of a fairly regularly folded surface. The evidence for the presence of an amorphous phase in polymer single crystals is reviewed briefly as well as the evidence for regular folding and adjacent reentry. The proposed model would allow simultaneous acceptance of the evidence for both an amorphous layer and a surface composed of regularly folded molecules; such evidence was heretofore contradictory. Experimental evidence for such a model is discussed and some predictions are made concerning the properties of such an adsorbed layer.

Some thermodynamic properties of bromobenzene from 0 to 1500 K. J. F. Masi and R. B. Scott, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 619-628 (Sept.-Oct. 1975).

Key words: bromobenzene; calorimetry; enthalpy; entropy; Gibbs energy; heat capacity; heat of fusion; heat of vaporization; thermodynamic properties, triple point.

Measurements were made of the heat capacity of crystalline and liquid bromobenzene from 11 to 300 K, of the triple point and heat of fusion at the triple point and of the heat of vaporization at one temperature. The adiabatic calorimeter used was precise over most of its range to ±0.1 percent; the purity of the sample was 99.998 mol percent. The triple point of pure bromobenzene is 242.401 K (−30.749 °C) ± 0.010°; the enthalpy and entropy of fusion are, respectively, 10702 ± 5 J mol^{-1} and 44.150 ± 0.022 J K^{-1} mol^{-1}. The heat and entropy of vaporization at 293.00 K are, respectively, 43 963 ± 60 J mol^{-1} and 150.0 ± 0.2 J K^{-1} mol^{-1}. Tables are given for the thermodynamic functions of the condensed phases from 0 to 300 K; the functions for the ideal gas from 100 to 1500 K, calculated from spectroscopic and molecular data using statistical mechanical methods, are also tabulated. The entropy of the ideal gas at 293.00 K and one atmosphere, from statistical mechanics, is 323.63 J K^{-1} mol^{-1}; the same quantity from the experimental measurements (third law) is 323.73 J K^{-1} mol^{-1}. No anomalies or additional transitions were observed.

Relativistic effects on line strengths for transitions in the hydrogenic isoelectronic sequence. S. M. Younger and A. W. Weiss, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 629-633 (Sept.-Oct. 1975).

Key words: Dirac theory; hydrogen; line strength; oscillator strength; relativistic corrections; spectroscopy.

Relativistic line strengths have been computed for a large number of transitions using Dirac wave functions for the one-electron, hydrogen-like ions. As expected, the results indicate that relativistic effects are quite small for low stages of ionization. However, in general, they also remain small throughout a large portion of the isoelectronic sequence, becoming typically of the order of 10 percent in the vicinity of $Z = 50$, after which they grow quite rapidly. This suggests that for multielectron ions a basically nonrelativistic theory might well be adequate for light atom isoelectronic ions through as much as 30 or 40 stages of ionization.

The enthalpies of combustion and formation of 2,2′-dichloroethyl sulfide. W. H. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 634-638 (Sept.-Oct. 1975).

Key words: combustion; dichloroethyl sulfide; enthalpy; formation; heat; mustard gas.

The enthalpies of combustion and formation of 2,2′-dichloroethyl sulfide (mustard gas) have been determined by combustion in an adiabatic rotating-bomb calorimeter. The bomb process has been corrected to:

$$C_4H_8Cl_2S(liq) + 7O_2(g) + 98\ H_2O(liq) \rightarrow$$

$$4\ CO_2(g) + [2\ HCl + H_2SO_4 + 100\ H_2O](liq)$$

for which the following values were obtained:

$$\Delta Hc°(25\ °C) = -3163.49 \pm 1.26\ kJ/mol\ and$$

$$\Delta Hf°(25\ °C) = -200.57 \pm 1.58\ kJ/mol.$$

Barothermal theory of two devices for measuring absorption coefficients. H. S. Bennett, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 5, 639-648 (Sept.-Oct. 1975).

Key words: absorption coefficients; barothermal behavior; Green's function; heat diffusion; weakly absorbing materials.

Two devices are proposed for measuring absorption coefficients in weakly absorbing materials. The first device measures cylindrical samples and the second device measures flat plate or disk samples. This paper reports on the derivations for the

steady-state and transient solutions to the heat diffusion equations which describe the barothermal behavior of the two proposed devices. In addition, Green's function techniques are used to describe the cyclic heating and cooling of the cylinders and plates.

November-December 1975

On the growth rate of spherulites and axialites from the melt in polyethylene fractions: regime I and regime II crystallization, J. D. Hoffman, L. J. Frolen, G. S. Ross, and J. I. Lauritzen, Jr., *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 671-699 (Nov.-Dec. 1975).

Key words: axialite; chain folds; crystallization rate; molecular weight; nucleation theory; polyethylene; regime I; regime II; spherulite.

The growth rate G of the crystalline bodies appearing in each of a set of 35 characterized polyethylene fractions ranging from 3600 to 807,000 in molecular weight has been measured as a function of the undercooling ΔT. In isothermal crystallization, only axialites were found from $M_w = 3600$ to 18,000. (For these runs, $\Delta T < 17.5$ °C.) From $M_w = 18{,}000$ to $M_w \cong 115{,}000$ coarse-grained nonbanded spherulites were found for $\Delta T > 17.5$ °C, and axialites for $\Delta T < 17.5$ °C; a rather sharp break occurred in the $\log_{10}G$ versus T data at $\Delta T \cong 17.5$ °C. Above $M_w \cong 115{,}000$, only nearly structureless "irregular" spherulites were found at all undercoolings corresponding to isothermal growth. Typical ringed spherulites were obtained only on quenching. Wide-angle x-ray data showed that the usual orthorhombic subcell predominated in all the morphologies encountered. Low-angle x-ray data showed that the specimens exhibited lamellar crystallization irrespective of the particular gross morphology involved. The growth rate data on each fraction were analyzed using $G = G_o \exp[-U^*/R(T - T_\infty)] \exp[-K_g/T(\Delta T)f]$ where $f \cong 1$ to obtain values of K_g and G_o. The value of Y in $K_g = Yb\sigma\sigma_e/(\Delta h_f)k$ was obtained for each morphology by applying the "Z" test of Lauritzen. $Y = 4$ for regime I crystallization (single surface nucleus leads to completion of substrate) and $Y = 2$ for regime II crystallization (numerous surface nuclei involved in substrate completion). It was found that the axialites obeyed regime I kinetics ($Y = 4$), the coarse-grained spherulites regime II kinetics ($Y = 2$), and the irregular spherulites "mixed" kinetics ($Y \sim 3$). The assumption that the substrate length L in Lauritzen's regime theory was ~ 5 μm led to the prediction of a rather sharp regime I → regime II transition (corresponding to a break in the $\log_{10}G$ versus T data) at $\Delta T \cong 17.5$ °C, in accord with experiment. The $\sigma\sigma_e$ value calculated from K_g and Y for $M_w \geq 20{,}000$ was approximately constant with molecular weight and independent of morphology; the limiting value of $\sigma\sigma_e$ from kinetic measurements was about 1285 erg^2/cm^4, corresponding to $\sigma_{e(\infty)} = 90.5$ erg/cm^2 and $\sigma = 14.2$ erg/cm^2. (This value of $\sigma_{e(\infty)}$ compares favorably with $\sigma_{e(eq)} = 93 \pm 8$ erg/cm^2 from melting point experiments.) The increase of $\sigma\sigma_e$ and σ_e that took place at low molecular weights on up to $\sim 20{,}000$ was treated using an expression given by Hoffman, *viz* $\sigma_e = \sigma_{e(\infty)}[(\nu + \beta_i)/(\nu + 1)]$ where ν = number of folds per molecule, $\beta_i = \sigma_{e(cilium)}/\sigma_{e(\infty)}$. Intermittent high and low values of σ_e were found experimentally in this region, showing that β_i varied intermittently with increasing molecular weight between 0.15 and ~ 0.7. Theoretical estimates of these upper and lower bounds for β_i are given. The variation of σ_e between its upper and lower bounds was tentatively explained in terms of the alternate appearance of short and long terminal cilia, few if any of the latter exceeding l_g^* in length, as the molecular weight increased. Estimates of the initial lamellar thickness l_g^* were made from σ_e, and compared with the appropriate low-angle x-ray spacings. A theoretical estimate of the ratio of the preexponential factors $G_{o(I)}$ and $G_{o(II)}$ for regimes I and II was compared with experiment with satisfactory results. The value of G_o is not strongly dependent upon the viscosity of the melt. The work of chain folding deduced from the growth rate data is close to 4.1 kcal/mol, which is in good agreement with other estimates.

Homogeneous nucleation in polyethylene; molecular weight dependence, G. S. Ross and L. J. Frolen, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 701-711 (Nov.-Dec. 1975).

Key words: chain folds; fractions; homogeneous nucleation; molecular weight; nucleation theory; polyethylene; surface free energies.

The droplet technique was used to obtain estimates of the isothermal rate of homogeneous crystal nucleation in highly supercooled melts of 8 characterized fractions of linear polyethylene (weight average molecular weights from 3,100 to 249,000). The data obtained from these experiments were analyzed in accord with current theories of homogeneous nucleation of chain folded crystals. Values for the quantity $\sigma^2\sigma_e$, where σ and σ_e are the lateral and end-surface free energies of the crystal, were estimated as a function of molecular weight.

Sample 3.2 K was found to be anomalous in its nucleation behavior. When we assume that this sample crystallizes in the extended chain form and calculate σ^3 instead of $\sigma^2\sigma_e$ the value for σ is found to be 10.57 ergs/cm^2 which is in reasonable agreement with the value 9.6 ergs/cm^2 found by other investigators for linear hydrocarbons. However, there remains the question as to whether sample 3.2 K ever underwent homogeneous nucleation.

For samples 9.70 K, 11.74 K and 23.0 K, $\sigma^2\sigma_e$ was found to increase rapidly due to a decrease in the number of cilia per chain fold as the molecular weight increases. For higher molecular weights the value for $\sigma^2\sigma_e$ levels off and the average value of $\sigma^2\sigma_e$ for samples 23.0 K to 249 K was found to be 19,000 ergs^3/cm^6.

The experimental value of the absolute nucleation frequency I_0, was found to differ from the theoretical value by approximately 1×10^{12}. If one assumes that the surface free energies are temperature dependent [i.e., $\sigma = \sigma_1(1 + \bar{x}\Delta T)$ and $\sigma_e = \sigma_{e1}(1 + \bar{y}\Delta T)$ where $\bar{x} = -0.0073$ and $\bar{y} = 0.014$] the average value of $\sigma^2\sigma_e$ changes only slightly (to 19,800 ergs^3/cm^6) due to the compensating effects in the signs of the temperature corrections and I_0 is close to the theoretical value, 1×10^{34} nuclei/cm^3/s.

Absolute isotopic abundance ratios and the atomic weight of a reference sample of potassium, E. L. Garner, T. J. Murphy, J. W. Gramlich, P. J. Paulsen, and I. L. Barnes, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 713-725 (Nov.-Dec. 1975).

Key words: absolute ratios; atomic weight; isotopic abundance; potassium; reference standard.

Solid sample, thermal ionization, mass spectrometry has been used to obtain absolute values for the isotopic abundance ratios of a reference sample of potassium. Standards of known isotopic composition, prepared by gravimetrically mixing nearly isotopically and chemically pure separated isotopes of ^{39}K and ^{41}K, were used for calibration. The absolute isotopic abundance ratios are $^{39}K/^{41}K = 13.8566 \pm 0.0063$ and $^{40}K/^{41}K = 0.0017343 \pm 0.0000061$ which yield atom percent compositions of $^{39}K = 93.2581 \pm 0.0029$, $^{40}K = 0.01167 \pm 0.00004$, and $^{41}K = 6.7302 \pm 0.0029$. The calculated atomic weight for potassium is 39.098304 ± 0.000058. The indicated uncertainties are overall limits of error which are the sum of the uncertainty components for ratio determinations and the components covering the effects of known sources of possible systematic error.

Absolute isotopic abundance ratios and the atomic weight of a reference sample of silicon, I. L. Barnes, L. J. Moore, L. A. Machlan, T. J. Murphy, and W. R. Shields, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 727-735 (Nov.-Dec. 1975).

Key words: absolute ratios; atomic weight; isotopic abundance; silicon.

Absolute values have been obtained for the isotopic abundance ratios of a reference sample of silicon using electron impact mass spectrometry. Samples of known isotopic composition prepared from nearly isotopically pure separated silicon isotopes were used to calibrate the mass spectrometers. The resulting absolute $^{28}Si/^{30}Si$ ratio $= 29.74320 \pm 0.00747$ and the $^{29}Si/^{30}Si$ ratio $= 1.50598 \pm 0.00086$ which yield atom percents of $^{28}Si = 92.22933 \pm 0.00155$, $^{29}Si = 4.66982 \pm 0.00124$ and $^{30}Si = 3.10085 \pm 0.00074$. The atomic weight calculated from this isotopic composition is 28.085526 ± 0.000056. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the means and allowances for the effects of known sources of possible systematic error. A study of natural $^{28}Si/^{30}Si$ ratio variations reported in the literature extends the estimated uncertainty in the atomic weight of natural silicon to $\pm$ 0.00039.

Absolute determination of electrochemical equivalent and the atomic weight of zinc I. Method, apparatus, and preliminary experiments, G. Marinenko and R. T. Foley, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 737-745 (Nov.-Dec. 1975).

Key words: atomic weight; coulometry; electrochemical equivalent; zinc atomic weight.

The use of a specially designed coulometer and a high accuracy coulometric circuit resulted in the accurate measurement of the electrochemical equivalent and atomic weight of zinc. The experimental conditions to make possible the final precise and accurate measurements were established. These include a study of mechanical losses from the anode during the electrolysis and the corrosion of zinc in various media used in the determination. The effects of both of these sources of error may be controlled. Mechanical losses are minimized when an amalgamated electrode is used; corrosion when an amalgamated electrode is used in an air free system. An electrolyte, 25 wt. percent NH_4Cl and 3 molal $ZnCl_2$, was used in these determinations. This report presents the account of research which was prerequisite for subsequent accurate determination of the electrochemical equivalent and the atomic weight of zinc.

Absolute determination of the electrochemical equivalent and the atomic weight of zinc. II. Final determination, G. Marinenko and R. T. Foley, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 747-759 (Nov.-Dec. 1975).

Key words: atomic weight; coulometry; electrochemical equivalent; zinc atomic weight.

A new, successful approach to the determination of atomic weights of suitable elements has been demonstrated in this research. An absolute constant-current coulometric method was employed for the determination of the electrochemical equivalent and the atomic weight of zinc. The effects of possible sources of systematic error were investigated and appropriate corrections applied. The newly determined values of the two constants are 0.3387958 mg C^{-1} and 65.3771 respectively. The uncertainty in the atomic weight of zinc was reduced by more than an order of magnitude. The publication of partial data resulted in the revision of the value of the atomic weight of zinc by the International Union of Pure and Applied Chemistry.

The use of synchrotron radiation as an absolute source of vuv radiation, D. L. Ederer, E. B. Saloman, S. C. Ebner, and R. P. Madden, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 761-774 (Nov.-Dec. 1975).

Key words: irradiances; radiometry; spectrometer calibration; standard source; synchrotron radiation; vacuum ultraviolet.

Synchrotron radiation has been used as a standard source to calibrate spectrographic instruments at the National Bureau of Standards (NBS). Conceptually it is straightforward to apply the calculable continuum distribution of synchrotron radiation to problems requiring a source of known irradiance if the electron energy, the radius of the electron orbit, and the beam current are known. In practice many factors affect the accuracy of such a calibration, such as temporal and spatial variations in electron beam, uncertainties in the orbital radius and maximum energy of the orbiting electron beam. These sources of error are discussed and the method of calibration on SURF-I is specified. A storage ring synchrotron radiation facility (SURF-II) is now operational at NBS. The calibration techniques developed for SURF-I are applied to SURF-II with anticipated improvements in calibration accuracy. For SURF-I the incident flux was determined with an accuracy of 15 percent while for SURF-II we anticipate accuracies of about 7 percent.

Corrections to paper entitled "Third Virial Coefficient for Air-Water Vapor Mixtures," R. W. Hyland and E. A. Mason, *J. Res. Nat. Bur. Stand. (U.S.)*, **79A** (Phys. and Chem.), No. 6, 775-776 (Nov.-Dec. 1975).

Key words: chemical association; Lennard-Jones potential parameters; third interaction virial coefficients; virial coefficients; water vapor-air mixtures.

This note points out errors in the values of the third virial coefficients for pure water vapor which appeared in a 1967 paper by Hyland and Mason. The errors arose while converting from the units of Goff and of Keyes to the desired units of $(l/mol)^2$. The consequences of the errors are outlined, and it is shown that there is no effect on the primary results of the paper, namely, in the preferred values of the third interaction virial coefficient for air-water vapor mixtures, C_{aww}.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 80A, JANUARY-DECEMBER 1976

January-February 1976

Line strengths and lifetimes of levels in neutral uranium, C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 1-7 (Jan.-Feb. 1976).

Key words: lifetimes in U I; oscillator strengths for U I; transition probabilities for U I; uranium spectrum.

Relative intensities of 549 U I lines observed in a dc copper arc are used to derive transition probabilities and oscillator strengths. Upper limits to lifetimes for 65 levels in neutral uranium atoms are determined.

Optical properties of nuclear matter, J. S. O'Connell, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 9-13 (Jan.-Feb. 1976).

Key words: absorption cross section; index of refraction; nuclear matter; optical properties; photon; plasma frequency.

The index of refraction and absorptive properties are estimated in nuclear matter consisting of protons and neutrons and in nuclear matter charge neutralized by electrons.

A study of the polarization of fluorescence of ordered systems with application to ordered liquid crystals, E. D. Cehelnik, K. D. Mielenz, and R. B. Cundall, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 15-33 (Jan.-Feb. 1976).

Key words: fluorescence; linear dichroism; liquid crystals; polarization; spectrofluorimetry; 1,6-diphenyl-1,3,5-hexatriene.

The fluorescence polarization of uniaxial molecules dissolved in an ordered medium is studied. A theoretical model is developed which relates the polarization of the fluorescence emission to molecular structure, orientation of absorption and emission dipole oscillators and the degree of ordering. This theory was tested experimentally using all trans 1,6-diphenyl-1,3,5-hexatriene dissolved in an ordered liquid crystal.

PVT and vapor pressure measurements on ethane, G. C. Straty and R. Tsumura, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 35-39 (Jan.-Feb. 1976).

Key words: density; ethane; vapor pressure; *PVT*.

New measurements of the vapor pressures and *PVT* properties of ethane are reported. *PVT* determinations have been made from near the triple point to 320 K at pressures to 33 MPa. The density range investigated extends to more than three times the critical density. The new measurements of the vapor pressures of ethane extend from 160 K to near the critical point.

Functional equations for the enhancement factors for CO_2-free moist air, L. Greenspan, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 41-44 (Jan.-Feb. 1976).

Key words: enhancement factor; moist air; saturated air.

Equations are presented which explicitly express the enhancement of water vapor in CO_2-free air from 0.1 to 2 MPa. The equations are approximations to the formulation of Hyland and provide the means of obtaining enhancement with very modest computational facilities. The agreement with Hyland's enhancement values is well within his estimated uncertainty.

Experimental values for the elastic constants of a particulate-filled glassy polymer. J. C. Smith, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 45-49 (Jan.-Feb. 1976).

Key words: composite materials; elastic constants; filled polymers; mechanical properties; particulate composites; Poisson's ratio; Young's modulus.

Young's modulus and Poisson's ratio have been measured simultaneously on a series of particulate composites containing volume fractions of filler up to 0.50. The composites consisted of small glass spheres imbedded in rigid epoxy polymer matrix. The measured values were compared with theoretical values calculated from current theories. A recently generalized and simplified version of van der Poel's theory provided the best agreement. It predicted values of Young's modulus for composites with filler volume fractions up to 0.35. Measured values of Poisson's ratio exhibited scattering, but were consistent with values calculated from van der Poel's theory.

Heat capacities of polyethylene IV. High molecular weight linear polyethylene, S. S. Chang, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 51-57 (Jan.-Feb. 1976).

Key words: glass transition; heat capacity; high molecular weight linear polyethylene; polyethylene; temperature drift; thermodynamic properties.

A high molecular weight linear polyethylene sample has been studied by adiabatic calorimetry from 10 to 380 K. Two broad temperature regions of unusual spontaneous temperature drift have been observed. The phenomena occurring around 240 K are similar to that observed in other polyethylene samples studied in this series, and are presumed to be caused by the relaxational processes in the amorphous phase. The weak exothermic behavior occurring around 160 K is presumed to be caused by the stabilization of the quenched sample.

Computer simulation of metastable fluid states in the Lennard-Jones system, H. J. Raveché and W. B. Streett, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 1, 59-64 (Jan.-Feb. 1976).

Key words: glassy state; Lennard-Jones system; Monte Carlo simulation; nucleation; overcompression; supercooling.

[1] The various NBS publications series are grouped under subheadings within this section. The several volumes of the Journal of Research are presented consecutively within their appropriate subheadings. If a particular publications series is sought, consult the table of contents or the edge index on the back cover.

Using the Monte Carlo method in statistical mechanics, we have simulated high density metastable states. We find that nucleation from a three dimensional fluid array to a crystalline solid is possible, but that periodic boundary conditions and the small size of the system inhibit the formation of perfect crystals. Evidence for the existence of an amorphous solid state has also been observed, and the pair correlation function of this state exhibits some of the features associated with random close-packed aarays of hard spheres. The possible relation between these simulations and the formation of glassy states in real systems is briefly discussed.

Relative enthalpy of solid beryllium aluminate (chrysoberyl), $BeO \cdot Al_2O_3$, from 1175 to 2025 K, and of liquid beryllium aluminate from 2170 to 2350 K, S. Ishihara and E. D. West, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 1, 65-73 (Jan.-Feb. 1976).

Key words: beryllium aluminate; chrysoberyl; drop calorimetry; enthalpy measurements; high temperature calorimetry; specific heat; thermodynamic properties.

The relative enthalpy of solid beryllium aluminate $BeO \cdot Al_2O_3$ from 1180 to 2025 K and liquid beryllium aluminate from 2170 to 2350 K was measured by "drop" calorimetry using an adiabatic "receiving type" calorimeter. The thermodynamic functions from 1175 to 2025 K and the enthalpy of melting at 2146 K are reported.

March-April 1976

Extinction coefficients of NO_2 and N_2O_4, A. M. Bass, A. E. Ledford, Jr., and A. H. Laufer, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 143-166 (Mar.-Apr. 1976).

Key words: absorption: extinction coefficients; N_2O_4; NO_2; spectra; temperature effects.

The extinction coefficient of NO_2 has been measured in the spectral range 185 to 410 nm as a function of temperature between 235 and 298 K. In order to correct for the effect of the dimer absorption, the extinction coefficient of N_2O_4 has also been measured. The effect of a decrease in temperature upon the NO_2 absorption is a reduction in the extinction coefficient of approximately 10 percent in the range 320 to 380 nm.

A study of the chemiluminescence of the $Pb + O_3$ reactions, M. J. Kurylo, W. Braun, S. Abramowitz, and M. Krauss, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 167-171 (Mar.-Apr. 1976).

Key words: chemiluminescence; electronic states; gas kinetics; laser enhanced reactions; O_3; PbO.

The chemiluminescent reaction of $Pb + O_3$ has been studied using both "cold" an dvibrationally excited O_3. Emission from new states *a* and *b* has been observed in addition to the A and B states. The reaction of vibrationally excited O_3 with Pb to yield PbO(A) appears to be faster than that using "cold" O_3.

Structure- and solvent-property relationships for the electronic energies of charge-transfer complexes between certain benzene derivatives, H. Argentar, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 173-187 (Mar.-Apr. 1976).

Key words: aromatic amine; benzene derivative; charge-transfer complex; dental materials; electron affinity; electron spin resonance spectroscopy; extrathermodynamic relationships; ionization potential; linear free-energy relationship; polarography; solvatochromic relationship; ultraviolet and visible spectroscopy.

A chemical model is proposed for describing charge-transfer complexes between aromatic amines and electron-accepting benzene derivatives containing a group having a double- or triple-bond conjugated with the benzene ring. According to this model, an electron migrates from the nitrogen atom of the amine to one of the atoms of the multiple-bonded group during charge-transfer interaction.

Structure-property relationships were derived for correlating: (1), the transition energies of the complexes; (2), the ionization, or oxidation, potentials of the amines, and (3), the electron affinities or reduction potentials of the electron acceptors, with the electron-donating abilities of the substituents of the various compounds. Transition energies calculated from reported spectroscopic data for these complexes were correlated using equations derived in this study. Similarly correlated were reported data for the above properties of the amine and electron acceptor.

Equations were derived for correlating the effect of variation in solvent on the transition energies of the complexes. Correlation of reported spectroscopic data indicated that the greatest effect is caused by variation in the refractive index; of secondary importance was the change in dielectric constant.

Bidirectional reflectometry. Part I. A high resolution laser bidirectional reflectometer with results on several optical coatings, J. J. Hsia and J. C. Richmond, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 189-205 (Mar.-Apr. 1976).

Key words: barium sulphate; bidirectional reflectance; bidirectional reflectometer; black coating; gonioreflectometer; magnesium oxide; mu sulphur; reflectance; reflectometer; sodium chloride.

A laser-source bidirectional reflectometer that is fully automated and has angular resolution on the order of one degree has been designed and built. The direction of incidence and viewing can be independently varied over an entire hemisphere except for directions more than 77.5° from the normal, and the two directions must be at least 2.5° apart. Bidirectional reflectances for 15 samples of black and white coatings are presented.

Bidirectional reflectometry. Part II. Bibliography on scattering by reflection from surfaces, J. C. Richmond and J. J. Hsia, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 207-220 (Mar.-Apr. 1976).

Key words: bibliography; emittance; heat transfer; measurement techniques; periodic surfaces; polarization; random surfaces; reflectance; reflectance of coherent radiation; scattering; scattering theory; surface roughness; transmittance.

In connection with the work on development of a high resolution laser source bidirectional reflectometer, a large number of papers were collected dealing with various aspects of the geometrical distribution of the radiant energy reflected from surfaces of different types.

Each paper has been classified into one or more classes on the basis of its technical content. There are eight general classes, with several subclasses in some of the general classes.

Because of the interest in this field, the bibliography is being published as a service to the public.

Energy levels, classified lines, and Zeeman effect of neutral thorium, R. Zalubas, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 2, 221-358 (Mar.-Apr. 1976).

Key words: energy levels; thorium; Th I; wavelengths; Zeeman-effect of Th I.

A list of about 9500 classified lines of Th I in the range 2345-29 662 Å is given. Lines in the range 2345-9239 A were observed and measured at NBS. Zeeman effect data for 2281 lines are listed. Lists of 254 even and 322 odd levels including their g values are presented. Among them there are 72 new levels, which were not contained in earlier publications.

May-June 1976

Fluorescence quantum yield measurements, J. B. Birks, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 3, 389-399 (May-June 1976).

Key words: fluorescence lifetime; fluorescence quantum efficiency; fluorescence quantum yields; fluorescence spectrum; fluorescence standards; molecular fluorescence parameters; observed (technical) fluorescence parameters; polarization; radiative and nonradiative transition probabilities; real fluorescence parameters.

Four *molecular fluorescence parameters* describe the behavior of a fluorescent molecule in very dilute ($\sim 10^{-6}$ M) solution: (i) the fluorescence spectrum $F_M(\bar{\nu})$; (ii) the fluorescence polarization P_M; (iii) the radiative transition probability k_{FM}; and (iv) the radiationless transition probability k_{IM}. These parameters and their temperature and solvent dependence are those of primary interest to the photophysicist and photochemist. $F_M(\bar{\nu})$ and P_M can be determined directly, but k_{FM} and k_{IM} can only be found indirectly from measurements of the secondary parameters, (v) the fluorescence lifetime τ_M, and (vi) the fluorescence quantum efficiency q_{FM}, where $k_{FM} = q_{FM}/\tau_M$ and $k_{IM} = (1 - q_{FM})\tau_M$.

The *real fluorescence parameters* $F(\bar{\nu})$, τ and ϕ_F of more concentrated ($c > 10^{-5}$ M) solutions usually differ from the molecular parameters $F_M(\bar{\nu})$, τ_M and q_{FM} due to concentration (self) quenching, so that $\tau > \tau_M$ and $\phi_F < q_{FM}$. The concentration quenching is due to excimer formation and dissociation (rates $k_{DM}c$ and k_{MD}, respectively) and it is often accompanied by the appearance of an excimer fluorescence spectrum $F_D(\nu)$ in addition to $F_M(\bar{\nu})$, so that $F(\bar{\nu})$ has two components. The *excimer fluorescence parameters* $F_D(\bar{\nu})$, P_D, k_{FD} and k_{ID}, together with k_{DM} and k_{MD}, and their solvent and temperature dependence, are also of primary scientific interest.

The *observed* (technical) *fluorescence parameters* $F^T(\bar{\nu})$, τ^T and $\phi_F{}^T$ in more concentrated solutions usually differ from the real parameters $F(\bar{\nu})$, τ and ϕ_F, due to the effects of self-absorption and secondary fluorescence. The technical parameters also depend on the optical geometry and the excitation wavelength. The problems of determining the real parameters from the observed, and the molecular parameters from the real, will be discussed.

Methods are available for the accurate determination of $F^T(\bar{\nu})$ and τ^T. The usual method of determining $\phi_F{}^T$ involves comparison with a reference solution R, although a few calorimetric and other absolute determinations have been made. For two solutions excited under identical conditions and observed at normal incidence

$$\phi_F{}^T/\phi_{FR}{}^T = n^2 \int F^T(\bar{\nu})d\bar{\nu}/n_R{}^2 \int F_R{}^T(\bar{\nu})d\bar{\nu}$$

where n is the solvent refractive index.

Two reference solution standards have been proposed, quinine sulphate in N H_2SO_4 which has no self-absorption, and 9,10-diphenylanthracene in cyclohexane which has no self-quenching. The relative merits of these solutions will be discussed, and possible candidates for an "ideal" fluorescence standard with no self-absorption and no self-quenching will be considered.

Some methods of luminescence efficiency measurements, A. Bril and A. W. de Jager-Veenis, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 3, 401-407 (May-June 1976).

Key words: cathode-ray excitation; luminescence; luminescence standards; phosphors; quantum efficiencies; radiant efficiencies; UV excitation; x-ray excitation.

Methods of absolute and relative radiant and quantum efficiency measurements are described for ultraviolet, visible, cathode-ray and x-ray excitations. Data on some standard luminescent materials are given.

On the actinometric measurement of absolute luminescence quantum yields, J. N. Demas and B. H. Blumenthal, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 3, 409-412 (May-June 1976).

Key words: absolute yield; chemical actinometry; correction factors; luminescence; quantum-flat actinometer; quantum yield.

The theory of the measurement of luminescent quantum yields using chemical actinometry is described. The sample's emission intensity is measured by nearly completely surrounding the sample with an actinometer solution, and the excitation intensity is directly measured with the same type of actinometer. The ratio of the measured sample emission intensity corrected for the fraction escaping through the excitation ports to the measured excitation intensity is the absolute luminescence yield. Equations, a suitable cell design, and computer calculated correction factors for different cell dimensions and optical densities are given. The absolute yield of the actinometer is not needed, only its relative response with wavelength. New quantum-flat actinometers which should greatly simplify the measurements are described.

The calorimetric detection of excited states, J. B. Callis, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 3, 413-419 (May-June 1976).

Key words: absolute quantum efficiency; absolute quantum yield; calorimetry; luminescence; photoacoustic spectrometer; piezocalorimeter; transducers; triplet formation.

Calorimetric techniques offer the photophysicist and photochemist the opportunity to measure a number of parameters of excited states which may be difficult to obtain by other techniques. The calorimetric strategy seeks to measure the heating of a sample resulting from radiationless decays or chemical reactions of excited states. Heating is best measured through volume and pressure transducers, and four calorimeters based on these are described. With calorimetric instrumentation one can perform measurements on samples in the gas, liquid and solid phases over a wide temperature range. Moreover time dependent processes with time constants ranging from microseconds to seconds are amenable to study. Examples of the application of calorimetric techniques to the determination of quantum yields of fluorescence, triplet formation and photochemistry are given.

Fluorescence efficiency of laser dyes, K. H. Drexhage, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 3, 421-428 (May-June 1976).

Key words: aminocoumarins; carbazine dyes; deuterium effect; fluorescence quantum yield; laser dyes; molecular structure; oxazine dyes; quenching; xanthene dyes.

The fluorescence efficiency of xanthene dyes, oxazine dyes, and 7-aminocoumarins is discussed. Relations with the molecular structure are pointed out and dependence on solvent and temperature is explained. Several new fluorescence standards are suggested.

Oscillator strengths for lines of ionized uranium (U II), C. H. Corliss, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 429-438 (May-June 1976).

Key words: oscillator strengths for U II; transition probabilities for U II; uranium spectrum.

Oscillator strengths for 49 lines of U II recently measured by Voight can be used to calibrate the intensity scale of the U II lines in the NBS Tables of Spectral-Line Intensities and derive a larger set of oscillator strengths of lower precision but consistent with the new measurements. The standard deviation of the differences between the two sets of *gf*-values for the 49 lines is 29 percent. Oscillator strengths of that precision are given for 776 additional lines from the NBS Intensity Tables. The uncertainty in absolute value is 67 percent.

Cancer detection by NMR in the living animal, I. D. Weisman, L. H. Bennett, L. R. Maxwell, Sr., and D. E. Henson, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 439-450 (May-June 1976).

Key words: cancer; mice; NMR; spin-lattice relaxation; spin-spin relaxation.

The purpose of this paper is to review *in vivo* NMR experiments on a transplantable tumor in mice and to discuss the feasibility of using noninvasive NMR for cancer detection in humans.

Modulus of natural rubber cross-linked by dicumyl peroxide. III. Some molecular interpretations, possible refinements of theory, and conclusions, L. A. Wood, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 451-463 (May-June 1976).

Key words: cross-linking of rubber; dicumyl peroxide; elasticity theory of rubber; entanglements in rubber; gel point; modulus of rubber; molecular interpretation of rubber elasticity; rubber elasticity; statistical theory of rubber elasticity; swelling of rubber network.

The shear modulus $G = 5.925 \times 10^{-3}(fp - 0.45)T + G^*$ (Part I), its energy component $G^* = 0.0684\ (fp - 0.45) + 2.70$ (Part II), and the number of effective sub-chains per unit volume $\nu_e = (G - G^*)/RT$ are given detailed molecular consideration. G is given in Mdyn cm^{-2} for rubber cross-linked by adding p parts of dicumyl peroxide per hundred of rubber, and heating until a fraction f of the peroxide is decomposed. ν_e is found to be approximately twice the density of cross-links, after a correction for impurities and chain ends is made. It cannot be computed as G/RT since only the entropy component of modulus is related to ν_e. The sub-chains for the most highly cross-linked rubbers studied had a molecular weight of about 575 g mol^{-1}, corresponding to about 8 isoprene units. The modulus corresponding to no added cross-links is not zero. It is determined chiefly by the energy component of the modulus; it does not arise from entanglements. The "front factor" is found to be unity.

An extensive literature survey yields values of the quantity $RT\Psi(\nu_2)$, where $\Psi(\nu_2)$ is the Flory-Rehner equation function of ν_2, the equilibrium volume fraction obtained by swelling the cross-linked rubber. $RT\Psi(\nu_2)$ is found to be greater than $G - G^*$, but not as large as G itself.

Calculations of configurations of doubly ionized copper (Cu III), J. Sugar and W. C. Martin, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 465-476 (May-June 1976).

Key words: atomic energy levels; atomic spectra; atomic theory; copper; doubly ionized copper; electron configuration.

The energy levels belonging to the configurations $3d^74s^2$ and $3d^8nl$ ($nl = 4s, 5s, 4p, 5p, 4d, 5d, 4f$, and $5g$) have been calculated. The radial energy integrals were treated as parameters and adjusted to give a least-squares fit to the observed levels. Two- and three-body effective electrostatic interactions for equivalent electrons were included, as well as two-body effective interactions for inequivalent electrons. Strong configuration interaction between $3d^74s^2$ and $3d^84d$ was taken into account. Values of the parameters are given for all the above configurations, and the calculated levels are given for all except $3d^84s$ and $3d^84p$ (for which essentially equivalent results have been published). Leading eigenvector percentages are given in appropriate coupling schemes.

The International Practical Temperature Scale of 1968 in the region 90.188 K to 903.89 K as maintained at the National Bureau of Standards, G. T. Furukawa, J. L. Riddle, and W. R. Bigge, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 477-504 (May-June 1976).

Key words: comparator; International Practical Temperature Scale of 1968; IPTS-68; oxygen point; platinum resistance thermometer; temperature standard; tin point; triple point of water; zinc point.

The reproducibility of the International Practical Temperature Scale of 1968 (IPTS-68) in the region 90.188 K to 903.89 K as maintained at the National Bureau of Standards is discussed. The realizations of the triple point of water, the freezing points of zinc and tin, and the boiling point of oxygen are described. The average of the standard deviations of the resistance measurements at the triple point of water of 213 platinum resistance thermometers received for calibration over a two-year period corresponds to ± 0.15 mK. The standard deviations of the resistance ratio $R(T)/R(0\ ^\circ C)$ obtained with check thermometers employed for monitoring the zinc, tin, and oxygen point measurements correspond to ± 0.28 mK, ± 0.30 mK, and ± 0.16 mK, respectively; the results of repeated calibrations with five thermometers show comparable reproducibility at the tin and oxygen points but the reproducibility is worse by a factor of two at the zinc point. When suitably packed for protection from possible mechanical shock platinum resistance thermometers can be shipped by common carrier and retain their calibrations.

Vapor pressure of water at its triple point, L. A. Guildner, D. P. Johnson, and F. E. Jones, *J. Res. Nat. Bur. Stand. (U.S.),* **80A** (Phys. and Chem.), No. 3, 505-521 (May-June 1976).

Key words: precision mercury manometer; triple point of water; vapor pressure of water.

The vapor pressure of water at its triple point was measured with exceptionally high accuracy by realizing it with a special apparatus and measuring the pressure with the NBS precision mercury manometer. The vapor pressure apparatus had a system for circulating the liquid water. Actual triple point conditions were established with a thin sheet of freshly distilled liquid flowing down over an exposed mantle of ice frozen on a vertical well. This technique reduced nonvolatile contaminants and the vapor was repeatedly pumped to remove accumulated volatile contaminants. A diaphragm pressure transducer was used to separate the water vapor from the helium used to transmit the pressure to the manometer. The value found for the vapor pressure of water at its triple point was 611.657 Pa with an uncertainty of ± 0.010 Pa from random errors, computed at 99 percent confidence limits. The systematic errors are estimated to be insignificant relative to the random errors.

July-August 1976

Diffuse reflectance spectroscopy; applications, standards, and calibration (with special reference to chromatography), R. W.

Frei, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 551-565 (July-Aug. 1976).

Key words: chromatography; color matching; color measurement; diffuse reflectance; Kubelka-Munk function; reflectance; reflectance standards; thin layer chromatography.

The multitude of areas in which diffuse reflectance spectroscopy can be applied has been described in several books and reviews and ranges from color measurements of textiles, pharmaceuticals, building materials, paper and pulp materials, etc., to adsorption studies and other basic investigations in physical, inorganic and organic chemistry.

The major area of application is still the measurement of color which has become indispensible in the quality control of colored products, dyes and pigments. Color matching practices and techniques with sophisticated instrumentation which can be fully computerized as well as the use of simpler filter instruments for quality control are mentioned.

Transferability of reflectance data i.e., color coordinates, depends on the quality of standards particularly when absolute measurements are desired. The difficulty of finding suitable "white standards" with good reflection properties at low UV and with a good long term stability is discussed. Similar arguments hold for sphere coating materials. For the measurement of fluorescing surfaces suitable standards are lacking which renders transfer of such data almost impossible.

The usefulness of diffuse reflectance techniques to study adsorption phenomena on small particle adsorbents is demonstrated with a malachite green-*o*-carboxylic acid lactone system studied by Kortüm. This or similar systems could be adopted to the measurement of relative surface areas on certain chromatographic adsorbents yielding more realistic values than the BET-method.

The most recent area of application has been in the field of chromatography for the in situ evaluation of chromatographic zones in flat-bed chromatography, electrophoresis and isoelectric focusing.

In chromatography, standardization is less problematic since usually relative measurements are sufficient. On the other hand one has to find suitable calibration procedures. The use of the Kubelka-Munk function is often questionable since we are usually not dealing with layers of infinite thickness and below 300 nm the conventional adsorbents such as silica gel, alumina or cellulose are strongly absorbing. Experiences with a new function combining the laws of Kubelka-Munk and Lambert-Beer are therefore presented.

The problem is also to find calibration techniques which account for chromatographic parameters. Until recently it was believed that a quantitative evaluation of chromatograms required a number of reference zones to be developed on the same chromatogram. In our experience this is no longer true. A novel calibration technique which utilizes the concept of transferable calibration factors is discussed. With this approach a quantitative evaluation of a chromatogram with only one reference spot is possible. Here again scanning and data acquisition can be fully automated. The application of proper calibration procedures to differential reflectance techniques and the measurement of multicomponent systems is briefly mentioned.

Finally it is demonstrated that it is possible to carry out in situ quantitative measurements on low UV absorbing compounds (down to 190 nm) separated on silica gel surfaces, provided suitable techniques and instrumentation are used.

The interpretation of diffuse reflectance spectra, H. G. Hecht, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 567-583 (July-Aug. 1976).

Key words: absolute absorptivities; continuum models; diffuse reflectance; radiative transfer; reflectance spectra; scattering coefficients; statistical models.

Numerous treatments of the diffuse reflecting properties of scattering media have been described. Many theories give an adequate account of the reflectance for a specific set of conditions for which the model was constructed and the solution tested experimentally. Only those models which are considered to be fairly general are considered here.

It is convenient to divide the theories into those based upon continuum models and those based upon statistical models. The continuum models typically describe the scattering and absorbing properties of a given medium in terms of two phenomenological constants. These models may all be regarded as varying levels of approximate solution to the general equation of radiative transfer. This provides a convenient basis for comparison of the various theories.

The statistical models are based upon a summation of transmittances and reflectances from individual layers or particles. Thus, some assumptions must be made about the nature of the fundamental units, and the validity of the ultimate result will depend upon how closely these assumptions correspond with reality. Only the statistical models lead to expressions from which absolute absorptivities and scattering coefficients can be calculated and related to the actual particle characteristics.

The relationship between the various models will be discussed and the features which typify the absorptivity and scattering coefficient according to each will be compared and related to the available experimental data. This leads to a consideration of the characteristics of appropriate model sytems and standards.

Calibration of reflectance standards, W. Budde, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 585-595 (July-Aug. 1976).

Key words: barium sulfate; diffuse reflectance spectra; magnesium oxide; opal glass; radiant flux; reflectance standards; standards calibration.

Measurements of the diffuse spectral reflectance are usually not made as direct measurement of the incident and the reflected radiant flux but rather as measurements relative to a standard of known reflectance value.

For the calibration of such standards, different methods have been described in the literature: 1. Goniophotometric methods also called Indicatrix methods or point-by-point methods; 2. Methods based on the Kubelka-Munk theory; 3. Integrating sphere methods according to Taylor, Benford, Sharp-Little, van den Akker, Korte.

Various materials such as magnesium oxide, barium sulfate or opal glass are being used as standards. Their suitability as transfer or as working standards will be discussed.

The results of comparative measurements between some of these methods will be given.

Understanding bidirectional reflectance and transmission for spac applications, J. B. Schutt, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 597-603 (July-Aug. 1976).

Key words: bidirectional radiometry; canopies; diffus reflectance; diffuse transmission; reflectance standards scattering surfaces.

Applications for optical diffusers in space projects are presented which include the functions of reflection, transmittance, and collection. These modes encompass such diverse uses as temperature regulation and ozone concentration monitors. Discussed is the cooperative aspect of diffuse reflectance and environmental stability. Magnesium oxide, sodium chloride and barium sulphate are evaluated in some detail. The importance of scene scattering behavior to modeling the earth's radiation budget and in determining thermal inertias of the earth's surface are discussed, because solar albedo serves as the weighting function in the solar input irradiance. Finally, work in the area of canopy reflectance modeling is reviewed with verification data included whenever available. Some knowledge of the bidirectional reflectance properties of vegetation is necessary for identification, acreage computations, and scene transferrance.

Standardization of light scattering measurement in conjunction with immunochemical analysis, G. J. Buffone, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 605-608 (July-Aug. 1976).

Key words: antibodies; antigens; biological polymers; immunochemical analysis; light scattering; polymers; proteins; solid standards.

Light scattering methods for the physical analysis of synthetic and biological polymers necessitates the use of scattering standards and absolute light scattering measurements. Standardization has not been employed when light scattering has been used to monitor immunochemical reactions using a kinetic or thermodynamic mode.

The concentration of a specific protein present in a complex matrix such as urine, serum or cerebrospinal fluid, is measured by reacting the protein of interest with its specific antibody and then measuring the excess light scattering of the solution produced by the formation of antigen antibody complexes. The lack of established light scattering standards in the area of immunochemical measurements make instrumental quality control difficult and has hindered direct comparison of data among investigators. Both solid and liquid light scattering standards would be necessary to encompass the wide range of instrumentation currently in use. Several solid standards which have been used in the past include reflecting diffusers such as vitrolite, magnesium carbonate crystal, casein paint on vitrolite, and solid opal glass transmitting diffusers such as flashed opal glass and solid opal glass. These standards, while applicable to manual light scattering photometers, are not suitable for recently developed automated instrumentation. Liquid standards in the form of Ludox®, solutions of polystyrene, suspensions of small diameter latex spheres and even pure organic solvents could be used more easily with the continuous flow and discrete automated analyzers. The introduction of instrumental standards at this level of analysis would result in improved overall quality control and facilitate data and method comparison between laboratories.

Errors in spectrophotometry and calibration procedures to avoid them, A. G. Reule, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 609-624 (July-Aug. 1976).

Key words: bandwidth; calibration; errors in spectrophotometry; interferences; multiple reflections; photometric linearity; polarization; sample characteristics; straylight; wavelength accuracy.

Based on simple principles, spectrophotometry nevertheless demands a lot of precautions to avoid errors. The following properties of spectrophotometers will be discussed together with methods to test them: spectral properties – wavelength accuracy, bandwidth, stray light; photometric linearity; interactions between sample and instrument – multiple reflections, polarization, divergence, sample wedge, sample tilt, optical path length (refractive index), interferences.

Calibration of master instruments is feasible only by complicated procedures. With such a master instrument standards may be calibrated which greatly simplify performance checks of instruments used for practical work. For testing high quality spectrophotometers the use of emission lines and nearly neutral absorbing solid filters as standards seems to be superior, for some kinds of routine instruments the use of absorption bands and liquid filters may be necessary.

Standardization in transmission spectrophotometry in the visible and ultraviolet spectral regions, A. R. Robertson, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 625-630 (July-Aug. 1976).

Key words: errors in spectrophotometry; photometric scale; slit width; spectral transmission; spectrophotometer standards; stray light; wavelength scale.

In an instrument as complex as a spectrophotometer there are many potential sources of error. Because of this it is useful to have available standard materials whose spectral transmittances are known accurately. Periodic measurement of such standards provides a useful indication of whether a spectrophotometer is producing accurate results.

If the spectral transmittance functions of these standards are chosen suitably, the measurements can provide diagnostic information to indicate what type of error is occurring. Among the factors that most often lead to errors in spectrophotometry are the slit-width, the wavelength scale, the photometric scale, and stray radiation. Suitable material standards can provide indications of the occurrence of these errors. However it is sometimes difficult to identify a particular error since often several errors will occur at the same time.

Several sets of standards for testing spectrophotometers are available or can be constructed easily. Most of these are glass filters, but interference filters, perforated screens, and rotating sectors are also used. Liquid filters have some advantages, especially in the ultraviolet where glass filters absorb too strongly to be useful. However difficulties in preparing and handling liquid filters can introduce uncertainties.

It is important that standard materials are insensitive to environmental conditions (such as temperature) and that they are stable over a long period of time. Unfortunately, many of the materials with the most suitable spectral characteristics are least suitable in these respects, and it would be very useful if new and better materials could be developed.

Acidic potassium dichromate solutions as ultraviolet absorbance standards, R. W. Burke and R. Mavrodineanu, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 631-636 (July-Aug. 1976).

Key words: absorbance linearity; accuracy; acidic potassium dichromate solutions; calibration of ultraviolet spectrophotometers; liquid filters; transfer standards; ultraviolet absorbance standards.

The absorbances of five concentrations of potassium dichromate in 0.001 *M* perchloric acid have been determined at eight wavelengths in the ultraviolet on the National Bureau of Standards Institute for Materials Research high-accuracy spectrophotometer. Four of the wavelengths – 235, 257, 313, and 350 nm – correspond to absorbance maxima or minima in the $HCrO_4^-$ spectrum and are useful wavelengths for checking the accuracy of the absorbance scale of narrow bandpass spectrophotometers. Although partial dimerization of $HCrO_4^-$ to

$Cr_2O_7^=$ produces small positive deviations from Beer's law at these wavelengths, the apparent absorptivities calculated for each concentration are reproducible to one part in a thousand. The estimated uncertainties in the absorptivity values are ±0.7 percent at 0.1 absorbance (A) and ±0.2 percent near $A = 1$. These uncertainties include all known sources of possible systematic error and the 95 percent confidence level for the mean. The remaining four wavelengths used for measurement are near two predicted isosbestic points in the $HCrO_4^-/Cr_2O_7^=$ spectra. The absorptivities at 345 nm are sufficiently independent of concentration that this wavelength can be used for checking absorbance linearity to one part in a thousand over the range $A = 0.2 - 1$.

Considerations for the use of semitransparent metallic thin films as potential transmittance standards in spectrophotometry, R. Mavrodineanu, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 637-641 (July-Aug. 1976).

Key words: evaporated metal-on-quartz; filters, transmittance; neutral filters; standard reference materials; transmittance characteristics; ultraviolet-visible filters.

Various characteristics of evaporated metal-on-fused silica filters are discussed in relation to their optical transmission properties. Special metal holders provided with shutters were designed to be used with these filters, and are described in detail. Transmittance measurements, performed in various conditions, are reported and indicate that the evaporated metal-on-fused silica filters might present an acceptable material as transfer standards in spectrophotometry.

Structure-related optical characteristics of thin metallic films in the visible and ultraviolet, H. E. Bennett and J. L. Stanford, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 643-658 (July-Aug. 1976).

Key words: absorption; dielectric layers; irregularities; metallic thin films; microirregularities; overcoating; plasmons; scatter.

Surface irregularities and crystalline order strongly influence both the scattered light and absorption of metallic films. These effects extend through all spectral regions but are particularly important in the visible and ultraviolet. Scattered light arises from several scattering mechanisms. Macroscopic irregularities such as dust, scratches and particulates are typically much less important than are microirregularities only a few tens of angstroms in height but covering the entire surface. For metals such as silver and aluminum, which have plasma edges in the ultraviolet, the excitation of surface plasmons resulting from these microirregularities causes additional incoherently reemitted or "scattered" light. Surface plasmon excitation also causes increased absorption in some wavelength regions. These effects are enhanced by dielectric overcoating layers, which both increase the absorption and scattering and shift the wavelength at which the peak occurs. Surface plasmon excitation is particularly important in the ultraviolet region, where the dielectric overcoating applied to prevent formation of an oxide film on aluminized mirrors, for example, can significantly change the mirror reflectance. Plasmon excitation is made possible by a momentum conserving process associated with material inhomogeneities and hence can presumably be caused by crystalline disorder in the metal surface as well as surface irregularities. If the disorder is present on a sufficiently fine scale, it also affects the band structure of the metal and hence its optical absorption. Examples of the effect of film structure on the optical properties of evaporated and sputtered metal films will be given.

Measurement of melting point and radiance temperature (at melting point and at 653 nm) of hafnium-3(wt.%) zirconium by a pulse heating method, A. Cezairliyan and J. L. McClure, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 659-662 (July-Aug. 1976).

Key words: hafnium; high-speed measurement; high temperature; melting point; pyrometry; radiance temperature.

A subsecond duration pulse heating method is used to measure the melting point and radiance temperature (at 653 nm) at the melting point of hafnium containing 3.12 weight percent zirconium. The results yield a value of 2471 K for the melting point on the International Practical Temperature Scale of 1968. The radiance temperature (at 653 nm) of this material at its melting point is 2236 K, and the corresponding normal spectral emittance is 0.39. Estimated inaccuracies are: 10 K in the melting point and in the radiance temperature, and 5 percent in the normal spectral emittance.

Nationwide survey of ^{60}Co teletherapy dosimetry, M. Ehrlich and G. L. Welter, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 663-668 (July-Aug. 1976).

Key words: absorbed dose; cobalt-60 gamma radiation; computation check; dose interpretation; mailings; results; therapy departments; thermoluminescence dosimeters; uncertainty; water phantom.

The National Bureau of Standards is performing a study of the ability of radiation-therapy departments to deliver prescribed absorbed doses of ^{60}Co gamma radiation to a water phantom. Batches of thermoluminescence dosimeters are mailed to participating therapy departments for irradiation under prescribed conditions. Upon return of the dosimeters, the participants' computations are checked and the absorbed dose is evaluated from dosimeter response. The rugged dosimetry system was assembled mainly from commercial components adapted to the present requirements of relatively high flexibility of readout parameters and data-handling techniques, and of relatively high accuracy. The uncertainty in the dose interpretation inherent in the system is estimated to be about 4 percent.

In order to illustrate the type of information that can be obtained from such a study, results of the first four mailings involving tests on 114 ^{60}Co gamma-ray beams are discussed. They show about 75 percent of the dose interpretations to be within 5 percent of the prescribed absorbed dose, and about 20 percent to be within 5 to 10 percent of this dose. Four dose interpretations showed discrepancies larger than 20 percent. Differences in the computations larger than 1 percent were observed in over one-half of the cases.

A self-balancing nanovolt potentiometric system for thermometry and calorimetry, S. S. Chang, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), No. 4, 669-675 (July-Aug. 1976).

Key words: automatic potentiometry; automation calorimetry; Diesselhorst ring; potentiometer; programmable potentiometer; self-balancing potentiometers; thermometry.

The principle of a self-balancing potentiometric system is described. The principle is applied to the modification of an existing manually operated thermo-free, low voltage potentiometer consisting of Diesselhorst ring elements. The modification involves the addition of reed relays which enable the potentiometer voltage to be set by digital signals. By incorporating a digital voltmeter, or an analog-to-digital converter, and a nanovolt amplifier with the modified potentiometer, self-balancing of the potentiometer may be achieved through either hardware logic implementation or direct digital control from a minicomputer. The resolution of this self-balancing potentiometric system for full scale input of 100 mV is about one to 10 parts in 10^8. With

real-time digital processing of the data, resolution of about 1 nV or better has been achieved for slowly changing input signals. The overall accuracy of the system is better than 10 ppm for voltage measurements and about 1 ppm for voltage ratio or resistance measurements.

September-December 1976

Deviation of international practical temperatures from thermodynamic temperatures in the temperature range from 273.16 K to 730 K, L. A. Guildner and R. E. Edsinger, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), Nos. 5 and 6, 703-738 (Sept.-Dec. 1976).

Key words: gas thermometry; International Practical Temperature Scale of 1968; temperature scale differences; thermodynamic temperatures.

The range over which thermodynamic temperatures have been realized by gas thermometry at the NBS has been extended to 730 K. The results are preserved by measuring the corresponding international practical temperatures. The difference between them is expressed as the following polynomial:

$$T/\mathrm{K} - T_{68}/\mathrm{K}_{68} = -120{,}887.784/T_{68}^2 + 1213.53295/T_{68} - 4.3159552 + 6.44075647 \times 10^{-3} T_{68} - 3.56638846 \times 10^{-5} T_{68}^2$$

which is valid in the range 273 to 730 K.

The difference found and the estimated uncertainties at the three defining fixed points in the range covered are

		Uncertainty	
t(°C)	$T/\mathrm{K} - T_{68}/K_{68}$	Random (99% confidence limits)	Systematic
100	−0.0252	±0.0018	±0.00054
231.9681	−0.0439	±0.0022	±0.0015
419.58	−0.0658	±0.0028	±0.0028

Measurements of the specific heats, C_σ, and C_v, of dense gaseous and liquid ethane, H. M. Roder, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), Nos. 5 and 6, 739-759 (Sept.-Dec. 1976).

Key words: constant volume; ethane; heat capacity; liquid; saturated liquid; specific heat; vapor.

The specific heats of saturated liquid ethane, C_σ, have been measured at 106 temperatures in the temperature range 93 to 301 K. The specific heats at constant volume, C_v, have been measured at 19 densities ranging from 0.2 to 3.1 times the critical density, at temperatures between 91 and 330 K, with pressures to 33 MPa, at 200 PVT states in all. The uncertainty of most of the measurements is estimated to be less than 2.0 percent. As the critical point is approached the uncertainty rises to about 5.0 percent. The measurements were performed to provide input data for accurate calculations of the thermodynamic properties for ethane. They are believed to be the most comprehensive specific heat measurements available for the liquid and vapor states of ethane.

Phase equilibria and crystal growth in the alkali antimonate systems Sb_2O_4-$NaSbO_3$, Sb_2O_4-$KSbO_3$, and Sb_2O_4-$NaSbO_3$-NaF, J. L. Waring, R. S. Roth, H. S. Parker, and W. S. Brower, Jr., *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), Nos. 5 and 6, 761-774 (Sept.-Dec. 1976).

Key words: alkali antimonates; crystal growth; ionic conductors; potassium antimonate; sodium antimonate; sodium antimony oxyfluoride.

Phase equilibrium diagrams have been constructed from experimental data for the systems Sb_2O_4-$NaSbO_3$, Sb_2O_4-$KSbO_3$, and Sb_2O_4-$NaSbO_3$-NaF. The system Sb_2O_4-$NaSbO_3$ contains only an intermediate pyrochlore type solid solution with a maximum melting point of 1490 °C at a Na:Sb atom ratio of 3:5. The Sb_2O_4-$KSbO_3$ system contains in addition to the pyrochlore phase a compound $3K_2O{\cdot}5Sb_2O_5$ which melts congruently at about 1450 °C and two polymorphs of $K_2O{\cdot}2Sb_2O_5$. The low temperature form of $K_2O{\cdot}2Sb_2O_5$ was found to be monoclinic $P2_1/c$ with $a = 7.178$, $b = 13.378$, $c = 11.985$ A, $\beta = 124°10'$. The melting point of Sb_2O_4 was found to be 1350 ± 5 °C and $NaSbO_3$ and $KSbO_3$ both melt congruently at 1555 ± 5 °C and 1410 ± 5 °C respectively. The previously reported cubic form of $KSbO_3$ was found to be a K^+ deficient phase stabilized by reaction with atmospheric moisture. A similar cubic phase which appears to be a good Na^+ ion conductor can be synthesized in the ternary system $NaSbO_3$-Sb_2O_4-NaF.

Vapor pressure formulation for water in range 0 to 100 °C. A revision, A. Wexler, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), Nos. 5 and 6, 775-785 (Sept.-Dec. 1976).

Key words: Clapeyron equation; saturation vapor pressure over water; steam; vapor pressure; vapor pressure of water; virial coefficients.

In 1971 Wexler and Greenspan published a formulation for the vapor pressure of water encompassing the temperature range 0 to 100 °C. In this paper a revision is made of that earlier formulation to make it consistent with the definitive experimental value of the vapor pressure of water at its triple point recently obtained by Guildner, Johnson, and Jones. The two formulations are essentially identical at temperatures from 25 to 100 °C.

For temperatures below 25 °C the new formulation predicts values that are higher than the 1971 formulation. At the triple point, the vapor pressure given by the new formulation is 611.657 Pa whereas the value given by the 1971 formulation is 611.196 Pa. A table is given of the vapor pressure as a function of temperature at 0.1-deg intervals over the range 0 to 100 °C on the International Practical Temperature Scale of 1968, together with values of the temperature derivative at 1-deg intervals.

Revised lifetimes of energy levels in neutral iron, C. H. Corliss and J. L. Tech, *J. Res. Nat. Bur. Stand. (U.S.)*, **80A** (Phys. and Chem.), Nos. 5 and 6, 787-797 (Sept.-Dec. 1976).

Key words: atomic spectra; energy levels; Fe I; iron; iron lifetimes; lifetimes in Fe I.

Mean radiative lifetimes for 408 energy levels of neutral iron are revised from our 1967 paper on the basis of comparison with 81 subsequently measured lifetimes. The standard deviation of the ratio of the revised values to the reference lifetimes is 30 percent.

3.2. PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 70B, JULY-DECEMBER 1966

July-September 1966

Error bounds for asymptotic solutions of differential equations. I. The distinct eigenvalue case, F. Stenger, *J. Res. NBS.* **70B**3-180, pp. 167-186 (July-Sept. 1966).

Key words: Asymptotic solutions; eigenvalues; error term; matrices; norm bounds; vector bounds; Volterra vector integral equations.

The method of Olver for bounding the error term in the asymptotic solutions of a second-order equation having an irregular singularity at infinity is extended to the general system of n first-order equations in the case when the eigenvalues of the lead coefficient matrix are distinct. Vector and norm bounds are given for the difference between an actual solution vector and a partial sum of a formal solution vector. Two cases are distinguished geometrically: In one it is possible to express the error vector by a single Volterra vector integral equation; in the other it is necessary to use a simultaneous pair of Volterra vector integral equations. Some new inequalities for integral equations are given in an appendix.

Error bounds for asymptotic solutions of differential equations. II. The general case, F. Stenger, *J. Res. NBS* **70B**3-181, pp. 187-210 (July-Sept. 1966).

Key words: Asymptotic solutions; error bounds; integral equations; matrices.

The results of the preceding paper are extended to the general system of n first-order differential equations having an irregular singularity of arbitrary rank at infinity. Formal solutions are explicitly constructed for the system in canonical form. Proofs of existence and uniqueness of solutions of integral equations defining the error are given. As an example, the case $n=2$ is solved completely, and a flow chart of the transformations of this case to canonical form is included.

On the approximation of functions of several variables, B. Mond and O. Shisha, *J. Res. NBS*, **70B**3-182, pp. 211-218 (July-Sept. 1966).

Key words: Approximations; convergence; multidimensional; polynomials; functions; variables; Hermite-Fejer; Bernstein; Chebyshev.

The purpose of this note is to point out how a certain type of approximation to functions of one real variable gives rise to similar approximations to functions of several variables. Information on the rapidity of convergence in the one dimensional case, yields at once corresponding information for the multidimensional case.

Finding a rank-maximizing matrix block, A. J. Goldman and M. Newman, *J. Res. NBS* **70B**3-183, pp. 219-220 (July-Sept. 1966).

Key words: Matrix; block; rank; algorithm.

An algorithm is developed for the following problem: Given three matrices of respective dimensions $s\times s$, $s\times t$, and $t\times s$, to find a $t\times t$ matrix such that the $(s+t)\times(s+t)$ matrix formed from the four blocks has maximum rank.

On certain discrete inequalities and their continuous analogs, A. M. Pfeffer, *J. Res. NBS*, **70B**3-184, pp. 221-231 (July-Sept. 1966).

Key words: Inequalities; norms; Wirtinger.

The purpose of this paper is to find inequalities between the L^2-norms of a function and its kth and mth derivatives.

October-December 1966

A random walk model of chain polymer adsorption at a surface. III. Mean square end-to-end distance, R. J. Rubin, *J. Res. NBS*, **70B**4-185, pp. 237-247 (Oct.-Dec. 1966).

Key words: Adsorption; chain polymer; critical energy; generating function; lattice model; partition function; random walk.

A 6-choice simple cubic lattice model of adsorption of an isolated polymer chain at a solution surface is investigated. The mean square components $\langle x^2(N)\rangle$ and $\langle z^2(N)\rangle$ of the end-to-end distance are computed as a function of the adsorption energy per monomer unit in the limit of a very long polymer chain. In the calculation, one end of the polymer chain consisting of N monomer units is constrained to lie in the surface; and $\langle x^2(N)\rangle$ and $\langle z^2(N)\rangle$ are, respectively, the mean square displacement of the free end of the chain parallel to the solution surface in one of the lattice directions and normal to the solution surface. The limiting value of $\langle x^2(N)\rangle/N$ as $N\to\infty$ is a continuous function of θ, the dimensionless adsorption energy per monomer unit, and is equal to 1/3 for $\theta\leqslant \ln(6/5)$ and $(1/2)[1+(1/4)(e^{\theta}-1)^{-1}]^{-1/2}$ for $\theta^{\theta}\ln(6/5)$. The limiting value of $\langle z^2(N)\rangle/N$ as $N\to\infty$ is a discontinuous function of θ and is equal to 2/3 for $\theta<\ln(6/5)$, 1/3 for $\theta=\ln(6/5)$, and 0 for $\theta>\ln(6/5)$. The relation of these results to earlier investigations and the generalization of these results to other cubic lattice models is discussed.

Abscissas and weights for Gaussian Quadrature for N=2 to 100, and N=125, 150, 175, and 200, C. H. Love, *J. Res. NBS*, **70B**4-186, pp. 249-256 (Oct.-Dec. 1966).

Key words: Gaussian quadrature; integral equations; numerical integration; zeros of Legendre polynomials.

The abscissas and weights for Gaussian Quadrature of order N=2 to 100, and N=125, 150, 175, and 200 are given. The abscissas are given to twenty-four places and the error is estimated to be no more than one unit in the last place. The weights are given to twenty-three places and the error is estimated to be no more than 1 unit in the last place.

Transverse impact of a linear three-element spring and dashpot model filament: Theory, J. C. Smith, *J. Res. NBS*, **70B**4-187, pp. 257-264 (Oct.-Dec. 1966).

Key words: Characteristics; impact; linear viscoelasticity; partial differential equations; stress waves; wave propagation.

The mathematics of wave propagation in a viscoelastic filament subjected to constant velocity transverse impact is discussed. The equations governing the stress-strain-tim

behavior are assumed to be those for a linear model consisting of a spring coupled in parallel with a spring and dashpot in series. The nature of the solution is discussed, and a method is described for calculating the configuration, and the stress, strain, and particle velocity distributions along the impacted filament. The method used consists of an integration along the characteristics of the system of differential equations describing the problem.

Functions for thermal stress calculation near a transient heat source on a flat surface, S. Jarvis, Jr., and G. Hardy, *J. Res. NBS* **70B**4-188, pp. 265-272 (Oct.- Dec. 1966).

Key words: Elastic stress; heat transfer; plane strain; thermal stress; yield stress.

When an initially unstressed elastic solid at uniform temperature is subject to a transient, locally two-dimensional heat flux on a flat surface, the two-dimensional total stress field near the wall is locally determined for short times and may be constructed from the functions described in this report; Fortran programs are available for their computation. In particular, maximum total stress and total stress fields for initially large heat fluxes are readily obtained for estimations of yield probability.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 71B, JANUARY-DECEMBER 1967

January-March 1967

Algorithms for frames and lineality spaces of cones, R. J.-B. Wets and C. Witzgall, *J. Res. NBS*, **71B**1-189, pp. 1-7 (Jan.- Mar. 1967).

Key words: Algorithm; cone; convex hull; face; frame; lineality space; linear programming.

A frame of a cone C is a minimal set of generators, and the lineality space L of C is the greatest linear subspace contained in C. Algorithms are described for determining a frame and the lineality space of a cone $C(S)$ spanned by a finite set S. These algorithms can be used for determining the vertices, edges, and other faces of low dimension of the convex hull of a finite set $H(S)$. All algorithms are based on the simplex method of linear programming. The problem of finding the lineality space can be successively reduced to problems in spaces of lower dimensions.

The coefficients of the powers of a polynomial, M. Newman, *J. Res. NBS*, **71B**1-190, pp. 9-10 (Jan.-Mar. 1967).

Key words: Binomial coefficients; bounds; polynomials.

It is shown that if $f(z)$ is a polynomial with no zeroes inside the unit circle and if r is any positive number, then the coefficients of $f^r(z)$ tend to zero like n^{1-r}, and this is best possible.

Stable evaluation of polynomials, C. Mesztenyi and C. Witzgall, *J. Res. NBS*, **71B**1-191, pp. 11-17 (Jan.-Mar. 1967).

Key words: Evaluation; Newton form; polynomial; relative error; round-off.

A class of Newton forms

$$P(x)=a_0+a_1(x-x_0)+\ .\ .\ .+a_n(x-x_0)\ .\ .\ .\ (x-x_{n-1})$$

are discussed which admit a stable evaluation algorithm in an interval $[A,B]$. Stability is defined in the paper. The estimate

$$\frac{\Delta P}{|P|}\leq 2+6\frac{M'(L)L}{M(L)},$$

where $L:=B-A$ and $M(x):=|a_0+|a_1|x+\ .\ .\ .+|a_n|x^n$, is shown to hold for the relative error of evaluation of $P(x)$ in $[A,B]$.

On involutions, O. Shisha and C. B. Mehr, *J. Res. NBS*, **71B**1-192, pp. 19-20 (Jan.-Mar. 1967).

Key words: Inverses; involutions; real functions.

Two methods are described of constructing real functions over the reals which are one-to-one, assume every real value and are their own inverses, and several examples are given. It is also shown that such a function, if everywhere continuous, is either the function $f(x)\equiv x$ or else is strictly decreasing.

Minimum number of subsets to distinguish individual elements, P. R. Meyers, *J. Res. NBS*, **71B**1-193, pp. 21-22 (Jan.-Mar. 1967).

Key words: Classification design; combinatorics; set theory.

Given a set S of cardinality m, we determine the minimum cardinality $f(m)$ for a family F of subsets of S such that each $s\epsilon S$ can be expressed as the intersection of some subfamily of F. The problem is solved in the following inverse form. For a given number n of subsets of S, find $g(n)$: the maximum number of elements of S which can be written as the intersection of some of these subsets. We show that $g(n)$ is the largest binomial coefficient for combinations of n things.

***E*-Transforms,** F. M. Ragab, *J. Res. NBS*, **71B**1-194, pp. 23-37 (Jan.-Mar. 1967).

Key words: Fourier-transform; functional transforms; generalized MacRobert's function; Hankel transform, *K*-transform; Laplace transform, MacRobert's function; *Y*-transform.

The following transform pair is established:

$$g(x)=\int_0^\infty (xy)^k[Ep;\alpha_r:q;\rho_t:(xy)^{\pm n}]f(y)dy;$$

$$f(x)=n^2\int_0^\infty (xy)^{-k}E\left[\begin{matrix}0 & q;1-\rho_t\mp\frac{1}{n}:(xy)^{\pm n}\\ 1;\mp\frac{1}{n} & p+1;1-\alpha_r\mp\frac{1}{n},1\end{matrix}\right]g(y)dy,$$

where n is any positive integer, and E is MacRobert's function and the generalized MacRobert's function, respectively.

Special choices of the parameters in the last transform lead in turn to the derivation of Hankel transform, *Y*-transform, *K*-transform, Fourier transform, Laplace transform and other integral transforms with tables to illustrate these new transforms.

Three observations on nonnegative matrices, A. J. Hoffman, *J. Res. NBS*, **71B**1-195, pp. 39-41 (Jan.- Mar. 1967).

Key words: Bounds; eigenvalues; nonnegative matrices.

Some results on nonnegative matrices are proved, of which the following is representative: Let $A=(a_{ij})$ be a nonnegative row stochastic matrix. If $\lambda\neq 1$ is an eigenvalue of A, then

$$|\lambda|\leq \min\left(1-\sum_j \min_i a_{ij},\sum_j \max_i a_{ij}-1\right).$$

Additional remarks on a theorem of M. Riesz, J. M. Smith, *J. Res. NBS*, **71B**1-196, pp. 43-46 (Jan.-Mar. 1967).

Key words: Commutator; matrix; orthogonal; quaternions; skew-symmetric; regular representation.

Let V be a real four-dimensional vector space, whose underlying geometry is the metric defined by the matrix

$$K=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&-1&0\\0&0&0&-1\end{bmatrix}$$

The following theorem is proved.

THEOREM: *If A and B are real, skew-symmetric, orthogonal (with respect to K) linear transformations on V, then $[A,B]=AB-BA$ is a multiple of a real, skew-symmetric orthogonal (with respect to K), linear transformation on V.*

The theorem is proved by use of the first and second regular representations of the real quaternions.

Methods are given for constructing all 4×4 matrices which are skew-symmetric and orthogonal with respect to K, and all 4×4 matrices which are skew-symmetric (in the Euclidean sense) and orthogonal with respect to K.

April-September 1967

Poincare's conjecture is implied by a conjecture on free groups, R. D. Traub, *J. Res. NBS* **71B**2&3-197, pp. 53-56 (Apr.-Sept. 1967).

Key words: Free group; handlebody; homeomorphism; simply connected; topology; 3-manifold; 3-sphere.

Poincare's conjecture is implied by a single group-theoretic conjecture. The converse is also valid modulo a hypothesis on the uniqueness of decomposition of the 3-sphere as the union of two handlebodies intersecting in a torus.

Construction of *EPr* generalized inverses by inversion of nonsingular matrices, J. Z. Hearon, *J. Res. NBS* **71B**2&3-198, pp. 57-60 (Apr.-Sept. 1967).

Key words: *EPr* matrices; generalized inverse; matrix.

Any matrix B such that $ABA=A$ is called a C_1-inverse of A and a C_1-inverse of A such that $BAB=B$ is called a C_2-inverse of A. Some properties of such inverses are established. It is shown that if A is p-square of rank $q<p$ and P is any positive semidefinite matrix, whose rank is the nullity of A, such that $U=A+P$ is nonsingular, then $B=U^{-1}AU^{-1}$ is a C_2-inverse of A with the property that null space B=null space B^*. That such a P exists for arbitrary square A is shown. The relation between this result and the work of Goldman and Zelen is discussed.

A generalized matrix version of Rennie's inequality, J. Z. Hearon, *J. Res. NBS* **71B**2&3-199, pp. 61-64 (Apr.-Sept. 1967).

Key words: Generalized inverse; inequality; matrix.

The matrix version of Rennie's inequality and the finite-dimensional version of Kantorovich's inequality are obtained by considering a positive definite matrix and its inverse. Generalizations of these inequalities are obtained in which the inverse matrix is replaced by a generalized inverse with certain prescribed properties. From the generalization of the Kantorovich inequality follows a (finite-dimensional) generalization of an inequality due to Strang.

Polar factorization of a matrix, J. Z. Hearon, *J. Res. NBS* **71B**2&3-200, pp. 65-67 (Apr.-Sept. 1967).

Key words: Generalized inverse; matrix; partial isometry.

It is known that if A is a bounded linear operator with closed range on a Hilbert space then A can be factored as $A=UH$, with U a partial isometry and H nonnegative and self adjoint. For the finite-dimensional case a strictly matrix-theoretic derivation is given based on the concept of a generalized inverse. Certain properties of the factors are given as well as conditions under which H or both U and H are uniquely determined by A. A pivotal item in the derivation is the representation of a square partial isometry as the product of a unitary matrix and an orthogonal projection. This representation is new, of some interest in itself and greatly simplifies the derivations.

Two classical theorems on commuting matrices, M. Newman, *J. Res. NBS* **71B**2&3-201, pp. 69-71 (Apr.-Sept. 1967).

Key words: Commuting matrices; group representations; normal matrices; Schur's lemma; simultaneous triangularization and diagonalization.

Simple proofs are given of the following classical theorems: (1) An arbitrary set of commuting matrices may be simultaneously brought to triangular form by a unitary similarity. (2) An arbitrary set of commuting normal matrices may be simultaneously brought to diagonal form by a unitary similarity.

A converse to Banach's contraction theorem, P. R. Meyers, *J. Res. NBS* **71B**2&3-202, pp. 73-76 (Apr.-Sept. 1967).

Key words: Contractions; functional analysis; metric spaces; topology.

The class of all continuous self-mappings of a metrizable space which can become contractions (in the sense of Banach) under metrics compatible with the topology on the space is characterized. The characterization amounts to a converse to the Contraction Mapping Principle.

***E*-transforms (II),** F. M. Ragab, *J. Res. NBS* **71B**2&3-203, pp. 77-89 (Apr.-Sept. 1967).

Key words: *E*-functions; integral transforms; inversion formulas; kernels.

The following class of integral transform pairs is established

$$g(x)=\int_0^\infty E\left(\begin{matrix}\nu-ix,\ \nu+ix,\ \alpha_1,\ \ldots,\ \alpha_p;\\ \beta_1,\ \ldots,\ \beta_q\end{matrix}\ \frac{1}{y}\right)f(y)dy, \tag{1}$$

$$f(x)=\frac{x^{\nu-1}}{i\pi^2}\int_0^\infty yg(y)\left[\frac{1}{i}\sum_{i,-i} ix^{iy}\sin(iy+\nu)\pi E\right. \tag{2}$$

$$\left.\left(\begin{matrix}1-\nu-iy,\ \beta_1-\nu-iy,\ \ldots,\ \beta_q-\nu-iy;x\\ 1-2iy,\ \alpha_1-\nu-iy,\ \ldots,\ \alpha_p-\nu-iy\end{matrix}\right)\right]dy.$$

The kernel in the transform (1) is MacRobert's E-function and integration is performed with respect to the argument of this function. In the inversion formula (2), the kernel is likewise an E-function, but the integration is performed with respect to its parameters.

Known special cases of this general transform pair is the Kantorovich-Lebedev transforms pair:

$$g(x)=\frac{2}{\pi^2}x\sinh(\pi x)\int_0^\infty y^{-1}K_{ix}(y)f(y)dy,$$

$$f(x)=\int_0^\infty K_{iy}(x)g(y)dy,$$

and the generalized Mehler transform pair

$$g(x)=\frac{x}{\pi}\sinh(\pi x)\Gamma\left(\frac{1}{2}-k+ix\right)\Gamma\left(\frac{1}{2}-k-ix\right)\int_0^\infty P^k_{ix-1/2}(y)f(y)dy,$$

$$f(x)=\int_0^\infty P^k_{iy-1/2}(x)g(y)dy.$$

Criterion for the stability of numerical integration methods for the solution of systems of differential equations, A. I. A. Karim, *J. Res. NBS* **71B**2&3-204, pp. 91-103 (Apr.-Sept. 1967).

Key words: Numerical integration; propagation of error; stability; systems of differential equations.

The problem of studying the growth of the error is most important for the numerical solution of differential equations. In this paper the Wilf's criterion is generalized to be applied for systems of differential equations. A general theorem is investigated and regions of stability have to be determined. The

use of an electronic computer is more essential for such regions to be characterized. These regions of stability have the property that, the error introduced at any stage tends to decay. The regions of stability for particular numerical methods are explicitly determined.

Discrete complex functions with prescribed boundary values and residues, E. L. Peterson, *J. Res. NBS* **71B**2&3-205, pp. 105-110 (Apr.-Sept. 1967).

Key words: Analytic functions; complex analysis; Dirichlet problem; discrete analytic functions.

R. Isaacs, J. Ferrand, R. J. Duffin, and several others have developed a function theory for "discrete analytic functions" defined on "discrete regions" in the "discrete complex plane." In this paper we bring to light some combinatorial-topological properties of "simple discrete regions," and we study some basic properties of discrete analytic functions that are defined on simple discrete regions. These combinatorial-topological properties and basic properties are then used to establish an existence and uniqueness theorem for discrete complex functions with prescribed "boundary values" and "residues" on an arbitrary simple discrete region.

Numerical solution of second-order linear difference equations, F. W. J. Olver, *J. Res. NBS* **71B**2&3-206, pp. 111-129 (Apr.-Sept. 1967).

Key words: Chebyshev series; difference equations; error analysis; Miller algorithm; recurrence methods; special functions.

A new algorithm is given for computing the solution of any second-order linear difference equation which is applicable when simple recurrence procedures cannot be used because of instability. Compared with the well-known Miller algorithm the new method has the advantages of (i) automatically determining the correct number of recurrence steps, (ii) applying to inhomogeneous difference equations, (iii) enabling more powerful error analyses to be constructed.

The method is illustrated by numerical computations, including error analyses, of Anger-Weber, Struve, and Bessel functions, and the solution of a differential equation in Chebyshev series.

Indefinite integrals involving Bessel functions, B. A. Peavy, *J. Res. NBS* **71B**2&3-207, pp. 131-141 (Apr.-Sept. 1967).

Key words: Bessel functions; indefinite integrals.

Expressions are derived for the indefinite integrals,

$$\int rf(r)\, C_0(\alpha r)dr$$

$$\int rf(r)\, C_0^2(\alpha r)dr$$

$$\int rf(r)C_0(\alpha r)\, C_0(\beta r)dr \qquad \alpha \neq \beta$$

$$\int rf(r)C_0(\alpha r)\, Z_0(\lambda r)dr$$

where $C_0(\alpha r)$ are zero order Bessel functions, $Z_0(\lambda r)$ are zero order modified Bessel functions and $f(r)$ is a polynomial in r. In general, the expressions given for the integrals are given in terms of prescribed functions of the Bessel functions, and the coefficients of these functions are determined from a finite series, the terms of which are found from recurrence relationships that involve only the polynomial $f(r)$. Coefficients of the terms of the finite series are given in tabular form for up to an eleventh degree polynomial.

October-December 1967

Calibration designs based on solutions to the tournament problem, R. C. Bose and J. M. Cameron, *J. Res. NBS* **71B**4-237, pp. 149-160 (Oct.-Dec. 1967).

Key words: Calibration; calibration designs; combinatorial analysis; difference sets; incomplete block designs; statistical experiment designs; tournaments; weighing designs.

In high precision calibrations one measures differences between nominally equal objects or group of objects and establishes a value for the individuals with reference to one or more standards. The solutions to the classical tournament problem, which calls for arranging v individuals into teams of p players so that a player is teamed the same number of times with each of the other players and also that each player is pitted equally often against each of the other players, provide balanced designs for scheduling the measurements. These designs are useful in weighing and other measurements when the objects to be measured can be combined into groups without loss of precision or accuracy in the comparisons.

This paper presents solutions to the tournament problem for all $v \leq 13$ and for $p \leq v/2$. The statistical analysis, a worked example, and computational procedures are given.

Bounds for the solutions of second-order linear difference equations, F. W. J. Olver, *J. Res. NBS* **71B**4-238, pp. 161-166 (Oct.-Dec. 1967).

Key words: Chebyshev series; difference equations; error bounds; Miller algorithm; recurrence relations; special functions.

Simple bounds are established for the solutions of second-order homogeneous linear difference equations in ranges in which the solutions are exponential in character. The results are applied to a recent algorithm for the computation of subdominant solutions of second-order linear difference equations, homogeneous or otherwise. Strict and extremely realistic bounds are obtained for the truncation error associated with the algorithm in a number of examples, including Anger-Weber functions, Struve functions, and the solution of a differential equation in Chebyshev series.

Notes on automorphic functions: An entire automorphic form of positive dimension is zero, M. I. Knopp, *J. Res. NBS* **71B**4-239, pp. 167-169 (Oct.-Dec. 1967).

Key words: Automorphic forms; discontinuous groups; Fourier expansion; H-groups.

Several new proofs are given of the fact that an entire automorphic form of positive dimension is zero. The first proof is modeled on the method used by Hecke to estimate the Fourier coefficients of cusp forms of negative dimension. The other proofs involve well-known theorems of complete function theory.

Solving equations exactly, M. Newman, *J. Res. NBS* **71B**4-240, pp. 171-179 (Oct.-Dec. 1967).

Key words: Exact solutions; Hilbert matrices; linear equations; modular arithmetic.

A congruential method for finding the exact solution of a system of linear equations with integral coefficients is described, and complete details of the program are given. Typical numerical results obtained with an existing program are given as well.

A system of equations having no nontrivial solutions, H. Gupta, *J. Res. NBS* **71B**4-241, pp. 181-182 (Oct.-Dec. 1967).

Key words: Diophantine equations; Prouhet-Terry-Escott problem; symmetric functions.

The object of this note is to prove the THEOREM: *The system of equations*

$$a_1^r + a_2^r + \ldots + a_{n-1}^r = b_1^r + b_2^r + \ldots + b_{n-1}^r \quad r = 2, 3, \ldots, n;$$

has no nontrivial solutions in positive integers.

Remarks on cut-sets, J. W. Grossman, *J. Res. NBS* **71B**4-242, pp. 183-186 (Oct.-Dec. 1967).

Key words: Basic cut-sets; cut-sets; graph theory; network flows; mathematics; segs.

This paper gives a theorem on combinations of segs in a finite, connected, undirected graph. Then the theorem is specialized to combinations of cut sets, giving a theorem first proven by Mayeda. The paper contains an example showing that modifiers added to Mayeda's theorem by Yau, in the Journal of the Franklin Institute, January 1962, yield a false theorem. Finally, the paper discusses the practicability of algorithms developed by Mayeda and Yau and based on Mayeda's theorem.

A pseudo primal-dual integer programming algorithm, F. Glover. *J. Res. NBS* **71B**4-243, pp. 187-195 (Oct.-Dec. 1967).

Key words: Gomory algorithm; integer programming; linear inequalities; maximization.

The Pseudo Primal-Dual Algorithm dolves the pure integer programming problem in two stages, systematically violating and restoring dual feasibility while maintaining an all-integer matrix. The algorithm is related to Gomory All-Integer Algorithm and the Young Primal Integer Programming Algorithm, differing from the former in the dual feasible stage by the choice of cuts and pivot variable, and from the latter in the dual infeasible stage by the use of a more rigid (and faster) rule for restoring dual feasibility.

The net advance in the objective function value produced by the algorithm between two consecutive stages of dual infeasibility is shown to be at least as great as that produced by pivoting with the dual simplex method. Example problems are given that illustrate basic features and variations of the method.

Properties of a useful biorthogonal system, L. V. Spencer and P. Flusser, *J. Res. NBS* **71B**4-244, pp. 197-211 (Oct.-Dec. 1967).

Key words: Biorthogonal functions; gamma-ray penetration theory; neutron penetration theory; polynomial approximations.

In radiation penetration theory, infinite medium flux distributions have for some years been calculated using biorthogonal functions called $U_n^k(z)$. In this paper the spaces spanned by these functions, transformation kernels, generating functions, recursion relations, asymptotic trends for large n, many expansions, and relations with well-known orthogonal polynomials are worked out.

On even matroids, W. T. Tutte, *J. Res. NBS* **71B**4-245, pp. 213-214 (Oct.-Dec. 1967).

Key words: Binary; bridge-separable; even; graphic; matroid.

This article is intended as a supplement to an earlier paper entitled "Lectures on Matroids."

The author takes this opportunity to correct some errors in "Lectures on Matroids." Theorems 4.31 and 4.372 are valid only for binary matroids, the plane of 4.281 must be connected, and the word "reductions" is used in 3.48 instead of "contractions."

Matrices of class J_2, J. S. Maybee, *J. Res. NBS* **71B**4-246, pp. 215-224 (Oct.-Dec. 1967).

Key words: Chains; cycles; Jacobi matrices; triple diagonal matrices.

Let J_2 be the set of $n \times n$ complex matrices $A = (a_{ij})$ such that $a_{j_1 j_2} a_{j_2 j_3} \ldots a_{j_r j_1} = 0$ for all r such that $3 \leq r \leq n$ and all distinct $j_1, j_2, \ldots, j_r$. Then many properties of this set are given, which may be regarded as generalizations of the properties of the set of triple diagonal matrices.

Partially isometric matrices, J. Z. Hearon, *J. Res. NBS* **71B**4-247, pp. 225-228 (Oct.-Dec. 1967).

Key words: Generalized inverse; matrix; partial; isometry.

The complex, not necessarily square matrix A is called a partial isometry if the vectors x and Ax have the same Euclidean norm whenever x is in the orthogonal complement of the null space of A. The main results of the paper give necessary and sufficient conditions for a matrix to be a partial isometry, for a partial isometry to be normal and for the product of two partial isometries to be a partial isometry. A factorization for an arbitrary matrix involving partial isometries is given. The concept of a generalized inverse is used in establishing the primary results.

Symmetrizable generalized inverses of symmetrizable matrices, J. Z. Hearon, *J. Res. NBS* **71B**4-248, pp. 229-231 (Oct.-Dec. 1967).

Key words: Generalized inverse; symmetrizable matrix.

The matrix A is said to be symmetrizable by V when V is positive definite and AV is hermitian. Several lemmas regarding symmetrizability are given. For three classes of generalized inverses it is shown that if A is symmetrizable by V there exists a generalized inverse in each class which is symmetrizable by V. The Moore-Penrose inverse (or pseudo-inverse) of a matrix symmetrizable by V is also symmetrizable by V if and only if the matrix and the pseudo-inverse commute.

Optimum branchings, J. Edmonds, *J. Res. NBS* **71B**4-249, pp. 233-240 (Oct.-Dec. 1967).

Key words: Algorithms; arborescences; branchings; combinatorics; graphs; linear programming; traveling salesman; trees.

An arborescence T is a tree whose edges are directed so that each is directed toward a different node. Exactly one node of T, called the root, has no edge of T directed toward it. Let G be any directed graph with a real numerical weight on each edge. A good algorithm is described for finding in G (if there is one) a spanning arborescence, with prescribed root, whose edges have maximum (or minimum) total weight.

Systems of distinct representatives and linear algebra, J. Edmonds, *J. Res. NBS* **71B**4-250, pp. 241-245 (Oct.-Dec. 1967).

Key words: Algorithms; combinatorics; indeterminates; linear algebra; matroids; systems of distinct representatives; term rank.

Some purposes of this paper are: (1) To take seriously the term, "term rank." (2) To make an issue of not "rearranging rows and columns" by not "arranging" them in the first place. (3) To promote the numerical use of Cramer's rule. (4) To illustrate that the relevance of "number of steps" to "amount of work" depends on the amount of work in a step. (5) To call attention to the computational aspect of SDR's, an aspect where the subject differs from being an instance of familiar linear algebra. (6) To describe an SDR instance of a theory on extremal combinatorics

that uses linear algebra in very different ways than does totally unimodular theory. (The preceding paper, Optimum Branchings, describes another instance of that theory.)

Bounds for the number of generators of a finite group, M. Newman, *J. Res. NBS* 71B4-251, pp. 247-248 (Oct.-Dec. 1967).

Key words: Bounds; elementary abelian groups; generator rank; Sylow subgroups.

It is proved that if G is a finite group of order n, then the generator rank of G does not exceed the total number of primes dividing n and is equal to this number for infinitely many groups G.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 72B, JANUARY-DECEMBER 1968

January-March 1968

Means and the minimization of errors, M. Aissen, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 1-4 (Jan.-Mar. 1968).

Key words: Arithmetic mean; geometric mean; harmonic mean; means; relative error.

Let $0 < a < b$. How should a number p be chosen so that the maximum 'relative error' obtained, by replacing a number x varying in the closed interval $[a, b]$, by p. is a minimum? For a large number of 'relative errors,' p must be chosen as the geometric mean of a and b.

On Taylor's theorem, O. Shisha, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 5 (Jan.-Mar. 1968).

Key words: Iterated integrals; remainders; Taylor series.

A simple way of looking at and proving Taylor's theorem.

Principal submatrices III: linear inequalities, R. C. Thompson, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 7-22 (Jan.-Mar. 1968).

Key words: Cauchy inequalities; Hermitian matrices; interlacing theorems; matrices; matrix inequalities; matrix theory; principal submatrices.

Let H be an $n \times n$ Hermitian matrix with eigenvalues $\lambda_1 \leqslant \lambda_2 \leqslant \ldots \leqslant \lambda_n$. Let $H(i|i)$ denote the principle submatrix of H obtained by deleting row i from H. Let $\xi_{i1} \leqslant \xi_{i2} \leqslant \ldots \leqslant \xi_{i,n-1}$ be the eigenvalues of $H(i|i)$. The famous Cauchy inequalities assert that $\xi_{i1}, \ldots, \xi_{i,n-1}$ interlace $\lambda_1, \ldots, \lambda_n$. It was recently proved by the present author that, for each fixed j, the arithmetic mean $n^{-1} \sum_{i=1}^{n} \xi_{ij}$ of the ξ_{ij} lies between $(1-\theta)\lambda_j + \theta\lambda_{j+1}$ and $\theta\lambda_j + (1-\theta)\lambda_{j+1}$, where $\theta = 1/n$. In the present paper the cases of equality in these inequalities for the arithmetic mean of the ξ_{ij} are discussed.

The diophantine equation $P(x, y) = (xy + d)z$, C. F. Osgood, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 23-28 (Jan.-Mar. 1968).

Key words: Algebraic equations; diophantine equations; integers; three variables.

Under certain conditions the algebraic equation $P(x, y) = (xy + d)z$, where $P(x, y)$ is a polynomial in x and y with integral coefficients and d is an integer, is shown to have an infinite number of distinct solutions with x, y, and z each an integer.

A note on the *G*-transformation, H. L. Gray and T. A. Atchison, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 29-31 (Jan.-Mar. 1968).

Key words: Improper integrals; nonlinear transformation.

Recent literature concerning the use of nonlinear transformations to evaluate numerically certain improper integrals of the first kind has shown that difficulties are encountered if the integrand f is such that

$$\lim_{t \to \infty} \frac{f(t+k)}{f(t)} = 1.$$

This note introduces a new nonlinear transformation which is in some cases quite useful when the above limit is one. A simple example is given to illustrate the use of this transformation.

The distribution of the sample correlation coefficient with one variable fixed, D. Hogben, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 33-35 (Jan.-Mar. 1968).

Key words: Analysis of variance; calibration; correlation coefficient; degrees of freedom; distribution; fixed variable; noncentral beta variable; noncentrality; Q variate.

For the usual straight-line model, in which the independent variable takes on a fixed, known set of values, it is shown that the sample correlation coefficient is distributed as Q with $(n-2)$ degrees of freedom and noncentrality $\theta = (\beta/\sigma) \sqrt{\Sigma(x_i - \bar{x})^2}$. The Q variate has been defined and studied elsewhere by Hogben et al. It is noted that the square of the correlation coefficient is distributed as a noncentral beta variable.

Solutions of the time-dependent Klein-Gordon and Dirac equations for a uniform electric field, V. W. Myers, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 37-42 (Jan.-Mar. 1968).

Key words: Dirac and Klein-Gordon equations; time-dependent solutions; uniform electric field.

The time-dependent Klein-Gordon and Dirac equations are solved for the motion of a charged particle in a classical uniform electrostatic field of infinite extent. The elementary solutions have a position dependence of the form $e^{ik \cdot r}$ with the component of k in the field direction varying linearly with time.

Analysis of a market split model, J. M. McLynn, A. J. Goldman, P. R. Meyers, and R. H. Watkins, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 43-60 (Jan.-Mar. 1968).

Key words: Demand; elasticity; mathematical economics; partial differential equations.

A mathematical analysis is given for a class of models describing how a "market" (i.e., some subset of the consuming public) might divide its patronage among p competing products ($p > 1$). The analysis is confined to the question of how the respective shares of market change with respect to changes in the variables describing the competing products. The split fractions which define the share of market are assumed to be functions of the choice-influencing attributes of *all* the competing products. The elasticities of the split fractions with respect to these attributes are assumed to be functions only of the split fractions themselves. Some functional forms (including the linear case) leading to self-consistent models are analyzed and their solutions derived.

Citation searching and bibliographic coupling with remote on-line computer access, F. L. Alt and R. A. Kirsch, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 61-78 (Jan.-Mar. 1968).

Key words: Bibliographies; citations; computer; information retrieval; remote consoles; timesharing.

Experiments were performed on a remote, multiple access computer to retrieve bibliographic items based on citation data. The citations were from some 25,000 physics papers. Estimates were made of the relevance of bibliographies derived from such

citations. Some extrapolations are made to future systems with remote multiple access capability.

Simple analytic expressions for the total Born approximation cross section for pair production in a coulomb field, L. C. Maximon, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 1, 79-88 (Jan.-Mar. 1968).

Key words: Born approximation; coulomb field; moderate energy cross section; pair production; Racah cross section; total photon cross section.

The total Born approximation cross section for pair production in a coulomb field given originally by Racah is used to derive two simple and rapidly convergent analytic expansions for this cross section, one valid for high energies, k, of the incident photon, the other for energies near the threshold. For $k > 4mc^2$ the fractional error involved in using the first four terms in the high energy expansion is $< 4.4 \times 10^{-5}$. For $k < 4mc^2$ the fractional error committed in using the first five terms of the low energy expansion is $< 1.1 \times 10^{-4}$. The leading terms in these expansions are the well known high energy and low energy limits of this cross section, respectively.

April-June 1968

The probability of an equilibrium point, K. Goldberg, A. J. Goldman, and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 93-101 (Apr.-June 1968).

Key words: Equilibrium; probability; theory of games.

A formula is derived for the probability that a "random" m-by-n two-person noncooperative game has an equilibrium-point solution in pure strategies. The limit of this probability as $m, n \to \infty$ is shown to be $1\text{-}1/e$. The probability is tabulated for $m, n \leq 10$.

On spaces and maps of generalized inverses, J. Z. Hearon and J. W. Evans, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 103-107 (Apr.-June 1968).

Key words: Generalized inverse; linear algebra; matrix.

Several classes of generalized inverses of a given $m \times n$ matrix are considered. A collection of continuous maps is given, each of which maps a class of generalized inverses onto a stronger class and the elements of the stronger class are the fixed points of the map. For the case of EPr matrices one of these maps is studied in more detail. The various classes of generalized inverses are characterized as subspaces of the space of all $n \times m$ matrices.

Differentiable generalized inverses, J. Z. Hearon and J. W. Evans, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 109-113 (Apr.-June 1968).

Key words: Differentiable generalized inverse; generalized inverse; matrix.

Necessary and sufficient conditions are given for a differentiable matrix to have a differentiable generalized inverse. It is shown that when these conditions are met there exist, for several classes of generalized inverses, a differentiable generalized inverse which coincides with a prescribed generalized inverse on a particular subset. The relations betweeen the derivative of a matrix and that of a differentiable generalized inverse are given.

Principal submatrices V: some results concerning principal submatrices of arbitrary matrices, R. C. Thompson, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 115-125 (Apr.-June 1968).

Key words: Eigenvalues; matrix; principal submatrices; rank; symmetric matrix.

This paper studies: (i) interlacing properties for the real eigenvalues of matrices; (ii) symmetric matrices with many equal principal minors; (iii) the determinantal characterization of the rank of a matrix.

Mathematical basis for the plasma kinetic equations (BBGKY), J. J. Sopka, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 127-133 (Apr.-June 1968).

Key words: BBGKY hierarchy equations; probabilistic basis for kinetic equations.

The general family of kinetic equations, which in plasma kinetics are called the BBGKY equations, are obtained rigorously from basic probabilistic considerations in order to exhibit explicity the conditions or assumptions under which they obtain.

On the diffusion of an ion sheet in Poiseuille flow, S. Jarvis, Jr., *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 135-143 (Apr.-June 1968).

Key words: Diffusion; ion flow tubes.

A nonuniform sheet of ions generated at time $t = 0$ diffuses in a cylindrical ion diffusion tube containing a nonreacting neutral species flowing with parabolic velocity distribution. Calculation of the on-axis ion density at a point z downstream as a function of time t is reduced to a single numerical integration for each (z, t) involving some functions which have been computed once for all. An example is given showing the effect of the velocity distribution compared with a uniform flow with the same flow rate. The results appear to be corroborated by experiment.

A class of thickness-minimal graphs, A. M. Hobbs and J. W. Grossman, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 2, 145-153 (Apr.-June 1968).

Key words: Bipartite graphs; graph theory; mathematics; planar graphs; thickness of graphs; t-minimal graphs.

The thickness of a graph G is the minimum number of planar subgraphs whose union is G. A t-minimal graph is a graph of thickness t which contains no proper subgraph of thickness t. In this paper, we show that the complete bipartite graph on two sets each containing $4t-5$ vertices is t-minimal for all $t \geq 2$. We also show that if the complete graph on 16 vertices has thickness 4, it is 4-minimal.

July-September 1968

Interaction in multidimensional contingency tables: an information theoretic approach, H. H. Ku and S. Kullback, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 3, 159-199 (July-Sept. 1968).

Key words: Contingency tables; estimation of cell frequencies from marginals; generalized independence; hypothesis testing; information theory; interaction; second-order interaction.

The problem of interaction in multidimensional contingency tables is investigated from the viewpoint of information theory as developed by Kullback. The hypothesis of no rth-order interaction is defined in the sense of an hypothesis of "generalized" independence of classifications with fixed rth order marginal restraints. For a three-way table, with given cell probabilities π_{ijk}, the minimum discrimination information for a contingency table with marginals $p_{ij\cdot}$, $p_{\cdot jk}$, and $p_{i\cdot k}$ is given by the set of cell probabilities $p^*_{ijk} = a_{ij}b_{jk}c_{ik}\pi_{ijk}$ where a_{ij}, b_{jk}, and c_{ik} are functions of the given marginal probabilities, that is, $\ln (p^*_{ijk}/\pi_{ijk}) = \ln a_{ij} + \ln b_{jk} + \ln c_{ik}$, representing no second-order interaction. The minimum discrimination information statistic, asymptotically distributed as χ^2 with appropriate degrees of freedom is

$$2\Sigma_{ijk}x_{ijk} \ln x_{ijk} - 2\Sigma_{ijk}x_{ijk} \ln x^*_{ijk} \geq 0$$

where x_{ijk} are the observed cell frequencies and x^*_{ijk} are the "no interaction" cell frequencies uniquely determined by a simple

convergent iteration process of the marginals on π_{ijk}. For lower order marginal restraints the usual independence hypotheses are generated when π_{ijk} are taken to be the cell probabilities under uniform distribution. It is shown that the set p^*_{ijk} satisfies definitions of no second order interaction in a $2 \times 2 \times 2$ table given by Bartlett and no interaction in a $r \times s \times t$ table by Roy and Kastenbaum, and is also related to that given by Good. Results of application to the analysis of some "classical" three-dimensional contingency tables are given, together with full details for two four-dimensional examples.

On the coupling of longitudinal and transverse waves in a linear three-element viscoelastic string subjected to transverse impact, J. C. Smith and J. T. Fong, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 3, 201-214 (July-Sept. 1968).

Key words: Characteristics; finite-difference equations; linear viscoelasticity; partial differential equations; transverse impact; wave propagation; waves in strings.

The problem of wave propagation in a simple viscoelastic string subjected to constant velocity transverse impact is reexamined. An error in an earlier solution by Smith (*J. Res. NBS* **70B**, 257 (1966)) is corrected and an alternate numerical scheme based on the method of characteristics but using an implicit formulation of finite-difference equations is presented. The constitutive equation used is that of a linear viscoelastic model consisting of a spring and Maxwell element in parallel. Results of an illustrative calculation are discussed.

Allocating service periods to minimize delay time, W. A. Horn, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 3, 215-227 (July-Sept. 1968).

Key words: Allocation; queueing theory; scheduling; switching theory; traffic flow; transportation theory.

Consider a facility which must divide its services, during the time interval $[0, T]$, among N streams of arrivals. The problem treated is that of finding a pattern of service which minimizes total delay to the members of the streams, taking into account the "dead time" which begins each service period. For each stream, it is required that final queue size equal initial size, and that the queue be empty sometime in $[0, T]$. Conditions for feasibility of solutions are given in the case where the instantaneous service rates are bounded above by known constants. In the event that all streams have constant arrival rates and are to be served the same number of times, an optimal service pattern is derived using a recent result of R. Rangarajan and R. M. Oliver.

The second orthogonality conditions in the theory of proper and improper rotations. I. Derivation of the conditions and their main consequences, H. Gelman, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 3, 229-237 (July-Sept. 1968).

Key words: Matrices; orthogonal transformations; rotation.

A new set of orthogonality conditions is derived for real three-by-three orthogonal matrices which describe transformations in Euclidean three-dimensional space. The principal consequences of these conditions are obtained. These are: (1) the existence and construction of the intrinsic vector of the transformation, (2) an equation connecting the trace of a transformation matrix with that of its square, which, for rotations, can be solved to give the well-known trace formula analytically, (3) a simple formula for the determinant of a transformation matrix directly in terms of the relative handedness of the two coordinate systems connected by the transformation, (4) the secular equation for a transformation matrix.

Thickness and connectivity in graphs, A. M. Hobbs and J. W. Grossman, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 3, 239-244 (July-Sept. 1968).

Key words: Conjectures; connectivity; cut-set; graph theory; mathematics; minimality; thickness of graphs.

A graph G has *thickness* t if and only if t is the smallest number of planar subgraphs of G whose union is G. A *thickness-minimal*, or *t-minimal*, graph is a graph of thickness t with no proper subgraph of thickness t. In this paper we show that, for every t, a cut set in a t-minimal graph can have no fewer than t edges. This theorem suggests that the connectivity of a t-minimal graph is bounded from below by t. We disprove this suggestion for every $t > 2$ by constructing a graph which contains a 2-connected t-minimal graph. Two theorems extend this result and develop additional properties of the construction method. In addition, we show that the connectivity of a graph of thickness t is at most $6t - 1$ and that the thickness of K_{22} is 4. Finally, we make four conjectures about graphs of thickness t.

October-December 1968

Principal submatrices VII: further results concerning matrices with equal principal minors, R. C. Thompson, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 249-252 (Oct.-Dec. 1968).

Key words: Matrix; principal submatrices; rank; symmetric matrix.

This paper characterizes real symmetric matrices A such that all $t \times t$ principal minors are equal and all $t \times t$ nonprincipal minors are of fixed sign, for two consecutive values of t less than rank A. It also characterizes matrices A (over an arbitrary field) in which all $t \times t$ principal minors are equal and all nonprincipal $t \times t$ minors are equal, for one fixed value of t less than rank A.

On the multipliers of the Dedekind modular function, J. Lehner, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 253-261 (Oct.-Dec. 1968).

Key words: Cancellation; commutator subgroup; modular group; multiplier; word.

The Dedekind modular function is defined by $\eta(\tau) = e^{\pi i \tau/12} \prod_1^\infty (1 - e^{2\pi i m\tau})$, Im $\tau > 0$, and satisfies the transformation equation $(c\tau + d)^{-1/2}\eta(A\tau) = v(A)\eta(\tau)$ for every $A \epsilon \Gamma$, the modular group, where $v(A)$ is a complicated 24th root of unity depending on A. Let G be the set of all $A \epsilon \Gamma$ for which $v(A) = 1$. *Then G is not a group,* but there are groups that are subsets of G, e.g., $\{S^{24}\}$, where $S = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$. *Main Theorem.* Every subgroup of Γ that is a subset of G is cyclic. Moreover $G \subset \Gamma'$, the commutator subgroup of Γ.

Minimax error selection of a discrete univariate distribution with prescribed componentwise bounds, A. J. Goldman and P. R. Meyers, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 263-271 (Oct.-Dec. 1968).

Key words: Linear programs; mathematical models; operations research.

The topic treated is that of finding a reproducible, plausible and computationally simple method of selecting a discrete frequency distribution with prescribed upper and lower bounds on its components. The problem is shown to be tractable when a minimax error selection criterion is employed, and "error" is measured by maximum absolute deviation between components. In this case one obtains a linear program of a special form admitting explicit solution. The vertices of the polyhedron of optimal solutions can also be found explicitly, and so their centroid can be calculated if unique specification is required.

Minimax error selection of a discrete univariate distribution with prescribed componentwise ranking, A. J. Goldman, *J. Res.*

Nat. Bur. Stand. (U.S.), **72B** (Math. Sci.), No. 4, 273-277 (Oct.-Dec. 1968).

Key words: Mathematical models; minimax estimation; probability distribution.

The topic treated is that of finding a reproducible, plausible and computationally simple method of selecting a discrete frequency distribution with a prescribed ranking of its components. The problem is shown to be tractable when a minimax error selection criterion is employed, and "error" is measured by maximum absolute deviation between components. The vertices of the polyhedron of optimal solutions can also be found explicitly, and so their centroid can be calculated if unique specification is required.

On the signs of the ν-derivatives of the modified Bessel functions $I_\nu(x)$ and $K_\nu(x)$, D. O. Reudink, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 279-280 (Oct.-Dec. 1968).

Key words: Bessel functions; ν-derivatives.

It is proved that $\partial I_\nu(x)/\partial\nu$ is negative and $\partial K_\nu(x)/\partial\nu$ is positive when $x > 0$ and $\nu > 0$.

Comparison of finite-difference computations of natural convection, K. E. Torrance, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 281-301 (Oct.-Dec. 1968).

Key words: Enclosures; finite-difference; fluid flow; natural convection; numerical.

Five numerical methods were compared for calculating two-dimensional, transient natural convection in an enclosure. Both implicit and explicit procedures were considered. Requirements for numerical stability were derived from analysis and experience, and when satisfied, the calculated flows for all methods were found to be similar. Consideration was also given to the accuracy and (energy and vorticity) conservation of the methods. One method was found to be conservative and stable without a restriction on the spatial mesh increment. This method can be successfully applied to nonlinear flows, but care must be exercised due to the presence of truncation errors which introduce false transport mechanisms.

Generalized inverses and solutions of linear systems, J. Z. Hearon, *J. Res. Nat. Bur. Stand. (U.S.)*, **72B** (Math. Sci.), No. 4, 303-308 (Oct.-Dec. 1968).

Key words: Generalized inverse; linear systems; matrix.

For an arbitrary complex matrix A we consider (1) the set of all matrices B such that $ABA = A$ and AB is Hermitian and (2) the set of all matrices B such $ABA = A$ and BA is Hermitian. It is shown that if B is in (1) then $x = By$ is a least-squares solution of $Ax = y$ and that if B is in (2) then $x = By$ is the solution of minimum Euclidian norm of the consistent systems $Ax = y$. The connection is exposed between the properties of the generalized inverses in (a) and (b) and the fact that among all matrices X satisfying $AXA = A$, that with minimum Euclidian norm is the Moore-Penrose inverse of A.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 73B, JANUARY-DECEMBER 1969

January-March 1969

A table of integrals of the error functions, E. W. Ng and M. Geller, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 1-20 (Jan.-Mar. 1969).

Key words: Astrophysics; atomic physics; Error functions; indefinite integrals; special functions; statistical analysis.

This is a compendium of indefinite and definite integrals of products of the Error function with elementary or transcendental functions. A substantial portion of the results are new.

Fourier coefficients of Mathieu functions in stable regions, H. Fruchting, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci), No. 1, 21-24 (Jan.-Mar. 1969).

Key words: Bisection method; eigenvalues; Fourier coefficients; Mathieu functions.

A method for calculating the Fourier coefficients of Mathieu functions in stable regions based on the method of bisection and Miller's recurrence algorithm is introduced. Some Fourier coefficients are calculated and compared with those given earlier by Tamir and Wang. It is shown that the method of Tamir and Wang fails for indices in the neighborhood of integers.

A note on the *T*-transformation of Lubkin, W. D. Clark, H. L. Gray, and J. E. Adams, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 25-29 (Jan.-Mar. 1969).

Key words: Convergence acceleration techniques; epsilon-transformation; nonlinear series transformation; numerical methods; series summability methods.

This paper is concerned with a sequence-to-sequence transformation studied extensively by Samuel Lubkin [*J. Res. NBS* **48**, 228-254 (1952)]. Lubkin has studied the rate of convergence of the transformed sequence, $\{T_n\}$, versus the original sequence, $\{S_n\}$. In this respect, the authors have shown that a more accurate evaluation of the transformation is achieved by the comparison of $\{T_n\}$ with $\{S_{n+1}\}$ instead of $\{S_n\}$. The main theorems proved are rate-of-convergence comparisons between $\{T_n\}$ and $\{S_{n+1}\}$ where $\{S_n\}$ is the sequence of partial sums of a convergent series whose terms are of constant sign or else are alternating.

The cylinder problem in thermoviscoelasticity, W. S. Edelstein, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 31-40 (Jan.-Mar. 1969).

Key words: Cylinder; Neumann series; thermoviscoelasticity.

Solutions are obtained for several axially symmetric plane strain problems involving a hollow circular viscoelastic cylinder. The cylinder is assumed to be subject to planar, axially symmetric body force and temperature fields. Displacement, traction, and mixed boundary conditions are considered.

Relations within sequences of congruential pseudo-random numbers, P. H. Verdier, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 41-44 (Jan.-Mar. 1969).

Key words: Congruential generators; multidimensional distributions; random number generators.

Conditions are exhibited under which simple, approximate linear relations may be found between sets of successive choices made by congruential pseudo-random number generators. These relations imply that the distributions in n-dimensional space produced by such generators can be very highly nonuniform. The results are illustrated with several examples. Restrictions on the parameters of the generator to minimize difficulties of this sort are discussed.

On the mean dimensions of restricted random walks, P. H. Verdier and E. A. DiMarzio, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 45-46 (Jan.-Mar. 1969).

Key words: Lattice; nonreversing walk; polymer dimension; random walk.

A simple method is presented for obtaining mean dimensions of certain restricted random walks on lattices.

The cube of every connected graph is 1-hamiltonian, G. Chartrand and S. F. Kapoor, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 47-48 (Jan.-Mar. 1969).

Key words: Cube of a graph; graph; hamiltonian.

Let G be any connected graph on 4 or more points. The graph G^3 has as its point set that of G, and two distinct points u and v are adjacent in G^3 if and only if the distance between u and v in G is at most three. It is shown that not only is G^3 hamiltonian, but the removal of any point from G^3 still yields a hamiltonian graph.

Minimum-length covering by intersecting intervals, W. A. Horn, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 1, 49-51 (Jan.-Mar. 1969).

Key words: Covering problems; Manhattan metric.

This paper considers the problem: Given a sequence $\{I_i\}_1^n$ of intervals on the real axis, find a sequence $\{J_i\}_1^n$ of closed intervals which minimizes the sum-of-lengths $S = \Sigma_1^n |J_i|$ subject to $I_i \subseteq J_i$ and $J_i \cap J_{i+1} \neq \phi$ for all i. The paper gives a simple algorithm for determining the J_i and notes that linear programming can be applied to the more complicated problem where S is changed to $\Sigma_1^n \alpha_i |J_i|$, $\alpha_i > 0$.

April–June 1969

An evaluation of linear least squares computer programs, R. H. Wampler, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 59-90 (Apr.-June 1969).

Key words: Computer programs; Gram-Schmidt orthogonalization; Householder transformations; least squares; linear equations; orthogonalization; orthogonal polynomials; regression; rounding error; stepwise regression.

Two linear least squares test problems, both fifth degree polynomials, have been run on more than twenty different computer programs in order to assess their numerical accuracy. Among the programs tested were representatives from various statistical packages as well as some from the SHARE library. Essentially five different algorithms were used in the various programs to obtain the coefficients of the least squares fits. The

tests were run on several different computers, in double precision as well as single precision. By comparing the coefficients reported, it was found that those programs using orthogonal Householder transformations or Gram-Schmidt orthonormalization were much more accurate than those using elimination algorithms. Programs using orthogonal polynomials (suitable only for polynomial fits) also proved to be superior to those using elimination algorithms. One program, using congruential methods and integer arithmetic, obtained exact solutions. In a number of programs, the coefficients reported in one test problem were sometimes completely erroneous, containing not even one correct significant digit.

The traffic assignment problem for a general network, S. C. Dafermos and F. T. Sparrow, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 91-118 (Apr.-June 1969).

Key words: Algorithm; least cost; traffic allocation; transportation.

A transportation network is considered. The traffic demands associated with pairs of nodes and the (convex) traveling cost functions associated with the links are assumed given. The two problems of finding the traffic patterns which either minimize the total cost or equilibrate the users' costs are formulated, and algorithms are constructed for the solution of these problems.

Sufficient conditions for the instability of numerical integration methods, A. I. Abdel Karim, *J. Res. Nat. Bur. Stand. (U.S.)*, 73B (Math. Sci.), No. 2, 119-123 (Apr.-June 1969).

Key words: Numerical integration; stability.

In a previous paper, a general theorem was investigated for the stability of numerical integration methods for the solution of systems of differential equations. In this paper, further theorems are developed as sufficient conditions for the instability of numerical integration methods. Applying these theorems, the instability of known formulas are checked easily at a glance.

The second orthogonality conditions in the theory of proper and improper rotations. II. The intrinsic vector, H. Gelman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 125-138 (Apr.-June 1969).

Key words: Axis and angle of rotation; coordinate inversion; coordinate reflection; improper rotations; matrices; orthogonal transformations; proper rotations; rigid rotations; rotation.

The properties of the intrinsic vector associated with a real three-by-three orthogonal transformation, are derived. For proper rotations the problem of extracting the axis and angle or a rotation from its matrix representation, is considered. It is shown that the intrinsic vector allows the determination of the axis and angle as unambiguously as possible, thus remedying the ambiguous treatment of this problem in the literature. Several examples of this use of the intrinsic vector are given. Its properties for improper rotations are also discussed.

The second orthogonality conditions in the theory of proper and improper rotations. III. The conjugacy theorem, H. Gelman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 139-141 (Apr.-June 1969).

Key words: Conjugacy; conjugacy theorem; conjugate rotations; matrices; orthogonal group; orthogonal transformations; rotation; rotation group; rotation-inversions.

The second orthogonality conditions are used to provide a concise proof of the theorem that two rotation matrices connected by an orthogonal similarity transformation have the same angles of rotations. This theorem is discussed in the context of its applicability to the problem of decomposing the real orthogonal group 0(3) into its classes of conjugate elements.

Subgroups of $SL(t,Z)$, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 143-144 (Apr.-June 1969).

Key words: Congruence subgroup property; free groups; free products; higher modular groups.

It is shown that if $t \geq 3$, then no subgroup of $SL(t,Z)$ of finite index is free (in fact is not even the free product of cyclic groups). Here $SL(t,Z)$ is the multiplicative group of $t \times t$ matrices over the integers of determinant 1.

Cuttable and cut-reducible matrices, R. B. Marimont, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 145-151 (Apr.-June 1969).

Key words: Compartmental systems; connectivity; graph; matrix.

An n square matrix having an $(n-1)$ principal minor which is block diagonal (or reducible) is called cuttable (or cut-reducible). The connectivity matrix of a graph having a cutpoint is cuttable. While neither block diagonal nor reducible, cuttable and cut-reducible matrices share with these matrices some of the theoretical and computational simplicity derived from a natural division into principal submatrices which are relatively independent of each other. Solution of linear compartmental systems are shown to be simplified by the presence of a cutpoint in the system.

Automorphic integrals with preassigned periods, J. Lehner, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 153-161 (Apr.-June 1969).

Key words: Automorphic form; automorphic integral; fundamental region; group; Poincaré series.

Let Γ be a discrete group of real 2×2 matrices of determinant 1. Generalizing the usual notion of abelian integral, Eichler has defined $\Phi(\tau)$ to be an automorphic integral of degree $2n-2$ on Γ if (1) $\Phi|A = \Phi + \omega_A$ for all $A \epsilon \Gamma$. Here n is a positive integer, ω_A is a polynomial in τ of degree $2n-2$ or less, and $\Phi|A = (c\tau + d)^{2n-2}\Phi(A\tau)$, where τ is confined to the upper half-plane. A consequence of (1) is that (2) $\omega_{AB} = \omega_A|B + \omega_B$. If Φ has at most poles but no logarithmic singularities, Φ is said to be of the second kind and this requires (3) $\omega_A = Q|(A-1)$ for all elements A that fix a real cusp of a fundamental region of Γ, where Q is a polynomial of degree $\leq 2n-2$. Eichler proved that the necessary conditions (2) and (3′) are also sufficient for the existence of a Φ on Γ with the preassigned "periods" ω_A, but only when Γ is a subgroup of finite index in the modular group. Here (3′) is a stronger version of (3). In the present paper this is generalized to all groups Γ that are finitely-generated and have translations, and we use the correct conditions (2), (3) rather than (2), (3′).

A digital computer technique for calculating the step response of lumped or distributed networks, J. R. Andrews and N. S. Nahman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73B** (Math. Sci.), No. 2, 163-176 (Apr.-June 1969).

Key words: Digital computer program; distributed networks; inverse Laplace Transformation; lumped networks; Rosenbrock cursor; step response; transmission line.

This paper discusses a technique to solve step response problems for lumped or distributed networks with the aid of a digital computer. The Rosenbrock graphical cursor technique for obtaining the step response from the frequency response through the inverse Laplace Transformation was adapted for computer use. In addition, it was modified to increase its accuracy when used with a digital computer.

The response of a series RLC lumped network is computed and the numerical solution is compared to the analytical solution. Also, a numerical solution is given for the step response of a transmission line processing skin-effect metal loss and Debye dielectric loss.

Symmetry and the crossing number for complete graphs, T. L. Saaty, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 2, 177-186 (Apr.-June 1969).

Key words: Complete graphs; intersections, symmetry.

This paper studies the minimum number of intersections of edges in a complete graph on n vertices drawn in the plane. The proofs are first given for $n \leq 10$. A theorem on the maximum number of intersections is also given. Geometric representations of these cases are included. Symmetry of the representations is then discussed as it applies to extensions from small values of n to larger values maintaining the minimality of the number of intersections. Based on a symmetry conjecture given in the paper, a proof is given for the general case of the minimum intersection problem.

July–September 1969

A table of integrals of the exponential integral, M. Geller and E. W. Ng, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 191-210 (July-Sept. 1969).

Key words: Diffusion theory; exponential integral; indefinite integrals; quantum mechanics; radiative equilibrium; special functions; transport problems.

This is a compendium of indefinite and definite integrals of products of the Exponential Integral with elementary or transcendental functions. A substantial portion of the results are new.

Principal ideals in matrix rings, M. Newman and S. Pierce, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 211-213 (July-Sept. 1969).

Key words: Dedekind ring; matrix ring; non-Noetherian ring; principal ideal ring.

It is shown that every left ideal of the complete matrix ring of a given order over a principal ideal ring is principal, and a partial converse is proven.

The second orthogonality conditions in the theory of proper and improper rotations. IV. Solution of the trace and secular equations, H. Gelman, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 215-223 (July-Sept. 1969).

Key words: Closed form of rotation matrix; orthogonal transformation; rotation; rotation matrix; secular equation; trace equation; trace formula.

The equation which connects the trace of a rotation matrix and that of its square, and the secular equation for a rotation matrix, both of which are direct results of the second orthogonality conditions, are solved by purely analytic methods based on the group property and the periodicity property of rotation matrices. The point is thus made that the well known formulas for the trace of a rotation matrix in terms of the angle of rotation and for the rotation matrix itself in terms of the axis and angle of rotation, are closely related to the algebraic properties of rotation matrices.

Minimax error selection of a univariate distribution with prescribed componentwise bounds and ranking, A. J. Goldman, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 225-230 (July-Sept. 1969).

Key words: Linear programs; mathematical models; minimax estimation; operations research; probability distribution.

The topic treated is that of finding a reproducible, plausible and computationally simple method of selecting a discrete frequency distribution with a prescribed ranking of its components and prescribed upper and lower bounds on these components. The problem is shown to be tractable when a minimax error selection criterion is employed, and "error" is measured by maximum absolute deviation among components. In this case one obtains a linear program of a special form admitting explicit solution.

Minimax adjustment of a univariate distribution to satisfy componentwise bounds and/or ranking, A. J. Goldman, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 231-239 (July-Sept. 1969).

Key words: Linear programs; mathematical models; minimax estimation; operations research; probability distribution.

Consider a discrete probability distribution, represented by an n-vector **a**. This paper treats the problem of adjusting **a** as little as possible, in the sense of minimizing $\max_i |x_i - a_i|$, to obtain a distribution **x** which satisfies given componentwise bounds $\mathbf{L} \leq \mathbf{x} \leq \mathbf{U}$, or a given componentwise ranking, or both. The resulting linear programs are shown to admit special explicit solution algorithms.

On the application of some interpolating functions in physics, A. J. Jerri, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 241-245 (July-Sept. 1969).

Key words: Cardinal series; interpolation; Regge poles; special functions.

J. M. Whittaker considered interpolating equidistant samples by using the cardinal series. In this paper we consider the extension provided by the generalized sampling theorem of Kramer for nonequidistant samples. We calculate some sampling functions for cases of interest in mathematical physics. In particular, this includes the S-matrix contribution due to Regge poles, especially when a series expansion other than that of Fourier-Legendre type is needed.

Commutator groups and algebras, L. Greenberg, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 247-249 (July-Sept. 1969).

Key words: Adjoint representation; commutator; Lie algebra; Lie group.

Let H and K be connected, Lie subgroups of a Lie group G. The group $[H,K]$, generated by all commutators $hkh^{-1}k^{-1}(h \epsilon H, k \epsilon K)$ is arcwise connected. Therefore, by a theorem of Yamabe, $[H,K]$ is a Lie subgroup. If $\mathfrak{H},\mathfrak{K}$ denote the Lie algebras of H and K, respectively, then the Lie algebra of $[H,K]$ is the smallest algebra containing $[\mathfrak{H},\mathfrak{K}]$, which is invariant under $ad\mathfrak{H}$ and $ad\mathfrak{K}$. An immediate consequence is that if H and K are complex Lie subgroups, then $[H,K]$ is also complex.

On a class of nonlinear transformations and their applications to the evaluation of infinite series, H. L. Gray and W. D. Clark, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 3, 251-274 (July-Sept. 1969).

Key words: Aitken transformations; G-transformations; nonlinear transformations; rapidity of convergence.

In this paper the problem of increasing the rate of convergence of infinite sequences and series is considered by means of a class of nonlinear transformations. The transformations employed are the discrete analogue of the so called G-transformations and the theory surrounding them is investigated in some detail. The theoretical results are demonstrated by numerous examples.

October-December 1969

Temperature renormalization in the non-linear Vlasov problem, W. L. Sadowski and Z. G. Ruthberg, *J. Res. Nat. Bur. Stand. (U.S.),* **73B** (Math. Sci.), No. 4, 281-291 (Oct.-Dec. 1969).

Key words: Expansion coefficients; Hermite polynomials; non-linear; numerical; plasma; truncation error; Vlasov equation.

Ways of improving the representation of the velocity distribution function in the solution of the non-linear Vlasov equation are discussed. Hermite polynomial coefficients for temperature renormalization are derived. Transformation properties of Hermite polynomials necessary to do this are discussed. Analytic expressions for the truncation error of the temperature renormalized functions are compared with the computer results.

Selective excitation of harmonics in a collisionless plasma by two counterstreaming electron beams, W. L. Sadowski and Z. G. Ruthberg, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73B** (Math. Sci.), No. 4, 293-300 (Oct.-Dec. 1969).

Key words: Electron trapping; non-linear; numerical; selective harmonic excitation; two-stream; velocity distribution; Vlasov equation.

The possibility of selective harmonic excitation in a one-dimensional plasma that obeys the Vlasov equation is discussed. Electron beams, collimated in velocity space, are used for this purpose. Conditions on the velocity distribution function to achieve selective excitation are given. The velocity distribution function is expanded in Gram-Charlier series and the expansion coefficients are given. Bounds on truncation errors of the expansion are derived and compared with computer results.

Simultaneous contractification, A. J. Goldman and P. R. Meyers, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73B** (Math. Sci.), No. 4, 301-305 (Oct.-Dec. 1969).

Key words: Contractions; functional analysis; metric spaces; topology.

Consider a finite family of continuous self-mappings of a topological space X, with a common fixed point. Suppose that for each member of the family, X has a metric for which that member is a contraction. It is shown that if the family is commutative, then X has a metric under which all members are (simultaneously) contractions. Additional hypotheses are given which ensure the same conclusion in the noncommutative case.

A theorem on convex hulls, W. A. Horn, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73B** (Math. Sci.), No. 4, 307-308 (Oct.-Dec. 1969).

Key words: Convex geometry; convex sets.

Let p be a point in the interior K° of the convex hull $K = K(S)$ of a bounded point-set S in a real Hilbert space. A quantity $R(p)$ is determined such that every closed ball of radius $>R(p)$, if it contains p, must also meet S.

The partitioning of interaction in analysis of variance, J. Mandel, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73B** (Math. Sci.), No. 4, 309-328 (Oct.-Dec. 1969).

Key words: Factorial experiments; interaction; nonadditivity; principal components; surface fitting.

A method is presented for the analysis of data representing functions of two variables, when the response can be tabulated in a rectangular array. The procedure is based on a partitioning of the row by column interaction effects into a sum of terms, each of which is the product of a row factor by a column factor. The factors in each term are estimated by a method involving the extraction of characteristic roots.

The method contains as special cases a number of procedures used for the handling of non-additivity in two way arrays. It is very useful for the fitting of empirical surfaces, but it is also applicable to cases in which the data depend on qualitative rather than quantitative factors.

Comparisons with other techniques are made and an illustrative example is given.

Highly restricted partitions, H. Gupta, *J. Res. Nat. Bur. Stand.* (*U.S.*), **73B** (Math. Sci.), No. 4, 329-350 (Oct.-Dec. 1969).

Key words: Generating functions; graph of a partition; partitions.

The function $g(n, m, h, k)$, which enumerates the number of partitions of n into exactly k summands each less than or equal to m and in which the number of different summands is exactly h, is here tabulated and studied.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 74B, JANUARY-DECEMBER 1970

January-March 1970

Partitions—a survey, H. Gupta, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 1-29 (Jan.-Mar. 1970).

Key words: Congruences; generating functions; identities; partitions; recurrence formulas.

A historical survey of some aspects of the theory of partitions is given here.

A relation between the coefficients and roots of two equations and its application to diophantine problems, T. N. Sinha, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 31-36 (Jan.-Mar. 1970).

Key words: Diophantine equations; Prouhet-Tarry-Escott problem; symmetric functions.

The object of this paper is to prove:

THEOREM 1: *The system of equations*

$$a_1^r + a_2^r + \ldots + a_n^r = b_1^r + b_2^r + \ldots + b_n^r (r = 1, 2, \ldots, j-1, j+1, \ldots, n+1)$$

where j *is odd, has no nontrivial solutions in positive integers.*

THEOREM 2: *No two equations* $a_1^r + a_2^r = b_1^r + b_2^r (r = s,t)$ *where the pairs of values of* r *range between* 1 *and* 4 *can have a nontrivial solution in integers.*

An enumeration problem for a congruence equation, R. A. Brualdi and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 37-40 (Jan.-Mar. 1970).

Key words: Circulants; congruences; permanents.

It is shown that the number of n-tuples $(x_0, x_1, \ldots, x_{n-1})$ of nonnegative integers such that

$$\sum_{i=0}^{n-1} x_i = n,$$

$$\sum_{i=0}^{n-1} i x_i \equiv 0 \bmod n,$$

is given by

$$\frac{1}{n} \sum_{d \mid n} \binom{2d-1}{d} \varphi\left(\frac{n}{d}\right).$$

Orthogonal decompositions of tensor spaces, S. Pierce, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 41-44 (Jan.-Mar. 1970).

Key words: Irreducible character; symmetry class of tensors; symmetry operator; tensor product.

Let V be an n-dimensional vector space over the complex numbers. Let H be a subgroup of S_m, the symmetric group on $\{1, \ldots, m\}$, and let $W = \overset{m}{\otimes} V$ be the tensor product of V with itself m times. In this note we give an orthogonal direct sum decomposition of W in terms of the system of inequivalent irreducible characters of H.

AMS Subject Classifications: Primary, 1580; Secondary, 2080.

Partitioned hermitian matrices, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 45-46 (Jan.-Mar. 1970).

Key words: Generalized matrix function; positive semidefinite hermitian matrix.

A class of Cauchy-Schwarz type inequalities for partitioned hermitian matrices is presented.

Bounds on a polynomial, T. J. Rivlin, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 47-54 (Jan.-Mar. 1970).

Key words: Bernstein polynomials; bounds; polynomials.

Methods for computing the maximum and minimum of a polynomial with real coefficients in the interval [0,1] are described, and certain bounds are given.

Entire functions of exponential type, F. Gross, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 1, 55-59 (Jan.-Mar. 1970).

Key words: Bounded index; convexity; entire function; exponential type; maximum modulus.

Let f be an entire function satisfying for some integer p and some constant C

$$\sum_{j=0}^{N} \left(\int_0^{2\pi} \left| f^{(j)}(re^{i\theta}) \right|^r d\theta \right)^{1/p} \geq C \sum_{j=N+1}^{\infty} \left(\int_0^{2\pi} \left| f^{(j)}(re^{i\theta}) \right|^p \right)^{1/p}$$

for sufficiently large r. Then f is of exponential type. Conversely, the above is satisfied whenever f is periodic of exponential type. Similar conditions on the maximum moduli $M_f(j)(r)$ yield the same result. The analogous condition on $|f^{(j)}|$ is also discussed.

April-June 1970

Acoustic propagation and stability within an inviscid, heat-conducting fluid, J. E. McKinney and H. J. Oser, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 2, 67-84 (Apr.-June 1970).

Key words: Absorption; acoustic; adiabatic; fluid; heat-conducting; inviscid; isothermal; Kirchoff-Langevin equation; stability; steady-state; thermal; transient.

Propagation of acoustic waves within a continuum of inviscid, compressible, heat-conducting fluid is evaluated in detail in terms of both frequency (steady-state) and time dependent (transient) functions. The analysis reveals that when the value of the ratio of specific heats, γ, lies between one and two, the apparent steady-state solutions are conjugate to unstable, or regenerative, "transient" solutions, and, thus, are unacceptable. Propagation is stable for other values ($\gamma = 1, \gamma \geq 2$). The common assumption that the steady-state phase velocity varies continuously with increasing frequency from adiabatic to isothermal values is shown to be invalid, except when $\gamma = 2$.

On some indefinite integrals of confluent hypergeometric functions, E. W. Ng and M. Geller, *J. Res. Nat. Bur. Stand. (U.S.),* **74B** (Math. Sci.), No. 2, 85-98 (Apr.-June 1970).

Key words: Bessel functions; confluent hypergeometric functions; electronic energies; indefinite integrals.

Analytical expressions and reduction formulas are developed for various indefinite integrals of the confluent hypergeometric

functions. These integrals are of the type $\int f(a,b,z)z^p e^{\alpha z}dz$, where f is one of the two Kummer functions $M(a,b,z) \equiv {}_1F_1(a;b;z)$ or $U(a,b,z)$, with real or complex a, b, z and α, and real p.

On complementary polar conical sets, C. Witzgall, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 2, 99-113 (Apr.-June 1970).

Key words: Conjugate functions; convex cones; duality; linear programming; orthogonality; polarity.

Tucker has formulated the Duality Theorem of Linear Programming in terms of orthogonality properties of a pair of complementary orthogonal linear manifolds with respect to the positive orthant. This theorem is generalized by substituting complementary polar conical sets for complementary orthogonal linear manifolds, and the generalization is proved under simple stability assumptions. Equivalence to Fenchel's Duality Theorem for conjugate convex functions is established. There are strong parallelisms to work by Kretschmer.

On contractive semigroups and uniform asymptotic stability, P. R. Meyers, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 2, 115-120 (Apr.-June 1970).

Key words: Contractions; control theory; functional analysis; semigroup; stability theory; topology.

This paper calls attention to the equivalence between two well-known mathematical ideas: contraction mappings (in the sense of Banach) and asymptotic stability. The equivalence is formalized by defining a flow (representing the possible movements over time of some system through its state space) as a continuous one-parameter semigroup of operators on a metric space, and then showing that these operators are all contractions (in suitably revised metrics) if and only if there is a uniformly asymptotically stable equilibrium point. Generalizations to other operator semigroups are also given.

Normal subgroups of the modular group, L. Greenberg and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 2, 121-123 (Apr.-June 1970).

Key words: Genus; index; modular group; normal subgroups.

A number of results on the normal subgroup structure of the classical modular group is announced. A typical result is that a normal subgroup of square-free index is necessarily of genus 1, apart from 4 exceptions.

July-September 1970

Hecke basis theorems for groups of genus 0, M. I. Knopp and J. R. Smart, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 131-148 (July-Sept. 1970).

Key words: Eisenstein series; Hecke group; H-group; modular form; parametrization of cusp forms.

A Hecke-type basis theorem is established for the cusp forms of negative even integral degree (multiplier system 1) on the class of Hecke groups. Hecke established the result for the classical modular group, which is the first of the Hecke groups. A second result is a parametrization theorem for entire automorphic forms of negative real degree (with arbitrary multiplier systems) on certain discrete groups of real linear fractional transformations of genus zero.

The distribution of eigenvalues of covariance matrices of residuals in analysis of variance, J. Mandel, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 149-154 (July-Sept. 1970).

Key words: Analysis of variance; covariance matrix; eigenvalues; interaction; matrix; residuals; two-way table; vacuum cleaner.

A rigorous definition is given for the concept of an "interaction matrix" (Z_{ij}) where $i=1$ to m and $j=1$ to n, in terms of two idempotent matrices A_r and B_s of rank r and s, respectively. It is then shown that the frequency distribution of the eigenvalues of $(Z)(Z)'$ depends only on r and s. Applications are given to matrices of residuals arising from two-way data, either by removing row and/or column-means, or by applying any number of sweeps of the "vacuum cleaner." The theorems are important in the theory of the analysis of two-way tables of nonadditive data.

Expansions with coefficient algorithms for time domain responses of skin effect lossy coaxial cables, D. R. Holt, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 155-173 (July-Sept. 1970).

Key words: Coefficient algorithms; expansions; inverse Laplace transform; reflectometry; skin effect; step response; system function; transmission.

Time domain step response expansions with coefficient algorithms are developed from the system function of a doubly terminated skin effect lossy coaxial transmission line. Three models of series impedance valid for (a) high frequency, (b) high and intermediate frequency, (c) high and low frequency, are incorporated into the system function. The system function is expanded via the method of polynomial expansions of analytic functions through generating relations and inverted term by term into the time domain through the inverse Laplace transform. Step responses for time domain reflectometry and transmission are developed, computed, and compared with experimental results.

Derivatives of the Grüneisen and Einstein functions, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 175-182 (July-Sept. 1970).

Key words: Einstein function; electrical resistivity; Grüneisen function; solid state physics; transport properties.

Expressions (in closed form) are derived for the first five derivatives of the Grüneisen and Einstein functions. Recursion formulas for the successive derivatives of both functions are also given. Computations are made and tabular results are given for the first five derivatives of the Grüneisen and Einstein functions.

Selecting nonlinear transformation for the evaluation of improper integrals, T. A. Atchison, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 183-185 (July-Sept. 1970).

Key words: Improper integral; nonlinear transformation.

Recent literature concerning the use of nonlinear transformations to evaluate numerically certain improper integrals of the first kind involves the determination of a transformation function g to improve the approximation. By approximating a given integrand f by an integrable function f_1 and then determining an associated g function for f_1, a nonlinear transformation may be constructed which will yield an improved approximation of the improper integral of f.

On the spheroidal functions, D. R. Rhodes, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 187-209 (July-Sept. 1970).

Key words: Mathieu functions; spheroidal functions.

A number of new properties of the spheroidal functions of arbitrary real order $\alpha > -1$ are established, including double orthogonality over two separate intervals simultaneously and the existence of a new kind of characteristic numbers $\gamma_{\alpha n}(c)$ that arise from it. Some computational formulas are derived and a few numerical results are shown.

Automatic computing methods for special functions, I. A. Stegun and R. Zucker, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 3, 211-224 (July-Sept. 1970).

Key words: Approximations; computer programs; computing pitfalls; continued fractions; error function; recurrence relations; series.

Some of the pitfalls of automatic computation are described as well as their possible avoidance. A detailed description is given of the methods for computing the error and complementary error function. The implementation of the method is given in a double precision ASA FORTRAN program. The test ("driver") program and test results are also given.

October-December 1970

A property of the triangle groups, J. Lehner, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 231-233 (Oct.-Dec. 1970).

Key words: Element of finite order; F-group; normal subgroup; triangle group.

The F-groups are the groups possessing faithful representations by Fuchsian groups of the first kind; their presentations are known explicitly. Among the F-groups are the well-known triangle groups $G=\{x, y|x^p=y^q=(xy)^r=1\}$. If p, q, r are distinct prime integers, every proper normal subgroup of finite index in G has no elements of finite order. In this paper it is proved that among the F-groups only the triangle groups with distinct prime p, q, r have this property.

Some theorems on tensor composite graphs, M. F. Capobianco, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 235-237 (Oct.-Dec. 1970).

Key words: Digraphs; graphs; products; tensor; trees.

If a graph (digraph) is isomorphic to the tensor product of two graphs (digraphs) it is said to be a tensor composite graph (digraph). If not, it is said to be tensor prime. Several theorems giving various properties of tensor composite graphs and digraphs are presented. Among those dealing with (undirected) graphs is the result that any tree is tensor prime. This does not hold for digraphs. An example is given of a tensor composite digraph which is an unoriented tree. It is proved that a tensor composite digraph which is an oriented tree (an arborescence) does not exist. Some applications are presented.

The diophantine approximation of roots of positive integers, C. F. Osgood, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 239-242 (Oct.-Dec.).

Key words: Diophantine approximation; diophantine equation; effective computability.

The following result is established:

THEOREM: *Suppose that* $k \geq 150$ *and* m *are fixed positive integers. Then*

$$|\sqrt[k]{m}-pq^{-1}|<q^{-\frac{7}{8}k}$$

can hold for at most one pair of relatively prime positive integers p *and* q *with* $q \geq 2^9(\sqrt[k]{m}+1)^6$.

The new feature of this result is that the lower bound on q is given explicitly and is "small."

The minimum number of problems to cover all subproblems, H. J. Greenberg, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 243-247 (Oct.-Dec. 1970).

Key words: Combinatorics; dynamic programming; optimization; systems of distinct representatives; theory of computation.

The following problem is motivated and then solved, using the theory of systems of distinct representatives. Let $M=\{1, 2, \ldots, m\}$, and for each sequence σ of distinct members of M, let $\langle\sigma\rangle$ be the associated subset. Suppose given a mathematical problem $P(S)$ for each subset S of M, and an algorithm A which when applied to σ solves not only $P(\langle\sigma\rangle)$ but also all $P(\langle\tau\rangle)$ where τ is an initial segment of σ. What is the smallest number of applications of A needed to solve the entire ensemble of problems $\{P(S):S \subset M\}$?

Error estimates for the solution of linear algebraic systems, Brother K. E. Fitzgerald, F.S.C., *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 249-306 (Oct.-Dec. 1970).

Key words: Error estimates; evaluation of computer programs; inverse of a matrix; linear systems and matrices.

In this paper bounds for the error of a computed inverse of a matrix are developed. These are then applied to the solution of a single system. Methods for improving the approximate inverse are then discussed with some observations on the dangers involved in their practical use on a computer and some safeguards are indicated. Some computer programs for matrix inversion are then evaluated by means of the bounds developed.

On the singular values of a product matrices, W. Watkins, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 307-309 (Oct.-Dec. 1970).

Key words: Matrices; singular values.

The purpose of this note is to give necessary and sufficient conditions for the singular values of a product of matrices to be equal to certain products of their singular values. We then analyze the case of equality in a matrix inequality of Ostrowski.

Contractifiable semigroups, P. R. Meyers, *J. Res. Nat. Bur. Stand. (U.S.)*, **74B** (Math. Sci.), No. 4, 311-319 (Oct.-Dec. 1970).

Key words: Contractions; functional analysis; operators; semigroups; stability theory.

Consider a continuous semigroup of operators on a metric space, indexed $\{T_t\}$ by the nonnegative real numbers. It is shown that if any one of the operators can be made into a contraction by some topology-preserving remetrization, then for each $\lambda\epsilon(0, 1)$ there is a metric under which each operator $T_t(t>0)$ becomes a contraction constant λ^t. With the operators regarded as describing the evolution of an autonomous dynamical system, this metric can be used to define a Lyapanov function.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 75B, JANUARY-DECEMBER 1971

January-June 1971

Bounds to truncation errors in biorthogonal polynomial approximations, with illustrative applications to gamma-ray transport distributions, L. V. Spencer, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 1-16 (Jan.-June 1971).

Key words: Biorthogonal polynomials; gamma-ray transport; moment method; neutron transport; polynomial truncation errors; Sievert function.

Problems of gamma-ray and neutron penetration in infinite, homogeneous media can be solved in terms of infinite sums of a certain type of biorthogonal polynomial system. Many calculations have used a few terms, perhaps 4 to 8, successfully due to good apparent convergence. This paper develops expressions for bounds to the truncation error of these finite sums. Examples and applications are given of the functions used to obtain the error bounds.

A theorem on matrix commutators, J. M. Smith, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 17-21 (Jan.-June 1971).

Key words: Commutator; matrix; orthogonal; skew-symmetric.

Let $P = I_p + (-I_q)$, the direct sum of the $p \times p$ identity matrix and the negative of the $q \times q$ identity matrix. The following theorem is proved.

THEOREM: *If the matrices* A *and* B *are* P*-orthogonal (orthogonal with respect to* P*) and* P*-skew-symmetric (skew-symmetric with respect to* P*) then* [A,B] = AB − BA *may be expressed as the difference,* C − D, *of matrices which are* P*-orthogonal,* P*-skew-symmetric.*

Explicit expressions for the matrices C and D are given.

A special permutation matrix decomposition for combinatorial design incidence matrices, E. C. Johnsen and T. F. Storer, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 23-30 (Jan.-June 1971).

Key words: Block design; combinatorial analysis; configurations; König's theorem; matrices; matrix equations; permutation matrix decompositions; 0, 1 matrices.

By a well-known theorem of König, every 0,1 matrix A of order v with all row and column sums equal to $k > 0$ can be decomposed into a sum of k permutation matrices of order v. Here we consider whether A, trace $A = 0$ or v, can have a special permutation matrix decomposition called a *special König decomposition*. The question is answered more or less satisfactorily using certain graph factorization theorems of Petersen and Tutte. Symmetric counterexamples are given to show that not all such matrices have special König decompositions; however, it is shown that symmetric incidence matrices *for* $\langle v, k, \lambda \rangle$ designs always have special König decompositions.

The Casimir check for the algebraic matrices of the configuration $(d+s)^n p$, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 31-47 (Jan.-June 1971).

Key words: Casimir operator; checking parameters; $(d+s)^n p$, SU_3.

By using the eigenvalues of the Casimir operator for the group SU_3, checking parameters were obtained for 12 electrostatic interaction matrices of the configuration $(d+s)^n p$.

Convex homotopy, W. A. Horn, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 49-61 (Jan.-June 1971).

Key words: Convex functions; convex sets; homotopy.

Given any two continuous, convex functions f and g on a compact, convex set with certain properties ("regular" convexity), it is shown that an infinite number of homotopies of f and g exist which are also convex. One such homotopy in particular (the "basic" homotopy) is shown to have nice monotonicity properties and can be used as a basis for constructing other homotopies. A method of constructing the basic homotopy is given for the case where the domain of f and g is a line segment. (Theorems are for normed linear spaces only.)

The powers of a connected graph are highly hamiltonian, V. N. Bhat and S. F. Kapoor, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 63-66 (Jan.-June 1971).

Key words: Graph; hamiltonian; power of a graph.

Let G be a connected graph on p points. It is proved that if any k points are deleted from the graph G^{m+2}, $1 \leq m \leq p-3$ and $0 \leq k \leq m$, then the resulting graph is hamiltonian.

Exact solutions of linear equations with rational coefficients, A. S. Fraenkel and D. Loewenthal, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 69-75 (Jan.-June 1971).

Key words: Congruences; exact solutions; linear equations; modular arithmetic.

Improvements of a congruential method for finding the exact solutions of systems of linear equations with rational coefficients are described. Typical execution times on the CDC 1604-A are given, as well as the Fortran program.

An improvement of the Fischer inequality, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 77-80 (Jan.-June 1971).

Key words: Fischer inequality; Hadamard determinant theorem; permanent; positive definite hermitian matrix.

An improvement of the classical Fischer inequality for the determinant of a positive definite hermitian matrix is proved. It is used to analyze the Hadamard determinant theorem.

On the Smith normal form, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 81-84 (Jan.-June 1971).

Key words: Invariant factors; principal ideal rings; Smith normal form.

An elementary proof is given of the fact that if A, B are nonsingular $n \times n$ matrices over a principal ideal ring R, then the kth invariant factor of AB is divisible by the kth invariant factor of A and by the kth invariant factor of B, $1 \leq k \leq n$. Some consequences are drawn.

On certain optimal quadrature formulas, S. Haber, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 1 and 2, 85-88 (Jan.-June 1971).

Key words: Analytical functions; approximation; Gaussian quadrature; integration; optimal quadrature; quadrature.

A class of optimal quadrature formulas defined by V. L. N. Sarma in a probabilistic context is shown to be identical with a class of formulas defined previously, in a different manner, by P. J. Davis. As a result a contrast is drawn between the maximum of the error of a quadrature formula over the unit sphere in a certain function space, and its average—in Sarma's sense—over that sphere.

July-December 1971

Some elementary formulas in "matrix calculus" and their applications, J. T. Fong, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 97-107 (July-Dec. 1971).

Key words: Chain rule; continuum mechanics; gradient; matrices; matrix calculus; partial differentiation; product rule; tensor function; trace.

A collection of elementary formulas for calculating the gradients of scalar- and matrix-valued functions of one matrix argument is presented. Using some of the well-known properties of the operator "trace" on square matrices, alternative definitions of gradients and simple examples of calculating them using the product rule and the chain rule for differentiation are treated in an expository fashion in both component and matrix notations with emphasis on the latter. Two examples in continuum mechanics are presented to illustrate the application of the so-called "matrix calculus" of differentiable functions.

Linear transformations on matrices, M. Marcus, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 109-115 (July-Dec. 1971).

Key words: Determinant; generalized matrix function; invariants; matrices; rank.

Let K be a field and let $M_n(K)$ denote the vector space of all $n \times n$ matrices over K. Suppose $I(X)$ is an invariant defined on a subset $\mathcal{U}$ of $M_n(K)$. This paper surveys certain results concerning the following problem. Describe the set $\mathcal{L}(I, \mathcal{U})$ of all linear transformations $T: \mathcal{U} \to \mathcal{U}$ that hold the invariant I fixed:

$$I(T(X)) = I(X), \qquad X \in \mathcal{U}$$

Eigenvalues of sums of Hermitian matrices. III., R. C. Thompson and L. F. Garbanati, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 117-124 (July-Dec. 1971).

Key words: Eigenvalues; linear inequalities; singular values.

Two classes of nonlinear inequalities for the eigenvalues of sums of Hermitian matrices are obtained. These nonlinear inequalities are shown to follow from linear inequalities established in parts I and II of this series. A new inequality for the singular values of matrix products is also obtained.

A new type of boundary value coupling for second order Sturm-Liouville systems, J. Geist, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 125-138 (July-Dec. 1971).

Key words: Boundary value problems; coupled equations; differential equations; self-adjoint equations; Sturm-Liouville systems.

A natural generalization of the familiar second order Sturm-Liouville system is presented. This generalization consists of considering a number of differential equations defined on different intervals, instead of just one equation on one interval. The self-adjoint character of the differential equations is retained in the generalization, but the boundary conditions are relaxed considerably. The most general boundary conditions which can be accommodated by this sort of generalization of Sturm-Liouville theory are discussed. The existence of eigenvalues is proved, and a generalized orthogonality and a weak eigenfunction expansion theorem are derived.

An ergodic source which is not a function of any finite Markov process, R. D. Traub, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 139-148 (July-Dec. 1971).

Key words: Information theory; Markov process; probability theory; ring theory; stochastic process.

The problem of deciding when a stationary stochastic process is a function of a finite Markov process has been considered by several authors, leading to an elegant necessary and sufficient condition. Taking a different approach, this note uses elementary ring theory to prove that a certain explicitly constructed stationary ergodic process is not a function of any finite Markov process.

On entire functions of exponential type, S. M. Shah and W. C. Sisarcick, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 149-156 (July-Dec. 1971).

Key words: Bounded index; entire function; exponential type; maximum modulus.

Let f be an entire function and let $p \geq 1$ and

$$I(l, r) = \left\{ \int_0^{2\pi} |f^{(l)}(re^{i\theta})|^p d\theta \right\}^{1/p}.$$

Let $C > 0$. If there exists a positive integer N such that for $k = 0, 1, \ldots, N$,

$$\sum_{j=0}^{N} \frac{I(k+j, r)}{j!} \geq C \sum_{j=N+1}^{\infty} \frac{I(k+j, r)}{j!},$$

for all sufficiently large r, then f is of exponential type not exceeding $\{2 \log (1(1/c)) + 1 + \log (2N)!\}$. If this condition is replaced by related conditions, then also is of exponential type.

A table of integrals of the error function. II. Additions and corrections, M. Geller and E. W. Ng, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math Sci.), Nos. 3 and 4, 157-178 (July-Dec. 1971).

Key words: Error functions; indefinite integrals; special functions.

This is an extension of a compendium of indefinite and definite integrals of products of the error function with elementary or transcendental functions recently published by the authors.

A note on the time dependence of the effective axis and angle of a rotation, H. Gelman, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 179-186 (July-Dec. 1971).

Key words: Angular velocity; effective axis and angle of rotation; intrinsic vector; kinematics of a rigid body; rotation group; spatial rotation.

The time dependent rotation of one orthogonal coordinate system with respect to a fixed one is considered in the parametrization based on the effective axis and angle of the rotation, a parametrization which has recently been used to discuss the irreducible representations of the rotation group. The method of the intrinsic vector is used to derive the equations of motion for the instantaneous effective axis and angle. A new representation of the angular velocity is obtained in a rotating orthogonal coordinate system generated by a unit vector along the effective axis, and a new geometrical interpretation of the effective angle is given.

A numerical solution of integral equation of the first kind applied to slit correction in small-angle x-ray scattering, J. Mazur, *J. Res. Nat. Bur. Stand. (U.S.)*, **75B** (Math. Sci.), Nos. 3 and 4, 187-207 (July-Dec. 1971).

Key words: Conditions for convergence of solutions; integral equation of first kind; shifting operators; slit correction; slit weighting-function; small-angle x-ray scattering; strong numerical instability.

A novel approach to the problem of the slit correction in small-angle x-ray scattering is presented, based on a matrix inversion method. The integral equation for the slit correction is written as a Volterra equation of the first kind. This equation is reduced to a system of simultaneous equations, expressed in matrix form. The order of the matrix is equal to the number of experimentally determined points. To obtain these equations, one has to expand the unknown functions in Taylor series around each point to be subsequently determined. There is, however, a difficulty inherent in this method due to the fact that most of the series expansions of the function to be determined lead to a strong numerical instability. However, a general method is developed, which enables us to find shifting operators leading to numerically stable systems of equations. The "unsmearing" of the experimental data is then performed by standard matrix inversion procedures

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 76B, JANUARY-DECEMBER 1972

January-June 1972

Minimax-based selection, adjustment and disaggregation for incompletely specified univariate distributions, A. J. Goldman, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 1-38 (Jan.-June 1972).

Key words: Linear programs; mathematical models; minimax estimation; operations research; probability distribution.

This paper deals with making a nominal choice from a class of discrete univariate probability distributions about which one has "incomplete information" such as component-wise bounds, a component-wise ranking, or both. In some cases, an initial distribution is provided, to be "adjusted" so as to be compatible with the incomplete information. The first part of the analysis systematizes and unifies the contents of four earlier papers treating such problems using a minimax-error or minimax-adjustment approach. The second part applies the same approach to situations in which an "aggregate" of the desired distribution is stipulated, either exactly, or approximately by component-wise bounds. All problems discussed in the paper can be formulated as linear programs, but relatively explicit solution methods are sought; unresolved difficulties arising in this attempt are identified.

Three results for trees, using mathematical induction, W. A. Horn, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 39-43 (Jan.-June 1972).

Key words: Helly's theorem; mathematical induction; minimum-length coverings; node-covering; trees.

The paper illustrates the use of mathematical induction to extend results which are true for a line segment to trees. Three separate theorems are stated and proved, each of which has some importance in its own right.

Abstract groups as doubly transitive permutation groups, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 45-50 (Jan.-June 1972).

Key words: Character; cosets; matrix representation; nilpotent group; normalizer; solvable group.

The question considered is this: Which abstract groups have representations as doubly transitive permutation groups? Moreover, given an abstract group, can all doubly transitive representations be found? The paper is expository. Various results which bear on the question are presented in an elementary way.

Covariances of two sample rank sum statistics, P. V. Tryon, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 51-52 (Jan.-June 1972).

Key words: c Sample problem; covariances; Mann-Whitney-Wilcoxon statistics; rank sum statistics; statistics.

This note presents an elementary derivation of the covariances of the $c(c-1)/2$ two-sample rank sum statistics computed among all pairs of samples from c populations.

Efficient techniques for unbiasing a Bernoulli generator, J. A. Lechner, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 53-60 (Jan.-June 1972).

Key words: Bernoulli; binomial; coin-tossing; computer; efficiency; generator; random numbers; statistics.

Consider the problem of operating on a sequence of i.i.d. Bernoulli variables with unknown mean p to produce a sequence of symmetric Bernoulli variables. Define the efficiency of any proposed method to be the average number of binary output digits per input digit. The following results are proved: (A) No method exists having efficiency greater than $-p\log_2 p - q\log_2 q$, where $q=1-p$. (B) Methods do exist with efficiency arbitrarily close to the bound just given. Examples are given, and compared with other methods in the literature. A technique for finding the methods of (B) above is given.

Checks of the algebraic matrices for the configurations $(d+s)^n p$, C. Roth, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 1 and 2, 61-80 (Jan.-June 1972).

Key words: Checking parameters; $(d+s)^n p$; electrostatic interaction; relative phases; spin-orbit interation.

By constructing suitable combinations of algebraic matrices enabling the resulting eigenvalues to be predicted theoretically, checking parameters were obtained for 32 interaction parameters of the configuration $(d+s)^n p$.

July-December 1972

"Plural-series" approximations of functions, L. V. Spencer, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 91-108 (July-Dec. 1972).

Key words: Biorthogonal function; gamma-ray transport; moment methods; neutron transport; polynomial representations; radiation penetration.

A method is given for developing approximations to neutron and gamma-ray transport distributions in the form of a superposition of U_n^k polynomial series multiplied by exponentials and characterized by different scale factors. Convergence conditions and error bound expressions are given. Biorthogonality properties are worked out. Examples are given in which these approximations are compared with polynomial approximations.

Scheduling a time-shared server to minimize aggregate delay, A. J. Goldman, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 109-117 (July-Dec. 1972).

Key words: Computer systems; optimization; scheduling; time-sharing.

A simplified analysis is given of a problem situation, previously treated in the literature, which pertains to the delay-minimizing allocation of servicing times among N incoming streams requiring "processing" of some kind by a single "server" (e.g., a time-shared computer). The original problem is generalized to permit different "weights" for the delays suffered by different streams.

Normal matrices with entries from an arbitrary field of character $\neq 2$, M. H. Pearl and A. I. Penn, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 119-143 (July-Dec. 1972).

Key words: Field; matrices; normality.

Let F be an arbitrary field of characteristic $\neq 2$ and let conjugation in F be defined by an arbitrary involutory automorphism (possibly the identity mapping). A matrix with entries from F is normal if it commutes with its conjugate transpose. Several conditions which are equivalent to normality when F is the complex field are properly nested when F is an arbitrary field. Of these conditions, normality is the weakest and unitary diagonalizability is the strongest.

When the underlying field is closed the unitarily diagonalizable matrices are those which possess a spectral representation with Hermitian idempotents. These matrices may be characterized in terms of their EP properties.

A matrix is indecomposable if it has a single elementary divisor of the form $(x-s)^i$. For $i>1$, normal indecomposable matrices do not exist when F is the complex field. However there exists field for which normal indecomposable matrices of all finite orders exist. A matrix is a normal indecomposable matrix if and only if it can be expressed as $r(B)$ where $r(x)$ is a polynomial such that $r(0)\neq 0$ and B is a matrix having the single elementary divisor x^i and satisfying the equation $B^*=sB$ for some scalar s.

When the involutory automorphism of F is the identity mapping indecomposable normal matrices of even order exist if and only if the vector space F^n is hyperbolic, and in this case the matrices are symmetric. Moreover, indecomposable normal matrices of odd order exist if and only if F^n is the orthogonal sum of a hyperbolic space and a one dimensional space, and in this case both symmetric and nonsymmetric indecomposable normal matrices exist.

Distance coordinates with respect to a triangle of reference, K. Goldberg, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 145-152 (July-Dec. 1972).

Key words: Area coordinates; distance coordinates; Plane Geometry; radical center; triangle of reference.

With respect to a triangle of reference $A_1A_2A_3$, each point P in the plane of the triangle, has unique *area* coordinates: $P=(b_1, b_2, b_3)$ with $b_1+b_2+b_3=1$. *Distance* coordinates are introduced such that $P=[d_1, d_2, d_3]$, with d_k the distance from P to A_k. It is shown that there is an explicit function $f(x_1, x_2, x_3)$ such that $f(d_1^2, d_2^2, d_3^2)=0$ is necessary and sufficient for $P=[d_1, d_2, d_3]$, each d_k nonnegative. The partial derivatives $f_k(x_1, x_2, x_3)=\partial f(x_1, x_2, x_3)/\partial x_k$ are such that $b_k=f_k(d_1^2, d^2, d^2)$ for each k. Other results relating the b_k and the d_k are given. The use of $f(x_1, x_2, x_3)$ in solving geometric problems is shown.

On regular sets of polynomials whose zeros lie in prescribed domains, M. A. Farag and M. Nassif, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 153-159 (July-Dec. 1972).

Key words: Basic sets; Cannon sum of basic sets; lower semiblock matrices; order of basic sets; zeros of polynomials in regular sets.

The relation between the mode of increase of regular basic sets of finite span and the order of magnitude of the zeros of polynomials $\{p_n(z)\}$ belonging to them is investigated. Upper bounds are obtained for the order of the basic sets when the zeros of $p_n(z)$ lie either in the unit circle or in a circle whose radius increases in a certain manner with the index n of the polynomial.

The Stieltjes Constants, J. J. Y. Liang and J. Todd, *J. Res. Nat Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 161-17 (July-Dec. 1972).

Key words: Bernoulli numbers; Euler-Maclaurin method Euler transform; Euler's constant; multiple precisio package; Riemann zeta function.

The Stieltjes Constants are the coefficients in the Lauren expansion of the Riemann Zeta function $\xi(z)$ about its simpl pole at $z=1$. They can be represented as the limit of the differ ence between the sum of the first n terms of a series and th integral of its n-th term.

The first 20 coefficients have been computed to 15 D usin the Euler-Maclaurin method. As a by-product the sums of th series

$$\tau_n=\sum_{2}^{\infty}(-1)^k(\log k)^n/k$$

have been obtained to 15 D for $n=1(1)20$.

Confidence limits for the abscissa of intersection of two linea regressions, J. J. Filliben and J. E. McKinney, *J. Res. Na Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 179-19 (July-Dec. 1972).

Key words: Abscissa; confidence limits; glass transition intercept; intersection; linear; regression; second orde transition; statistics; variance.

A method to determine the confidence limits for the absciss of the intersection of two linear regressions has been developec This method does not require the assumption of equal varianc for the two regressions, as was necessary with previous method A numerical example is included on thermodynamic, glas transition data for which this method is applicable. Comparison are made between the results using equal and unequal varianc assumptions. A FORTRAN subroutine is included for comput tions using both assumptions.

Weighting methods for Monte Carlo calculation of polym configurations, F. L. McCrackin, *J. Res. Nat. Bur. Stan (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 193-200 (July-De 1972).

Key words: Boltzmann factors; importance samplin Monte Carlo; non-self-intersecting walks; polymer co figurations; random walks.

In the Rosenbluth and Rosenbluth method of computing pol mer configurations, the configurations are weighted in order remove bias of the estimated parameters of the configuration This weighting method is investigated and generalized f importance sampling and Boltzmann factors. The estimat are found to be unbiased in the limit for an infinite sample configurations, but to have a bias for a finite sample. The stan ard deviations of the estimates are also derived.

Product solutions and separation of variables, A. J. Goldma *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. and 4, 201-204 (July-Dec. 1972).

Key words: Difference equations; functional equatior separation of variables.

This paper consists of two independent notes, whose comm features are (a) their concern with "product-form" functions a (b) their use of an abstract-algebra setting to isolate the esse tial features of the problems treated. The first note furth generalizes the generalizations given by Chu and Diaz (19 of their observation that Euler's difference equation $y(x+1)$ $y(x)=f(x)$, when f is of period 1, has the product-form soluti

$v(x) = xf(x)$. The second note formalizes and rigorously proves the fact that a function is separable jointly in its variables if it is separable in each individual variable.

A note of the multiplicative property of the Smith normal form, M. Marcus and E. E. Underwood, *J. Res. Nat. Bur. Stand. (U.S.)*, **76B** (Math. Sci.), Nos. 3 and 4, 205-206 (July-Dec. 1972).

Key words: Compound; divisors; matrix.

This paper contains an elementary proof of the fact that if A and B are n-square matrices over a principal ideal domain R with relatively prime determinants then $S(AB) = S(A)S(B)$ where $S(A)$ is the Smith normal form of A.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 77B, JANUARY-DECEMBER 1973

January-June 1973

Some Hamiltonian results in powers of graphs, A. M. Hobbs, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 1-10 (Jan.-June 1973).

Key words: Combinatorics; connectivity; Euler graphs; 2-factors; graph theory; Hamiltonian circuits; Hamiltonian connected; powers of graphs.

In this paper we show that the connectivity of the kth power of a graph of connectivity m is at least km if the kth power of the graph is not a complete graph. Also, we prove that removing as many as $k-2$ vertices from the kth power of a graph ($k \geq 3$) leaves a Hamiltonian graph, and that removing as many as $k-3$ vertices from the kth power of a graph ($k \geq 3$) leaves a Hamiltonian connected graph. Further, if every vertex of a graph has degree two or more, then the square of the graph contains a 2-factor. Finally, we show that the squares of certain Euler graphs are Hamiltonian.

On a functional equation, A. O. L. Atkin, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 11-13 (Jan.-June 1973).

Key words: Analysis; continuous; equation; function; real.

Subject to suitable conditions of continuity and normalization, it is shown that the equation $f(x,y)+f(x+y,z)=f(y,z)+f(x,y+z)$ implies $f(x,y)=g(x)+g(y)-\epsilon(x+y)$. The result has application in physics to the motion of an electron in a crystal lattice.

Matroid designs, P. Young and J. Edmonds, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 15-44 (Jan.-June 1973).

Key words: Balanced incomplete block designs; matroid designs; matroids.

Matroids are investigated in which equicardinality conditions are imposed on the flats. Such matroids are shown to be closely related to certain types of BIBD's. Existence and uniqueness theorems for these structures are derived, together with a boundedness criterion on their rank. Several classes are exhibited, including finite projective and affine geometries, certain t-designs (Steiner systems) and so-called trivioids. By viewing certain t-designs as matroids, new ways of constructing BIBD's are derived. Three new series of 3-designs and two new 4-designs are obtained by these methods. A matroid analysis of the 5-(24,8,1) design of Witt is presented, and examples are obtained from it of matroids having equicardinal hyperplanes but not equicardinal flats in lower ranks. Several general conjectures and existence problems for these types of matroids are suggested.

Extrapolation techniques related to transcendence proofs, K. B. Stolarsky, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 45-51 (Jan.-June 1973).

Key words: Baker's extrapolation method; extrapolation; Hermite interpolation formula; transcendental numbers; transcendence proofs.

An extrapolation method used by A. Baker to study linear forms in the logarithms of algebraic numbers is further refined, and used to study a general extrapolation problem involving a function holomorphic in a large disk.

A catalog of minimal blocks, A. M. Hobbs, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 53-60 (Jan.-June 1973).

Key words: Blocks; combinatorics; examples of graphs; graph theory; minimal blocks; planar graphs; thickness of graphs; two-connected graphs.

In this paper we provide a catalog of the minimal blocks with 10 and fewer vertices, together with a discussion of the methods and theorems used to produce the catalog. In addition, we prove a theorem which is a strengthening of a similar theorem of Fleischner [2] on the structure of minimal blocks.

On the eigenvalues of A+B and AB, H. Wielandt, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 1 and 2, 61-63 (Jan.-June 1973).

Key words: Angular field of values; eigenvalues; field of values; hermitian; inertia; positive semidefinite.

Using the usual field of values and the angular field of values inclusion sets are found for the eigenvalues of sums and products of $n \times n$ complex matrices. For instance if the field of values of B does not contain 0 it is found that the quotient of the field of values of A by that of B contains the eigenvalues of AB^{-1}. Applications are made to the polar form (AB where A is unitary and B positive semidefinite) and to products AB with A hermitian and $B+B^*$ positive definite.

July-December 1973

An application of Schur's lemma on irreducible sets of matrices in continuum mechanics, J. T. Fong, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 73-79 (July-Dec. 1973).

Key words: Continuum mechanics; elasticity; integration; matrix calculus; matrix identity; matrix theory; reducibility; Schur's lemma; strain energy.

In a recent study of the thermodynamic restrictions of a theory of compressible, viscoelastic fluids, Fong and Simmons (ZAMP **23**, No. 5 (1972)) encountered a problem of integrating the following matrix identity:

$$\underline{\underline{M}}[\underline{\underline{H}}\hat{U}_{,C}(\underline{\underline{H}}^T\underline{\underline{M}}\underline{\underline{H}})\underline{\underline{H}}^T - \hat{U}_{,C}(\underline{\underline{M}})] - \underline{\underline{H}}\hat{U}_{,C}(\underline{\underline{H}}^T\underline{\underline{H}})\underline{\underline{H}}^T \equiv \underline{\underline{O}},$$

where $\hat{U}_{,C}$ denotes the gradient of the scalar-valued function $U = \hat{U}(\boldsymbol{C})$ with respect to its matrix argument $\boldsymbol{C}$ which is symmetric and positive-definite. The identity is valid for every symmetric positive-definite $\boldsymbol{M}$ and every unimodular $\boldsymbol{H}$. The symbol $\boldsymbol{H}^T$ denotes the transpose of the matrix $\boldsymbol{H}$. The solution of the problem is presented here in detail as an example of applying, probably for the first time, Schur's lemma on irreducible sets of matrices in theoretical continuum mechanics.

Remarks on a problem of Rademacher in the theory of modular forms, M. I. Knopp, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 81-83 (July-Dec. 1973).

Key words: Dedekind function; modular form; partition function; Poincaré series.

Rademacher quite some time ago posed the question of deriving the classical functional equation of $1/\eta(z)$ ($\eta(z)$ is the Dedekind modular form) directly from the exact expression he had found for the partition function, $p(n)$, which arises as the Fourier coefficient of $1/\eta(z)$. Although he had been able to solve a similar problem for the absolute invariant $J(z)$, Rademacher was unable to solve the problem for $1/\eta(z)$. We here relate this question to some more recent results of Douglas Niebur, which reduce the problem to one of identically zero Poincaré series of degree $-5/2$.

The characterizations of $(A_q(U))$, M. E. Sheingorn, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 85-92 (July-Dec. 1973).

Key words: Automorphic functions; Hardy spaces.

For $q > 1$ Bers defines a Banach space $A_q(U) = \left\{ f \epsilon H(U) \mid \int_U |f(u)|(1-|u|^2)^{q-2} dxdy < \infty \right\}$ and shows that any bounded linear functional Λ on $A_q(U)$ may be represented as $\Lambda(f) = \int_U f(u)\bar{G}(u)(1-|u|^2)^{2q-2} dxdy$ where $G \epsilon B_q(U) = \{ h \epsilon H(U) \mid \sup_{u \epsilon U} |h(u)|(1-|u|^2)^q < \infty \}$ and is unique. This work is done in [1]. Duren, Romberg, and Shields, pursuant to their work on H^p for $p < 1$, define a Banach space $B^p(p<1) = \left\{ f \epsilon H(U) \mid \int_0^{2\pi} \int_0^1 |f(re^{i\theta})|(1-r)^{1/p-2} dr d\theta < \infty \right\}$. They show that a bounded linear functional Λ on B^p may be uniquely represented as $\Lambda(f) = \lim_{r \to 1} \int_0^{2\pi} f_r(e^{i\theta}) \bar{g}(e^{i\theta}) d\theta$ where

(i) $f_r(e^{i\theta}) = f_r(re^{i\theta})$

(ii) $g \epsilon A = \{ h \epsilon H(U) \mid g$ is continuous on $\bar{U}\}$ and $g^{(n-1)}$, and $n-1$ *st* derivative of g, is in $\Lambda_\alpha = \{ h \epsilon H(U) \mid h'(re^{i\theta}) = 0((1-r)^{\alpha-1}) \}$. (Here $\alpha = 1/p - n$ where $n < 1/p < n+1$, so $\alpha \neq 0$. If $1/p = n+1$, the conditions on g are: $g \epsilon A$, $g^{(n-1)} \epsilon \Lambda_* = \{ h \epsilon H(U) \mid h''(re^{i\theta}) = 0((1-r)^{-1}) \}$.) This work appears in [2].

In this paper, after showing that $B^p \cong A_q(U)$ with $1/p = q$, we derive the relationship between G and g, namely:

$$G(z) = \sum_{k=0}^{2n+1} A_k \cdot g^{(2k+1)}(z) \cdot z^{2k+1},$$

($|z| < 1$) where A_i are constants, $A_{2n+1} \neq 0$. (in this case $q = 1/p$ is an integer. The Theorem is slightly different if q is not an integer.)

Character induced subgroups, R. Merris and W. Watkins, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 93-99 (July-Dec. 1973).

Key words: Character of central type; central idempotent; Frobenius Reciprocity; group algebra; orthogonality relations; tensor product.

Given a finite group G with an irreducible character χ, define $G_\chi = \{ g \epsilon G : |\chi(g)| = \chi(1) \}$. Then $\chi(1)^2 \leq [G : G_\chi]$. We investigate the case of equality. There are applications to symmetry classes of tensors and generalized matrix functions.

Performance testing of a FORTRAN library of mathematical function routines—A case study in the application of testing techniques, D. W. Lozier, L. C. Maximon, and W. L. Sadowski, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 101-110 (July-Dec. 1973).

Key words: Automated testing; bit comparison; FORTRAN library; function validation; mathematical functions; performance tests.

This paper describes an application of testing methodology and techniques developed by the authors to aid in improving the quality of mathematical software. These techniques differ radically in several aspects from techniques previously used, the most important difference being that the testing is not based exclusively on random arguments. Instead, throughout the range of each function use is made of special arguments that are designed to detect programming errors and to test the performance of an algorithm in different regions. The function values are tested against reference values which are stored on reference tapes generated by a highly authenticated system of subroutines.

Since the effectiveness of such a testing system in discovering errors and performance limitations can be fully ascertained only through actual use, we report the results of employing our system to test an existing FORTRAN library of mathematical function routines. Specific aspects of the numerical accuracy of the library used in this test case are discussed in order to illustrate the effectiveness of a well-designed testing system as an analytic tool for the evaluation of mathematical software.

Since documentation provides information necessary to perform testing and contains specifications that reflect the results of testing, our study includes comments on the documentation.

No information on timing or storage requirements is presented in this case study.

Bessel functions *I* and *J* of complex argument and integer order, D. J. Sookne, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 111-114 (July-Dec. 1973).

Key words: Bessel functions; backward recursion; error bound; Miller algorithm; difference equation.

A computer program is described for calculating Bessel functions $J_n(z)$ and $I_n(z)$, for z complex, and n a nonnegative integer. The method used is that of backward recursion, with strict control of error, and optimum determination of the point at which to begin the recursion.

Certification of an algorithm for Bessel functions of real argument, D. J. Sookne, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 115-124 (July-Dec. 1973).

Key words: Bessel functions; bit comparison; error bounds.

The accuracy of routine BESLRI is certified.

Bessel functions of real argument and integer order, D. J. Sookne, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 125-132 (July-Dec. 1973).

Key words: Backward recursion; Bessel functions; difference equation; error bounds; Miller algorithms.

A computer program is described for calculating Bessel functions $J_n(x)$ and $I_n(x)$, for x real, and n a nonnegative integer. The method used is that of backward recursion, with strict control of error.

Certification of an algorithm for Bessel functions of complex argument, D. J. Sookne, *J. Res. Nat. Bur. Stand. (U.S.)*, **77B** (Math. Sci.), Nos. 3 and 4, 133-136 (July-Dec. 1973).

Key words: Backward recursion; Bessel function; bit comparison; error bounds; relative error.

Computer tests of algorithm BESLCI are described, and the results of the test are given.

Triangles generated by powers of triplets on the unit circle, C. R. Johnson and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.),* **77B** (Math. Sci.), Nos. 3 and 4, 137-141 (July-Dec. 1973).

Key words: Convex hull; unit circle; Weyl's Theorem.

Let α, β, γ be three distinct complex numbers of modulus 1. It is shown that there is essentially one exception to the following statement: For some positive integer m, 0 is in the closed convex hull of $\alpha^m, \beta^m, \gamma^m$. The exception occurs for the normalized triple

$$1, e^{2\pi i/7}, e^{2k\pi i/7},$$

where $k=3$ or 5. This question was motivated by the problem of determining when a positive integer m and a nonzero $n \times 1$ vector χ exist such that

$$\chi \approx A^m \chi = 0,$$

where A is a given matrix of $M_n(C)$.

Tables and graphs of the stable probability density functions, D. R. Holt, *J. Res. Nat. Bur. Stand. (U.S.),* **77B** (Math. Sci.), Nos. 3 and 4, 143-198 (July-Dec. 1973).

Key words: Accuracy; approximations; asymptotic expansion; Cauchy distribution; characteristic function; closed forms; contour; convergence; curves; distribution function; error; Fourier transform; infinite series; interpolation; limit distribution; normal distribution; polynomials; probability density function; quadrature; stable distribution; sums of independent random variables; tables; truncation.

Four-decimal-place tables are presented of the probability density function $p(\chi; \alpha, \beta)$ of the stable distribution for $\alpha = 0.25(.25)2.00$, $\beta = -1.00(.25)1.00$, and nonnegative χ in steps varying by factors of 10 from 0.001 to 100 such that interpolation is possible, the tabulation being terminated where $p(\chi;\alpha,\beta)$ falls to 0.0001. The largest such value of χ is 338, for $\alpha = 0.25, \beta = -1.00$. Graphs of $p(\chi; \alpha, \beta)$ are also provided for essentially the above values of α and β. The methods of calculation (from the characteristic function), checking, and interpolation with respect to χ, β, and (to some extent) α are described. The most important properties of stable distributions are summarized. Some applications are cited. A selected bibliography with 91 items is included.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 78B, JANUARY–DECEMBER 1974

January-March 1974

A class of positive stable matrices, D. Carlson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 1-2 (Jan.-Mar. 1974).

Key words: positive stable matrix; sign-symmetry; spectrum.

A square complex matrix is positive sign-symmetric if all its principal minors are positive, and all products of symmetrically-placed minors are nonnegative. It is proved that every positive sign-symmetric matrix is positive stable.

The Smith normal form of a partitioned matrix, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 3-6 (Jan.-Mar. 1974).

Key words: elementary divisors; invariant factors; partitioned matrices; Smith normal form.

It is shown that if

$$M=\begin{bmatrix} M_{11} & M_{12} & \cdots & M_{1t} \\ 0 & M_{22} & \cdots & M_{2t} \\ & \cdots & & \\ 0 & 0 & \cdots & M_{tt} \end{bmatrix}$$

is a matrix over a principal ideal ring R such that the matrices M_{ii} are square and have pairwise relatively prime determinants, then the Smith normal form of M is the same as the Smith normal form of

$$M_{11}+M_{22}\dot{+}\cdots\dot{+}M_{tt}.$$

A Lyapunov theorem for angular cones, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 7-10 (Jan.-Mar. 1974).

Key words: cramped; field of values; open positive convex cone; polar decomposition; positive definite; spectrum; square matrix.

The well known theorem of Lyapunov is generalized to characterize matrices whose spectra lie in a given open convex angular sector. Related facts about positive definite matrices, the polar decomposition and matrices with cramped spectra are also given.

Second, third, and fourth order D-stability, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 11-13 (Jan.-Mar. 1974).

Key words: D-stable; positive stable matrix; spectrum.

For $n=2$, 3, and 4, conditions are given for the real n by n D-stable matrices. The 3 by 3 sufficient condition is easily checkable and reveals to be D-stable a class of matrices which is not included in any known, general sufficient condition.

Comparison of some FORTRAN programs for matrix inversion, K. E. Fitzgerald, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 15-33 (Jan.-Mar. 1974).

Key words: error estimates; evaluation of computer programs; execution time; inverse of a matrix; iterative refinement; linear systems.

In this paper several programs for computing the inverse of a matrix are compared primarily on the basis of execution time. Accuracy estimates and two programs that use iterative refinement are included. It is shown that for small matrices, improvement procedures are worthwhile but for large matrices, one must be more careful in their use. Two other points are also brought out: the value of multiplying matrices before taking the norm of a product and the need for some kind of an error estimate to be included in the output of every program.

On characters of subgroups, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 35-38 (Jan.-Mar. 1974).

Key words: Frobenius Reciprocity Theorem.

Let H be a subgroup of G. Let χ be an irreducible character of H. Let χ^G be the character of G induced by χ. The irreducibility of χ^G is discussed. In particular, if H is normal in G, then χ^G is irreducible if and only if χ cannot be extended to any subgroup of G which properly contains H.

These results have application to the determination of irreducibility of a class of representations of the full linear groups.

Integer arithmetic determination of polynomial real roots, G. W. Reitwiesner, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 1, 39-43 (Jan.-Mar. 1974).

Key words: Budan theorem; exact computation; integer arithmetic; modular arithmetic; polynomial; polynomial real roots; roots; Sturm theorem.

The real roots of a polynomial with rational coefficients may be evaluated to absolute precision by integer arithmetic. Based upon the theorems of Sturm and Budan, two algorithms for this evaluation are described, and some comparative observations are offered.

April-June 1974

Rational equivalence of unimodular circulants, S. Pierce, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 63 (Apr.-June 1974).

Key words: circulant, totally positive unit.

We answer a question of M. Newman by providing all unimodular positive circulants are rationally equivalent to the identity.

How to determine the accuracy of the output of a matrix inversion program, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 65-68 (Apr.-June 1974).

Key words: approximate inverses; approximate solutions; error bounds; high speed digital computation; matrix norms.

If A is a given nonsingular matrix and X an approximate inverse of A such that $N(R)<1$, where $R=I-AX$ and N is any matrix norm, then it is shown that

$$\frac{N(XR)}{1+N(R)}\leq N(A^{-1}-X)\leq\frac{N(XR)}{1-N(R)}.$$

This inequality provides the means for checking the output of a matrix inversion program. Methods for checking the solution of a single linear system are also discussed.

A conjecture on a matrix group with two generators, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 69-70 (Apr.-June 1974).

Key words: free groups; matrix groups; roots of unity.

Let ζ be a primitive qth root of unity. It is conjectured that the group generated by

$$A=\begin{pmatrix} 1 & \zeta \\ 0 & 1 \end{pmatrix} \quad \text{and} \quad B=\begin{pmatrix} 1 & 0 \\ \zeta & 1 \end{pmatrix}$$

is never free. The conjecture is proved when q is an even prime power, or an odd prime power having 2 as a primitive root.

A property of equivalence, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 71-72 (Apr.-June 1974).

Key words: elementary divisors; equivalence; Kronecker products.

It is shown that if K, A, B are nonsingular matrices over a principal ideal ring R such that $K \otimes A$ is equivalent to $K \otimes B$, then A is equivalent to B.

Comments on the discrete matrix model of population dynamics, R. Freese and C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 73-78 (Apr.-June 1974).

Key words: eigenvalue; net reproduction rate; oscillations; Perron-Frobenius theory; rate of natural increase; stable population.

This paper examines several aspects of the discrete matrix model of population transition. Certain appropriate applications of matrix theory and exploitation of the specific form of the model should serve to enhance its already well-developed status. The aspects dealt with include (1) a simplification of the Perron-Frobenius theory; (2) row and column sum bounds on maximal eigenvalues; (3) relations between oscillations in a population and the remaining eigenvalues; (4) implications of stability for the transition matrix; and (5) relations between characteristic quantities of a stable population.

Fixed-point solution of plant input/location problems, A. J. Goldman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 2, 79-94 (Apr.-June 1974).

Key words: *CES*; economics; Leontief; location theory; plant location; production functions; transportation; Weber problem, mathematical programming.

This paper considers the following generalization of the Weber plant location problem: the plant's output level is fixed, and its levels of input from its supply points, as well as its location, are among the decision variables. Hurter and Wendell (J. Reg. Sci., 1972) showed that this problem admits a kind of separability when the plant's production function lies in a certain class including the Cobb-Douglas forms. The present paper (a) determines the extent of that function-class, (b) carries out the explicit separation for the *CES* generalization of the Cobb-Douglas functions, and (c) discusses simple fixed-point-type iterative solution algorithms, similar to that well-known for the ordinary Weber problem, for several production functions (Cobb-Douglas, *CES*, and various two-stage technologies). Local convergence of these algorithms is established; computational experience will be reported in a separate Part II.

A new proof of Pick's theorem, S. Minsker, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci), No. 2, 95-96 (Apr.-June 1974).

Key words: Bieberbach's theorem; coefficient estimate; univalent analytic function.

Pick's theorem states that, if f is a univalent analytic function on the open unit disk with $f(0)=0$ and $f'(0)=1$, and $|f| \leq M$ then $\left| \frac{f''(0)}{2} \right| \leq 2\left(1-\frac{1}{M}\right)$. A new proof of this result is given, and a comparison with the usual proof is made.

July-September 1974

A sufficient condition for matrix stability, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 103-104 (July-Sept. 1974).

Key words: M-matrix; principal minors; stable matrix.

An n by n complex matrix A is said to be positive stable if Re $(\lambda) > 0$ for each eigenvalue λ of A. If A satisfies both of the following two conditions, then A is positive stable: (1) for each $k=1,\ldots,n$, the real part of the sum of the k by k principal minors of A is positive; and (2) the minimum of the real parts of the eigenvalues of A is itself an eigenvalue of A. Special cases include hermitian positive definite matrices and M-matrices.

Computation of the field of values of a 2 × 2 matrix, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 105-107 (July-Sept. 1974).

Key words: eigenvalues; ellipse; field of values; square matrix.

It is known that the field of values, $F(A) \equiv \{x^*Ax : x^*x=1, x \in C^2\}$, of a 2×2 matrix A is a convex set whose boundary is an ellipse. This is used to compute $F(A)$ explicitly from the entries of A when A is 2×2 and real. Employing known properties of the field of values, this may then be used to estimate $F(A)$ when A is $n \times n$ and real.

The factorization of a matrix as the commutator of two matrices, J. M. Smith, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 109-112 (July-Sept. 1974).

Key words: anticommuting; commutator; factorization matrix; orthogonal; skew-symmetric.

Let $P=I_p+(-I_q)$, the direct sum of the $p \times p$ identity matrix and the negative of the $q \times q$ identity matrix. The following theorem is proved.

THEOREM: *If* $X=cZ$ *where* Z *is a* 4×4 P-*orthogonal*, P-*skew symmetric matrix and* $|c| \leq 2$, *there exist matrices* A *and* B, *both of which are* P-*orthogonal and* P-*skew-symmetric, such that* $X=AB-BA$. Methods for obtaining certain matrices which satisfy $X=AB-BA$ are given. Methods are also given for determining pairs of anticommuting P-orthogonal, P-skew-symmetric matrices.

Complete elliptic integrals resulting from infinite integrals of Bessel functions, S. Okui, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 113-135 (July-Sept. 1974).

Key words: applied mathematics; Bessel functions; complete elliptic integrals; engineering; infinite integrals; modified Bessel functions; physics; signal statistics.

Infinite integrals of Bessel and modified Bessel functions reducible to complete elliptic integrals are compiled. These formulas are of great use in solving problems of applied mathematics, physics and engineering.

The convex hull of the transposition matrices, L. S. Joel, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 137-13 (July-Sept. 1974).

Key words: combinatorial analysis; convex set; linear inequalities; permutations.

The convex hull of the n by n transposition matrices is characterized as the set of symmetric doubly stochastic matrices with trace $n-2$. A similar characterization (with trace $\geq n-2$) is given for the convex hull of the union of transposition matrices and the identity matrix.

Computational experience with an algorithm for finding the k shortest paths in a network, D. R. Shier, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 139-165 (July-Sept. 1974).

Key words: double-sweep method; graph; k shortest paths; network; network algorithms; shortest path.

A particular computer implementation of the Double-Sweep method for calculating the k shortest paths in a network is described. Results are presented for a series of computational experiments performed on rectangular grid networks.

How bad is the Hadamard determinantal bound?, C. R. Johnson and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 3, 167-169 (July-Sept. 1974).

Key words: determinant; expected value; Hadamard determinantal bound; uniform distribution.

The Hadamard bound for the determinant of an n by n matrix is a good one in that equality may be attained in a rich class of cases. However, the bound generally gives up a good deal, and we answer the title question "on the average." Assuming the entries of $A=(a_{ij})$ are uniformly distributed over some interval symmetric about the origin, the expected value of the ratio of $(\det A)^2$ to the square of the Hadamard bound is found to be $(n!)/(n^n)$. The expectations of the square of the Hadamard bound and of $(\det A)^2$ are also computed individually, and their ratio turns out also to be $(n!)/(n/n^n)$.

October-December

Saddlepoints in P-pivot classes of skew matrices, M. L. Stein, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 4, 181–191 (Oct.–Dec. 1974).

Key words: combinatorial equivalence; linear inequalities; linear programs; pivot operations; skew-symmetry.

A finite class of skew matrices can be associated via "principal pivots" with a self-dual linear system. Given a row index h, it is known that there is a skew matrix in the class with nonnegative hth row. Using this "saddlepoint theorem," we prove a similar result for nonpositive rows. An open question is whether such a class of skew matrices contains one with both a nonnegative row and a nonpositive row. We show that this "double saddlepoint property" holds for arbitrarily large degenerate cases and for all skew matrices of small order.

Maximizing the number of spanning trees in a graph with n nodes and m edges, D. R. Shier, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 4, 193–196 (Oct.–Dec. 1974).

Key words: combinatorial analysis; enumeration; graphs; maximigation; spanning trees; trees.

The problem considered is that of determining, among all graphs on n nodes and m edges, those having the maximum number of spanning trees. The possible candidate graphs can be obtained by deleting some number k of edges from a complete n-node graph. For $k \leq n/2$, it is shown that the maximum occurs when the k edges are mutually nonadjacent.

The field of values and spectra of positive definite multiples, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 4, 197–198 (Oct.–Dec. 1974).

Key words: eigenvalues; field of values; H-stable; positive definite matrix; spectrum.

Suppose $0 \neq \lambda \epsilon C$ and $A \epsilon M_n(C)$. We show constructively that λ is an eigenvalue of HA for some $H^* = H >$ if and only if $\lambda = x^*Ax$ for some $x \epsilon C^n$. The characterization of H-stable matrices is then an easy corollary.

Automatic computing methods for special functions. Part II. The exponential integral $E_n(x)$, I. A. Stegun and R. Zucker, *J. Res. Nat. Bur. Stand. (U.S.)*, **78B** (Math. Sci.), No. 4, 199–215 (Oct.–Dec. 1974).

Key words: computer programs; continued fraction; exponential integral; key values; recurrence relation.

Accurate, automatic, efficient methods for computing the exponential integral $E_n(x)$ are detailed and implemented in an American National Standard FORTRAN program. The driver program and test results are also included.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 79B, JANUARY-DECEMBER 1975

January-June 1975

Ideal elements for perturbed Keplerian motions, A. Deprit, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 1-15 (Jan.-June 1975).

Key words: celestial mechanics; orbit perturbation; satellite ephemeris; variation of parameters.

A new set of elements is proposed to describe Keplerian motions subject to perturbing forces. The resulting equations do not break down for small eccentricities, small inclinations and rotations of the ideal frame reference that are half turns. The parameters are selected with a view of simplifying the programming of the right-hand members.

Generalized or adjoint reciprocity relations for electroacoustic transducers, A. D. Yaghjian, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B**(Math. Sci.), Nos. 1 and 2, 17-39 (Jan.-June 1975).

Key words: linear differential operators; reciprocity relations; scattering matrix; transducers.

The "equations of motion" of a linear electroacoustic transducer are written in the alternative forms $L^{-}X=\bar{0}$, $\bar{L}^{-}\bar{X}=0$, where the matrices $L^{=}$ are linear differential expressions. $X=(\bar{E},\bar{H},\bar{u})$ represents electroacoustic fields, and the superscripts distinguish selected normalizations of the equations of motion. To each operator $L^{=}$ corresponds a mathematically defined adjoint operator $(L^{=})^{a}$ and an associated adjoint transducer, whose material tensor parameters are given by certain transpositions and interchanges of the parameters of the given transducer. Dissipative characteristics (lossiness, losslessness, or "gaininess") of the material of the given transducer are preserved pointwise in the adjoint transducers. A generalized reciprocity lemma leads to relations of reciprocal type between external properties of the given and the adjoint transducers. In the self-adjoint cases, the conventional electroacoustic reciprocity and antireciprocity relations are obtained and the derivation of those relations is critically confirmed. The generalized or adjoint reciprocity relations have been applied in the plane-wave scattering-matrix formalism developed for electroacoustic transducers by D. M. Kerns.

Corollaries of the adjoint reciprocity relations, analogous to conventional reciprocity theorems, but involving properties of adjoint pairs of transducers, are derived. Examples are discussed of transducers for which it is feasible to form the adjoint tranducers.

The diophantine equation $p^2x^4+3px^2y^2+y^4=z^2$, p an odd prime, T. N. Sinha, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 41-44 (Jan.-June 1975).

Key words: diophantine equation; infinite descent; quadratic residues.

The object of this paper is to prove:

THEOREM 1. *The equation*

$$p^2x^4+3px^2y^2+y^4=z^2$$

where p *is an odd prime, has no solutions in integers with* $xy\neq 0$ *if* $p=5$ *or* $p\equiv 3,7 \pmod{20}$ *or* $p\equiv 13 \pmod{40}$.

A condition for the diagonalizability of a partitioned matrix, C. R. Johnson and M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 45-48 (Jan.-June 1975).

Key words: diagonalizable matrix; partitioned matrix.

When U and V are diagonalizable matrices the diagonalizability of

$$\begin{bmatrix} U & N \\ 0 & V \end{bmatrix}$$

is equivalent to the solvability in X of

$$UX-XV=N.$$

A corollary and simple generalization are given.

Linearly independent sets of isotropic Cartesian tensors of ranks up to eight, E. A. Kearsley and J. T. Fong, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 49-58 (Jan.-June 1975).

Key words: algebra; alternating tensor; Capelli's identity; Cartesian tensor; group representation; invariant; isotropic tensor; Kronecker delta; orthogonal group; tensor.

This paper contains a complete listing of isotropic Cartesian tensors of ranks up to eight with their associated reduction equations for obtaining linearly independent sets whenever the reduction is called for. In particular, the listing is compiled only for isotropic tensors associated with the rotation group $O^{+}(3)$ of the three-dimensional underlying vector space. Based on an identity originally due to Capelli (1887), reduction equations for tensors of odd ranks beginning at rank five and even ranks beginning at rank eight are shown to be nontrivial. Significance of the computational result in both pure and applied mathematics is discussed.

Maximal network flows, matroids and matchings, E. Minieka, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 59-62 (Jan.-June 1975).

Key words: independence properties; matroids; maximal flows; network flows.

This paper represents new proofs for some known network flow results. First, maximal network flows are expressed as matroids, and then Gale's characterization of matroids is used to prove the existence of various lexicographic network flows. Second, an independence property of maximum flows is proved and this property is related to an independence property of Brualdi and Scrimger.

A note on the metrizability of spaces with countably based closed sets, R. R. Sabella, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nov. 1 and 2, 63-64 (Jan.-June 1975).

Key words: co-convergent; contra-convergent; Nagata spaces; open neighborhood assignments; stratifiable spaces; U-linked sequences.

The main result of this note is a generalization of an earlier theorem on the metrizability of spaces with countably based

closed sets. Use is made of some results related to co-convergent spaces which are spaces having countably based compact sets.

Charge profiles in parallel-plate ionization chambers, G. F. L. Ferreira, L. Nunes de Oliveira, and B. Gross, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 1 and 2, 65-75 (Jan.-June 1975).

Key words: charge profiles; ionization chambers; numerical integration.

Numerical integration of the differential equations describing charge transport in plane-parallel ionization chambers allows to obtain charge profiles in addition to current-voltage curves. It is found that charge densities may exhibit maxima within a certain range of saturation. The effect is interpreted in terms of field modulation of carrier velocities.

July-December 1975

Two submatrix properties of certain induced norms, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 97-102 (July-Dec. 1975).

Key words: consistency; matrix norm; monotonicity; principal submatrix; spectral radius; vector norm.

Induced matrix norms N, defined consistently for all orders up to a given order, which have the property:

$$N(\hat{A}) \leq N(A)$$

for all principal submatrices $\hat{A}$ of an arbitrary m x m complex matrix A are characterized. Conditions are also given which insure that

$$N(A \oplus B) = \max \{N(A), N(B)\}$$

Properties of neighboring sequences in stratifiable spaces, R. R. Sabella, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 103-105 (July-Dec. 1975).

Key words: co-convergent; contra-convergent; Nagata spaces; open neighborhood assignments; stratifiable spaces; U-linked sequences.

In T_0-spaces metrizability can be characterized in terms of mutual convergence of "neighboring sequences." In this paper Nagata spaces are characterized in terms of a convergence property of neighboring sequences and more generally it is shown that in all stratifiable spaces, neighboring sequences satisfy a similar convergence property.

Maximin facility location, P. J. Slater, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 107-115 (July-Dec. 1975).

Key words: center; centroid; facility location; graph; tree.

Using the criterion that vertex u of a graph G is "more central" than vertex v if there are more vertices closer to u than to v, the security center and security centroid of a graph are defined. Several results, including the fact that the security center of a tree is the centroid, are presented. A simple algorithm to find the security center (centroid) of a tree is presented. The problem of finding the security center of G is shown reducible to a search over a single block of G.

Similarity of partitioned matrices, R. B. Feinberg, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 117-125 (July-Dec. 1975).

Key words: matric equation; partitioned matrix; rational canonical form; similarity.

Suppose that A, B, and T are matrices of order $r \times r$, $s \times s$, and $r \times s$ respectively over a field F. We prove that

$$\begin{bmatrix} A & T \\ 0 & B \end{bmatrix}$$

is similar to

$$\begin{bmatrix} A & 0 \\ 0 & B \end{bmatrix}$$

if $AX - XB = T$, for some matrix X. We also give some corollaries and a simple generalization.

On the dimension group of classical physics, C. H. Page, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 127-135 (July-Dec. 1975).

Key words: angle; dimension; logarithm; neper; radian.

The basic principles of the group properties of physical quantities are reviewed. The problems associated with the dimensions of *angle* and *logarithm* are solved by using functional equations, instead of analytic expressions, for defining functions of non-numerical quantities. It is concluded that the neper and radian are related by $Np = -j$ rad, so that when the radian is considered as a base unit, the neper becomes a derived unit, and is the SI unit for logarithmic quantities.

Complete elliptic integrals resulting from infinite integrals of Bessel functions. II., S. Okui, *J. Res. Nat. Bur. Stand. (U.S.)*, **79B** (Math. Sci.), Nos. 3 and 4, 137-170 (July-Dec. 1975).

Key words: Bessel functions; complete elliptic integrals; hyperbolic function; infinite integrals; modified Bessel functions; noise theory; signal statistics; trigonometric functions.

Infinite integrals involving products of Bessel and trigonometric or hyperbolic functions reducible to complete elliptic integrals are compiled. The table also contains certain types of infinite double integrals of modified Bessel functions. All results are expressed in conveniently compact form suited for practical applications.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICAL SCIENCES, VOLUME 80B, JANUARY-DECEMBER 1976

January-March 1976

Nonnegative sums of roots of unity, M. Newman, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 1-4 (Jan.-Mar. 1976).

Key words: algebraic numbers; conjugates; roots of unity.

Let q, n be integers > 1, and let $\rho_1, \rho_2, \ldots, \rho_n$ be distinct qth roots of unity. It is shown that $\rho_1{}^k + \rho_2{}^k + \ldots + \rho_n{}^k \geq 0$ for all integral k if and only if n is a divisor of q and the set $\{\rho_1, \rho_2, \ldots, \rho_n\}$ coincides with the set $\{1, \zeta_n, \zeta_n{}^2, \ldots, \zeta_n{}^{n-1}\}$, where $\zeta_n = \exp(2\pi i/n)$.

Plane-wave scattering-matrix theory of antennas and antenna-antenna interactions: Formulation and applications, D. M. Kerns, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 5-51 (Jan.-Mar. 1976).

Key words: antenna-antenna interactions; antenna measurements; antenna theory; scattering-matrix theory of antennas.

In recent years a considerable amount of theoretical, experimental, and computational work in the development and application of techniques for accurate measurement of microwave antennas has been successfully completed at the National Bureau of Standards (and work is continuing). This paper presents and extends the basic plane-wave scattering-matrix formalism and presents new generalized or adjoint reciprocity relations for antennas. The PWSM formalism is eminently suitable for the formulation and solution of problems involving interactions at arbitrary distances and for the expression of conventional asymptotic quantities, such as gain, effective area, and polarization. It has in particular enabled derivation of two new techniques that permit accurate, "probe-corrected" antenna measurements at greatly reduced distances: (1) by deconvolution of transverse scanning data, taken with $d \ll d_R$ (where $d_R \equiv a^2/2\lambda$) and (2) by extrapolation of received signal observed as a function of distance d, with $d \sim d_R$. These techniques basically determine the scalar product, C, of two vectors characteristic respectively of the transmitting and the receiving antennas. Formulas for utilization of C-data, taking full account of polarization characteristics and not requiring reciprocal antennas, are given for (a) one-unknown-antenna, (b) generalized two-identical-antenna, and (c) generalized three-antenna measurement techniques.

Optimal facility location for normally and exponentially distributed points, I. N. Katz and L. Cooper, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 53-73 (Jan.-Mar. 1976).

Key words: always convergent algorithms; exponentially distributed points; facility location; location theory; normally distributed points; numerical analysis; optimization; stochastic Weber problem.

N destinations in the plane $\{P_j : j = 1, \ldots, N\}$ are given as independent random variables with specified probability densities, and the problem is to find the location of the point P which minimizes the expected sum of the Euclidean distances PP_j.

In this paper, upper bounds for the minimizing sum of distances are found in terms of solutions to corresponding deterministic problems and the first and second moments of the probability densities. Three commonly occurring classes of bivariate probability densities: (A) normal, (B) exponential, and (C) symmetric exponential, are then considered. Numerical tests are presented which show that in all cases, Steffensen's iteration is effective in accelerating convergence. Finally it is shown that in contrast to the deterministic case, P need not be in the convex hull of the means of P_j and a sufficient condition is given for P to be in this convex hull.

Real, 3×3, D-stable matrices, B. E. Cain, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 75-77 (Jan.-Mar. 1976).

Key words: arc-connectedness; Carlson-Johnson conjecture; D-stable; positive stable matrix.

We characterize the 3×3 real D-stable matrices.

Transient solutions for stratified fluid flows, D. W. Fox, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 79-88 (Jan.-Mar. 1976).

Key words: fluid dynamics; fundamental solution, intitial value problem; partial differential equations; stratified flow, internal waves, buoyant flows.

The solution to an initial value problem for the flow of a buoyant inviscid incompressible fluid in three-space is given in terms of a fundamental solution. The initial values and the distribution of source strength can be quite general subject only to mild restrictions on smoothness. The fundamental solution and its associated velocity and displacement fields are given explicitly and in some detail.

Equivalence of partitioned matrices, R. B. Feinberg, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 89-98 (Jan.-Mar. 1976).

Key words: determinantal divisors; equivalence; matric equation; partitioned matrix; Smith normal form.

It is shown that if $M = \begin{bmatrix} A & T \\ 0 & B \end{bmatrix}$ is a partitioned matrix over a principal ideal domain R such that the matrices A and B are both square, then M is equivalent to $A+B$ $\langle = \rangle$ the matric equation $T = AY + XB$ is solvable. The result is generalized to treat the case when

$$M = \begin{bmatrix} M_{11} & M_{12} & \cdots & M_{1t} \\ 0 & M_{22} & \cdots & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ 0 & \cdots & 0 & M_{tt} \end{bmatrix}$$

where each M_{ii} is square.

Tables of binomial coefficients and Stirling numbers, K. Goldberg, F. T. Leighton, M. Newman, and S. L. Zuckerman, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 1, 99-171 (Jan.-Mar. 1976).

Key words: binomial coefficients; modular computation; Stirling numbers.

Tables of binomial coefficients and of Stirling numbers are given, along with the most important formulas and relationships satisfied by them. The tables were computed using modular arithmetic.

April-June 1976

The dependence of inspection-system performance on levels of penalties and inspection resources, A. J. Goldman and M. H. Pearl, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 189-236 (Apr.-June 1976).

Key words: inspection; mathematical model; regulation; strategy; theory of games.

This paper presents three simple mathematical models, all of game-theoretic type, dealing with an inspector-inspectee relationship. The inspectee always tries to maximize his net gain, which is the amount he obtains by "cheating" less the amount he is penalized when caught. The first model assumes a zero-sum payoff and so the inspector tries to minimize the inspectee's net gain. In the second model, the inspector tries to deter cheating without concern for the extraction of penalties. In the third model we assume that the probabilistic pattern of the inspector's strategy is known to the inspectee and that the inspector constructs his strategy with this in mind. Each of these models is analyzed and optimal solutions are obtained. Several simple examples are presented to show the relation between the level of cheating and the levels of inspection resources and penalty.

A minimax-measure intersection problem, P. R. Meyers, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 237-243 (Apr.-June 1976).

Key words: combinatorial analysis; combinatorial probability; measure theory; minimax.

The problem solved is that of selecting n subsets of the unit interval, each of measure α, so as to minimize the maximum of the measures of their p-fold intersections. This is achieved by minimizing the sum of the measures of these p-fold intersections.

Inverting sparse matrices by tree partitioning, D. R. Shier, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 245-257 (Apr.-June 1976).

Key words: block Gaussian elimination; graph; inversion; partitioning; sparse matrix; tree.

This paper studies the tree partitioning of a graph whose definition is based on the pattern of zero elements present in a given matrix. This partitioning then indicates a particularly advantageous strategy for employing block Gaussian elimination over a certain class of matrices. The strategy is exploited for matrix inversion, where it is especially appropriate for problems which require finding only selected submatrices of the inverse. A graph-theoretic algorithm is given for automatically generating tree partitioning for any matrix. Combinatorial properties of this procedure are also discussed.

The structure of higher degree symmetry classes of tensors, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 259-264 (Apr.-June 1976).

Key words: decomposable (or pure) tensor products; irreducible complex character; orthogonality relations; permutation group.

The paper is concerned with symmetry classes of tensors which arise from a permutation group G and irreducible character χ of G. In case χ is of degree 1, a well-known algorithm is available for inducing a basis of the symmetry class from the underlying vector space. When the degree of χ is greater than 1, no comparable construction has been discovered. The difficulties are discussed and results obtained in some special cases.

The Kronecker power of a permutation, R. Merris, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 265-268 (Apr.-June 1976).

Key words: bell numbers; branching theorem; Clebsch-Gordon series; irreducible character; matrix functions; multiple transitivity; permutation group; Stirling numbers.

Let G be a permutation group of degree n. Think of the elements, σ, of G as n-square permutation matrices. The paper concerns a reduction of the representation $\sigma \rightarrow$ the rth Kronecker power of σ. In case G is the full symmetric permutation group, a formula is given which involves the Stirling numbers of the second kind.

On Iohvidov's proofs of the Fischer-Frobenius theorem, R. C. Thompson, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 269-272 (Apr.-June 1976).

Key words: Hankel matrix; Toeplitz matrix.

A short proof is given of theorem of Fischer and Frobenius exhibiting a conjunctive transformation mapping Toeplitz matrices onto Hankel matrices.

Matrix algebra and eigenvalues for the bead/spring model of polymer solutions, J. T. Fong and A. Peterlin, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 273-284 (Apr.-June 1976).

Key words: bead/spring model; dilute polymer solutions; eigenvalue; hydrodynamic interaction; matrix algebra; necklace model; polymer physics.

Based on purely matrix-algebraic arguments, we prove three new results on the eigenvalue problem [Zimm, 1956] arising from modeling the bulk hydrodynamic and dielectric properties of very dilute polymer solutions:

1. Let N be the number of identical segments joining $N+1$ beads of a bead/spring model for any polymer molecule. Then for any N, the well-known hydrodynamic interaction matrix $\underline{\underline{H}}$ is positive definite if the so-called interaction parameter h^* is less than $(2\sqrt{2}+1)/7$ or 0.547. 2. Let $\underline{\underline{A}}$ be the tridiagonal matrix governing the elastic link force on each bead. Then if $\underline{\underline{H}}$ is positive definite, there exists a matrix $\underline{\underline{Q}}$ such that $\underline{\underline{Q}}^{-1}\underline{\underline{H}}\,\underline{\underline{A}}\,\underline{\underline{Q}}=\underline{\underline{Q}}^{T}\,\underline{\underline{A}}\,\underline{\underline{Q}}=\underline{\underline{\Lambda}}$, where $\underline{\underline{\Lambda}}$ is a diagonal matrix. 3. (Equivalence Statement due to Lodge and Wu [1971]). The nonzero eigenvalues of the matrix product $\underline{\underline{H}}\,\underline{\underline{A}}$ are completely determined by solving the eigenvalue problem associated with a symmetric matrix $\underline{\underline{S}}$, where $S_{ij}=H_{ij}+H_{i-1,j-1}-H_{i-1,j}-H_{i,j-1}, i,j=1,2,\ldots,N$.

To illustrate the significance of these results, numerical output for N as large as 300 based on a Fortran program for several values of h^* is given.

Predictable regular continued cotangent expansions, J. Shallit, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 285-290 (Apr.-June 1976).

Key words: continued cotangent; continued fraction; quadratic irrational.

Expansions of the form $x=\cot(\text{arc cot } n_0 - \text{arc cot } n_1 + \text{arc cot } n_2 - \ldots)$ are discussed. It is shown that if x is of the form $(1/2)(c+\sqrt{c^2+4})$, then the n's are predictable by a simple recurrence.

Continued fractions derived from the expansion of x are also given.

Automatic computing methods for special functions. Part III. The sine, cosine, exponential integrals, and related functions, I. A. Stegun and R. Zucker, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 291-313 (Apr.-June 1976).

Key words: continued fraction; cosine integral; exponential integral; FORTRAN program; hyperbolic sine and cosine integrals; key values; recurrence relations.

Accurate, efficient, automatic methods for computing the sine, cosine, exponential integrals and hyperbolic sine and cosine integrals are detailed and implemented in an American National Standard FORTRAN program. The functions are also tabulated to 35 significant figures for arguments $0, 10^j (10^j) 10^{j+1}$ with $J = -2(1)2$.

Definite integrals of the complete elliptic integral K, M. L. Glasser, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 2, 313-323 (Apr.-June 1976).

Key words: complete elliptic integral; cubic lattice; definite integral; special functions.

Definite integrals whose integrands contain the complete elliptic integral of the first kind are compiled.

July-September 1976

A note on pairs of matrices with product zero, C. R. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 333-335 (July-Sept. 1976).

Key words: eigenvalues; independence; quadratic form; random variable; singular value decomposition.

Pairs of not necessarily hermitian matrices for which $AB = BA = 0$ are characterized in terms of the singular values of $A + B$. This provides a generalization and a simpler proof of a classical result on the independence of quadratic forms in normal random variables.

Finding the circuits of a matroid, E. Minieka, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 337-342 (July-Sept. 1976).

Key words: algorithm; graph; matroid; network; operations research.

Given the bases of a matroid, this paper presents a primal algorithm and a dual algorithm for finding the circuits of the matroid.

One-sided tolerance limits for the normal distribution, $P = 0.80$, $\gamma = 0.80$, R. H. Wampler, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 343-346 (July-Sept. 1976).

Key words: noncentral t-distribution; normal distribution; statistics; tolerance limits.

A table is given of factors k used in constructing one-sided tolerance limits for a normal distribution. This table was obtained by interpolation in an existing table of percentage points of the noncentral t-distribution. The accuracy of the table is estimated, and a comparison is made of the presently computed factors with a previously published approximation.

Spectral measures and separation of variables, D. W. Fox, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 347-351 (July-Sept. 1976).

Key words: convolution; Hilbert space; separation of variables; spectral measure; tensor products.

This article gives an expression for the spectral measure corresponding to a self-adjoint operator for which separation of variables is possible. The construction makes use of the amalgamation theorem for normal operators in a natural way to obtain the required measure as a tensor convolution of the spectral measures of the part operators.

A survey of selected aspects of stratified and rotating fluids, R. G. Rehm, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 353-402 (July-Sept. 1976).

Key words: buoyant flows; geophysical fluid flows; inertial waves; internal waves; rotating fluids; stratified fluids; waves in fluids.

A survey is presented of phenomena in stratified and rotating fluids. Care is taken to define important quantities, to discuss basic concepts, to derive the fundamental equations and to present the basic nondimensional parameters associated with these flows. After a rather extensive section on waves, the analogy between stratified and rotating flows is discussed. Then nonlinear processes and transport and diffusion processes are reviewed. Although this report is rather brief in parts, it displays the rich variety of phenomena in stratified and rotating fluids. It also tabulates many of the important references.

This report also contains a discussion of some applications. Physical oceanography, physical limnology and meteorology are all areas of application in the earth sciences. The variety of application is stressed at the expense of depth and completeness. The more technological application of plumes in bodies of water or in the atmosphere is also discussed.

Finally, some important problem areas are briefly surveyed. These areas are turbulence, nonlinear processes, numerical computation of flows, and further applications.

A more tractable solution to a singular integral equation obtained by solving a related Hilbert problem for two unknowns, J. A. Pennline, *J. Res. Nat. Bur. Stand. (U.S.)*, **80B** (Math. Sci.), No. 3, 403-414 (July-Sept. 1976).

Key words: analytic function; Cauchy principle value; Hilbert problem for two unknowns; singular integral equation; wave-guide boundary problem.

The singular integral equation

$$\int_0^1 \left(\frac{1}{x-\sigma} + \frac{\frac{1}{2}}{x+\sigma} \right) \psi(x)\, dx = h, \quad 0 < \sigma < 1,$$

is converted into another singular integral equation

$$\frac{1}{2} \int_1^\infty \frac{\phi(t)}{t-x}\, dt + \frac{3}{2} \sqrt{x} \int_1^\infty \frac{\phi(t)}{\sqrt{t}(t-x)}\, dt = \frac{-2h}{\sqrt{x}}, \quad 1 < x < \infty$$

where

$$\phi(x) = \frac{\psi\left(\frac{1}{\sqrt{x}}\right)}{\sqrt{x}}.$$

The former was derived from a boundary value problem in wave guide theory, and the solution is known. By solving a related Hilbert problem for two unknown functions, the solution of the latter integral equation is obtained. Then, the expression

$$\psi(x) = \frac{1}{x}\, \phi\left(\frac{1}{x^2}\right)$$

is compared to the former known expression obtained for $\psi(\chi)$, and the new expression is found to be more tractable.

Sampling expansion for a Laguerre-L_ν^α transform, A. J. Jerri, *J. Res. Nat. Bur. Stand. (U.S.),* **80B** (Math. Sci.), No. 3, 415-418 (July-Sept. 1976).

Key words: Laguerre transform; sampling function; Whittaker's cardinal function.

The Whittaker cardinal (or sampling) series expansion, which is associated with a finite limit Fourier transform, has been extended to include other kernels that are solutions of the Sturm-Liouville problem. To date all illustrations on this generalized sampling expansion have been associated with orthogonal functions on finite intervals. In this note, we present a sampling expansion for a Laguerre-L_ν^α transform where we shall use the Laguerre polynomials $L_n^\alpha(x)$ which are orthogonal on the semi-infinite interval $(0, \infty)$ with respect to the weight function $e^{-x}x^\alpha$.

October-December 1976

An inequality for doubly stochastic matrices, C. R. Johnson and R. Bruce Kellogg, *J. Res. Nat. Bur. Stand. (U.S.),* **80B** (Math. Sci.), No. 4, 433-436 (Oct.-Dec. 1976).

Key words: diagonal scaling; doubly stochastic matrix; Perron-Frobenius eigenvalue.

Interrelated inequalities involving doubly stochastic matrices are presented. For example, if B is an n by n doubly stochastic matrix, x any nonnegative vector and $y = Bx$, then $x_1x_2....x_n \leq y_1y_2....y_n$. Also, if A is an n by n nonnegative matrix and D and E are positive diagonal matrices such that $B = DAE$ is doubly stochastic, then $\det DE \geq \rho(A)^{-n}$, where $\rho(A)$ is the Perron-Frobenius eigenvalue of A. These two mentioned inequalities are actually equivalent.

Improved error bounds for second-order differential equations with two turning points, F. W. J. Olver, *J. Res. Nat. Bur. Stand. (U.S.),* **80B** (Math. Sci.), No. 4, 437-440 (Oct.-Dec. 1976).

Key words: error bounds; parabolic cylinder functions; turning points; uniform asymptotic approximations; Weber's equation.

New error bounds are given for approximate solutions of differential equations of the form

$$d^2w/d\zeta^2 = \{u^2(\pm\alpha^2 - \zeta^2) + \psi(u,\alpha,\zeta)\}w$$

in terms of parabolic cylinder functions. Here ζ is a real variable, α is a bounded real parameter, u is a large positive parameter, and $\psi(u,\alpha,\zeta)$ is a continuous function of α and ζ. Zero values of α are admitted.

Pseudointersection graphs, P. J. Slater, *J. Res. Nat. Bur. Stand. (U.S.),* **80B** (Math. Sci.), No. 4, 441-445 (Oct.-Dec. 1976).

Key words: clique; clique graph; intersection graph; pseudointersection graph; set covering.

Pseudointersection graphs are defined and a parameter called the pseudointersection number of a graph, denoted $\omega^*(G)$ and closely related to the intersection number of G, denoted $\omega(G)$, is introduced. Relations between these parameters and conditions for them to be equal are examined. The problem of computing $\omega^*(G)$ is examined.

An efficient linear algebraic algorithm for the determination of isomorphism in pairs of undirected graphs, C. R. Johnson and F. T. Leighton, *J. Res. Nat. Bur. Stand. (U.S.),* **80B** (Math. Sci.), No. 4, 447-483 (Oct.-Dec. 1976).

Key words: graph isomorphism; labels; modified adjacency matrix; spectrum.

An algorithm, complete with a specific FORTRAN implementation, is presented for the problem of determining whether or not two undirected graphs are isomorphic. The algorithm, centered upon the eigenvalues and eigenvectors of a modified adjacency matrix and techniques for decreasing the size of the automorphism group, is quite different from others (most of which are combinatorially based) and tends to work relatively very quickly on difficult test cases as well as on typical examples. Complexity estimates are given for many eventualities.

3.3. PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 70C, JULY-DECEMBER 1966

July-September 1966

Some harmonic properties of an oscillating Fabry-Perot interferometer, M. Gadsden and H. M. Williams, *J. Res. NBS*, **70C**3-226, pp. 159-163 (July-Sept. 1966).

Key words: Fabry-Perot interferometer; airglow photometry.

The transmission of a spectral line through an air spaced Fabry-Perot interferometer is considered. The harmonic components of the transmission when the spacing of the interferometer is oscillated are discussed and it is found that the components can be used in a servocontrol system to offset drifts in the optical thickness of the interferometer. A possible use of such a controlled system in observations of the night airglow is discussed.

Precise reflection coefficient measurements with an untuned reflectometer, W. E. Little and D. A. Ellerbruch, *J. Res. NBS*, **70C**3-227, pp. 165-168 (July-Sept. 1966).

Key words: Microwave; impedance; measurements; reflectometer.

The precision tuned reflectometer technique of reflection coefficient measurement is, at present, the most accurate technique available. Utilization of the technique requires the use of tuners and sliding terminations to eliminate or reduce the inherent errors of a directional coupler.

This paper describes a reflection coefficient measurement technique that approaches the accuracy of the tuned reflectometer. Instead of tuners, the technique uses an ideal one-quarter wavelength waveguide section to eliminate the measurement error introduced by finite directional coupler directivity and to reduce to second order the error introduced by an equivalent generator mismatch.

A comparison of the quarter-wave technique with the tuned reflectometer technique through the measurement of the reflection coefficient of three 9/16 inch coaxial waveguide terminations is also included.

A versatile ratio instrument for the high ratio comparison of voltage or resistance, A. E. Hess, *J. Res. NBS*, **70C**3-228, pp. 169-172 (July-Sept. 1966).

Key words: DRRS (direct reading ratio set); junction; precision measurements; ratio; resistor; four-terminal; resistance decade; transresistance; URS (universal ratio set); VERI (versatile ratio instrument).

A 9-dial resistance ratio instrument capable of precise high ratio comparison of voltage or resistance (from 1/1 to 10^7/1) is described. Also described is the modification of a 6-dial universal ratio set to permit its additional use as a versatile ratio instrument. Paramount to the accuracy of these high ratio instruments is the carefully adjusted "common point" junction which is briefly discussed.

Console for the rapid and precise comparison of volt boxes, P. H. Lowrie, Jr., *J. Res. NBS*, **70C**3-229, pp. 173-185 (July-Sept. 1966).

Key words: Calibration; console; electrical; measurement; ratio; standards; voltage; volt box.

The comparison of volt boxes within uncertainties of ±0.01 percent or less has, in the past, been a long and difficult task at the NBS Boulder Laboratories. A console for this purpose recently put in use has reduced the time and labor to a great extent and, at the same time, has reduced the uncertainties associated with the measurement circuitry to less than 0.001 percent, thus allowing realizable calibration uncertainties of less than 0.005 percent. The console was designed as part of a system in which the operator was considered to be the decision-making link in the measurement chain. The circuitry, through the use of a contained computer and associated circuits, provides the operator with the data he requires in the form he chooses. The operator is thus freed from the need to consider minutiae, and thereby is able to concentrate on those factors requiring judgment.

Corrosion rates of binary alloys of nickel and iron measured by polarization methods, W. J. Schwerdtfeger, *J. Res. NBS*, **70C**3-230, pp. 187-194 (July-Sept. 1966).

Key words: Corrosion rates; Ni-Fe alloys; polarization techniques; polarization rate; polarization resistance; polarization circuits; Ni-Fe pitting.

Specimens of ten binary alloys of nickel and iron containing 3, 5, 10, 16, 20, 30, 36, 50, 57, and 81 percent Ni and of the metals nickel and iron were immersed for 7 months in 265 gallons of city water to which had been added 3 percent by weight of sodium chloride.

Cathodic and anodic polarization curves of the specimens were obtained at about 22 periodic intervals throughout the exposure period. Corrosion currents, calculated from currents at breaks in the curves, were converted to corrosion rates expressed as weight losses by applying Faraday's law. The calculated weight losses were in reasonable agreement with the actual weight losses.

The polarization rates, $\Delta V/\Delta I$, of the specimens calculated from cathodic polarization curves (cathodic control prevailed) at several intervals throughout the exposure period were plotted on logarithmic coordinates with respect to the corrosion current densities calculated from breaks in the same curves. Similarly, the averages of these $\Delta V/\Delta I$ values were also plotted on logarithmic coordinates versus the actual corrosion rates expressed as weight losses. Both plots conformed to the theoretical slope of -1.

The effect of cold-drawing on the creep behavior of a nickel-4.2 percent aluminum alloy, W. D. Jenkins and W. A. Willard, *J. Res. NBS*, **70C**3-231, pp. 195-205 (July-Sept. 1966).

Key words: Cold-drawing; creep; nickel alloys; Duranickel; nickel-aluminum precipitates; high temperatures; deformation.

Creep tests were made at 700, 900 and 1200 °F (644, 755 and 921 °K) on a nickel-4.2 percent aluminum alloy (Duranickel) initially as cold-drawn and as cold-drawn and age-hardened. Microstructural changes occurring during creep are correlated

with the flow, fracture, and ductility of the specimens. Light and electron microscope observations indicate that increases in creep strength were associated with the formation of rather straight discontinuous slip bands, a well defined subgrain structure, small precipitates of Ni_3Al and a general distribution of these precipitates throughout the grains. Creep strength at 1200 °F was relatively unaffected by prior cold-drawing or aging. Intercrystalline cracking, accompanied by low ductility, was evident at 900 and 1200 °F and slow creep rates; whereas transcrystalline cracking and high ductility values were observed at 700 °F.

Magnetic transformation and the influence of plastic strain on the shear modulus of Fe-Cr-Ni alloys, R. P. Mikesell and R. P. Reed, *J. Res. NBS*, **70C**3-232, pp. 207-210 (July-Sept. 1966).

Key words: Antiferromagnetic; cold-work; Fe-Ni-Cr alloys; Neel temperature; shear modulus; stainless steel.

The Fe-18Cr-9Ni and Fe-19Cr-9Ni alloys exhibit a decrease in shear modulus between 76 and 20 °K. Susceptibility measurements confirm that a paramagnetic to antiferromagnetic transition occurs at about 40 °K in these alloys. The shear modulus for the Fe-25Cr-21Ni alloy did not decrease between 76 and 20 °K which was consistent with the fact that the alloy remained paramagnetic to 4 °K. The effect of cold-work on the shear modulus above and below the Neel temperature is discussed.

October-December 1966

Some techniques for measuring small mutual inductances, D.N. Homan, *J. Res. NBS*, **70C**4-233, pp. 221-226 (Oct.-Dec. 1966).

Key words: Auxiliary generator; bridge; coaxial choke; mutual inductor; stray magnetic field; transformer.

A method of measuring small mutual inductances is presented. The smallest inductor measured was 0.1 μH. The circuit is a transformer-ratio-arm bridge with multiple balances and is described in detail. Uncertainties are of the order of one part in 10^7.

Several ideas for the design and construction of suitable mutual inductance standards are presented.

Deflection of centrally loaded thin circular elastic plates on equally spaced point supports, A. F. Kirstein, W. H. Pell, R. M. Woolley, and L. J. Davis, *J. Res. NBS*, **70C**4-234, pp. 227-244 (Oct.-Dec. 1966).

Key words: Bassali's theory; concentric loading; circular plates; deflection; elasticity; experimental; flexure; point supports; simplified approximate solutions; thin plates.

Bassali's general theory for the flexure of the thin circular elastic plate supported at an arbitrary number of points and subjected to transverse load over an eccentric circle is specialized to the case of a centrally loaded plate supported at points equally spaced on a circle concentric with the center. Simplified methods for approximating the results predicted by the more complicated theoretical expressions for deflection are presented along with the experimental results from 138 tests. Both the experimental results and the simplified equations are compared with the theory and agreement is found to be good.

Reproducibility of germanium resistance thermometers at 4.2 °K, M. H. Edlow and H. H. Plumb, *J. Res. NBS*, **70C**4-235, pp. 245-254 (Oct.-Dec. 1966).

Key words: Germanium resistors; germanium resistor reproducibility; low temperature thermometry; reproducibility of germanium resistors; thermal cycling at low temperature; thermometry.

NBS has needed a set of very reproducible germanium resistors that would be capable of maintaining temperature scales. This paper describes our procedure for selecting such a set.

A group of germanium resistors from three commercial sources have been thermally cycled between 4.2 °K and room temperature. The resistance-temperature calibrations at 4.2 °K were made with reference to a liquid helium bath so that reproducible temperatures could be determined from liquid helium vapor pressure measurements. Seven resistors out of 25 demonstrated reproducibilities (of the 4.2 °K calibration) of about 0.001 °K after undergoing the multiple cyclings. Guided by these results, we procured twelve, new, similar resistors which were cycled in a comparable procedure. After 85 cycles, in which 14 resistance-temperature calibrations were performed at 4.2 °K for each resistor, 10 of the 12 resistors demonstrated reproducibilities of approximately 0.001 °K.

The resulting set of secondary thermometers have undergone calibrations in the temperature ranges, 2 to 5 °K and 2 to 20 °K; reports of this work will be published in the near future.

Calibration of vibrating-sample magnetometers, W. E. Case and R. D. Harrington, *J. Res. NBS*, **70C**4-236, pp. 255-262 (Oct.-Dec. 1966).

Key words: Ferro- and ferrimagnetism; magnetization; magnetometer calibration; measurement of magnetization; saturation magnetization; vibrating-sample magnetometer.

An evaluation of two of the most widely accepted methods for calibrating vibrating-sample magnetometers is given. The comparison method uses a material of known magnetization such as pure nickel. In the slope method, the magnetometer is calibrated from the low field linear slope of the magnetization curve of a sample of high permeability.

The primary source of error in the comparison method arises from an uncertainty in the absolute magnetization of nickel and its dependence on environmental conditions. The study indicated that better accuracy can be expected from the slope method. The use of pure iron in this method was found preferable to high permeability ferrites.

Notes on the use of propagation of error formulas, H. H. Ku, *J. Res. NBS*, **70C**4-237, pp. 263-273 (Oct.-Dec. 1966).

Key words: Approximation; error; formula; imprecision; law of error; products; propagation of error; random; ratio; systematic; sum.

The "law of propagation of error" is a tool that physical scientists have conveniently and frequently used in their work for many years, yet an adequate reference is difficult to find. In this paper an expository review of this topic is presented, particularly in the light of current practices and interpretations. Examples on the accuracy of the approximations are given. The reporting of the uncertainties of final results is discussed.

The apparent thermal radiation properties of an isothermal V-groove with specularly reflecting walls, R. B. Zipin, *J. Res. NBS*, **70C**4-238, pp. 275-280 (Oct.-Dec. 1966).

Key words: Reflectance; specular walls; thermal radiation; V-grooves.

The reflection of a parallel beam of light incident in a V-groove is treated for the case when the walls are specularly reflecting. Methods of calculating apparent reflectances and absorptances are given. Experiments have been performed to test the theoretical calculations, and the agreement has been found to be satisfactory.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 71C, JANUARY-DECEMBER 1967

January-March 1967

Symmetrical bending of thin circular elastic plates on equally spaced point supports, A. F. Kirstein and R. M. Woolley, *J. Res. NBS*, 71C1-438, pp. 1-10 (Jan.-Mar. 1967).

Key words: Circular plates; concentric loading; design; elasticity; experiment; maximum stresses; symmetrical bending; symmetrically distributed load; theory.

A special application of Bassali's solution for transverse flexure of thin elastic plates supported at several points is presented for the case of symmetrical bending. Equations for moments, shearing forces, and stresses are developed which may be useful for design purposes. The experimental results although limited in quantity are in good agreement with the theoretical predictions.

Ultrasonic measurement of cylinder expansion at pressures to 40 kilobars, P. L. M. Heydemann and J. C. Houck, *J. Res. NBS*, 71C1-439, pp. 11-17 (Jan.-Mar. 1967).

Key words: Compressibility; cylinder distortion; high pressure; nickel; tellurium; ultrasonics.

For the accurate determination of internal pressures in solid-filled piston and cylinder devices the effective area and its change with pressure are very significant factors. The computation of the change of area with pressure from elastic theory leads however to considerable uncertainties.

The present paper describes how ultrasonic measurements made in solid-filled piston and cylinder devices to 45 kilobars are combined with measurements of the lengths of the samples as function of pressure and with ultrasonic measurements under hydrostatic pressure to yield values for cylinder expansion. The results are compared with values obtained from modified elastic theory.

A comparison of absorbed dose determinations in graphite by cavity ionization measurements and by calorimetry, B. Petree and P. Lamperti, *J. Res. NBS*, 71C1-440, pp. 19-27 (Jan.-Mar. 1967).

Key words: Absorbed dose; calorimeter; cavity ionization chamber; cobalt-60 gamma rays; comparison; graphite; $W \cdot \bar{s}_m$.

The absorbed dose in graphite from a cobalt-60 gamma-ray source was measured with a spherical air-filled cavity ionization chamber and with two spherical calorimeters. The instruments were constructed from high-purity graphite. The current per unit mass of air and the absorbed power per unit mass of graphite were determined with uncertainties of 0.40 and 0.17 percent respectively. When the two results are combined the value of $W_{air} \cdot \bar{s}_m$ is found to be 33.72 electron volts in graphite per ion pair in air, with an uncertainty of ±0.14 electron volts.

Germanium resistance thermometry in the range 2.1 to 5.0 °K, M. H. Edlow and H. H. Plumb, *J. Res. NBS*, 71C1-441, pp. 29-41 (Jan.-Mar 1967).

Key words: Calibration of germanium resistors; germanium resistors; thermometry.

The resistances of three encapsulated, hermetically sealed, arsenic-doped germanium resistors from a commercial source have been measured at every 0.1 °K from 2.1 to 5.0 °K in highly stabilized liquid helium baths; values of temperature were derived from vapor pressure measurements associated with the liquid bath.

Ten similar germanium resistors of common origin have been calibrated from 2.1 to 5.0 °K in a calibration comparator apparatus that is similar to a calorimeter in design. Calibrations were performed against a resistor that had been previously referenced to temperature through a helium-4 vapor pressure calibration.

Next, three of the resistors that were calibrated in the comparator apparatus were recalibrated in a liquid helium bath (at 2.2, 3.0 and 4.2 °K) and results from the two methods agree within ±1 milli-degree. The resistance-temperature data from both methods have been fitted to the polynomial equation

$$\log_{10} R = \sum_{n=0}^{m} A_n \cdot (\log_{10} T)^n$$

and the results of a computer program, which evaluates the coefficients, are presented.

Least squares technique for the analysis of periodic temperatures of the earth's surface region, T. Kusuda, *J. Res. NBS*, 71C1-442, pp. 43-50 (Jan.-Mar. 1967).

Key words: Earth temperature; least squares technique; thermal diffusivity of earth.

A least squares technique has been applied to periodic earth temperature data for the purpose of determining basic characteristics of earth temperature cycles, such as thermal diffusivity, average temperature, amplitude, and phase angle of the temperature cycle. A new procedure was developed for obtaining a single thermal diffusivity which represents an average over time and depth at a particular temperature site. This thermal diffusivity was obtained as a nonlinear part of least squares constants which yielded a best-fit harmonic curve to a given set of observed earth temperatures. The thermal diffusivity thus calculated and the calculation method developed are preferred to those obtained by current practice, which yields two thermal diffusivities, one based on amplitude decay and another on phase angle shift.

A new near-zone electric-field-strength meter, F. M. Greene, *J. Res. NBS*, 71C1-443, pp. 51-57 (Jan.-Mar. 1967).

Key words: Device, electroexplosive ordnance; field, near zone electromagnetic; hazards, electromagnetic radiation line, nonmetallic electrical transmission; line, semiconducting plastic transmission; meter, electric field-strength telemetry, novel form of.

The National Bureau of Standards has recently completed the development of prototype instrumentation for measuring the electric-field components of complex, high-level, near-zone electromagnetic fields. The instrumentation is intended for use in evaluating hazards of high-level electromagnetic radiation to electroexplosive ordnance devices at military installations. The

measuring range is from 0.1 to 1000 V per meter, at frequencies from 150 kHz to 30 MHz, with a present uncertainty of less than ±2 dB.

The design of the NBS meters is based on the use of a novel form of telemetry, which apparently has not been fully exploited heretofore. This involves the use of a completely nonmetallic electrical transmission line over which the field information is transmitted from the measuring antenna to a remote readout unit. The line is essentially "transparent" to the field being measured, and reduces the perturbation of the field two orders of magnitude below that normally experienced when using a metallic line. The high r-f line loss involved necessitates miniaturizing the r-f portions of the receiving and calibrating instrumentation and placing them and their associated battery supplies *inside* the measuring antenna. The design and performance of the meters are discussed in some detail.

Inductance and characteristic impedance of a strip-transmission line, R. L. Brooke, C. A. Hoer, and C. H. Love, *J. Res. NBS*, 71C1-444, pp. 59-67 (Jan.-Mar. 1967).

Key words: Characteristic impedance; inductance; and strip-transmission lines.

A general method is developed for determining the inductance and characteristic impedance of uniform transmission lines. A non-uniform current distribution is allowed in the transverse plane. The system is represented by a matrix equation which can be programmed for computer solution. The correct inductance and impedance are obtained as the result of a simple limiting process. The method is applied to one particular geometry, a four-tape stripline system. Results are given for the inductance, resistance, and current distribution as functions of frequency and resistivity for a particular geometry. A method for extending the results to strip lines with proportional dimensions is developed. An accuracy of one part in 10^5 was found to be feasible for the determination of the inductance per unit length.

Tensor permeability measurements at L-band frequencies using a degenerate mode cavity, L. B. Schmidt, R. D. Harrington, and W. E. Case, *J. Res. NBS*, 71C1-445, pp. 69-75 (Jan.-Mar. 1967).

Key words: Degenerate mode cavity; L-band cavity; polycrystalline garnets; tensor permeability.

The exact solution for the field equations of a cylindrical TM_{110} mode cavity has previously allowed accurate measurements of tensor permeability to be obtained at X-band frequencies. It is demonstrated that this method is also applicable at frequencies down to 1 GHz. A brief description of the cavity and measurement system for obtaining data at these lower frequencies is given. Both intrinsic and external permeability results on three commercially available polycrystalline garnets are shown. The larger size rods required for measurements at these frequencies result in some sample size effects in the data. In addition, a previously unreported absorption in the external tensor permeability of the materials was observed.

April-June 1967

An apparatus for measuring thermal expansion at elevated temperatures, B. D. Rothrock and R. K. Kirby, *J. Res. NBS*, 71C2-247, pp. 85-91 (Apr.-June 1967).

Key words: Controlled-gradient vacuum furnace; elevated temperatures; optical comparator; thermal expansion.

An apparatus has been developed for making precise measurements of the absolute thermal expansion of refractory materials at temperatures up to 1600 °C. This apparatus consists of an optical comparator and a controlled gradient vacuum furnace. Special care was taken on the techniques of measuring length and temperature and on the calibration of the microscopes and thermometers. The expansion data obtained with this apparatus on specimens of platinum and sapphire have a standard deviation of less than 30 ppm and are estimated to be accurate to within 50 ppm.

Determination and smoothing of Fourier coefficients representing piecewise continuous functions, B. A. Peavy, *J. Res. NBS*, 71C2-248, pp. 93-100 (Apr.-June 1967).

Key words: Continuous function; Fourier series; piecewise; smoothing.

This paper presents a method of solving for Fourier coefficients where the dependent variable can be expressed as a piecewise continuous function, when various conditions of continuity and smoothing are assumed. An example is included to show the effect of smoothing in the region of a discontinuity for a system composed of two materials that exhibit a discontinuity at their interface and surrounded by a third material which does not have a discontinuity. An advantage to be gained from smoothing is an increase in the convergence of a finite Fourier series representation of a piecewise continuous function in the region of the discontinuities.

A 2:1 ratio inductive voltage divider with less than 0.1 ppm error to 1 MHz, C. A. Hoer and W. L. Smith, *J. Res. NBS*, 71C2-249, pp. 101-109 (Apr.-June 1967).

Key words: Attenuator; bridge; high frequency; inductive voltage divider; ratio transformer.

A simple ratio transformer having a 2:1 ratio of input voltage to output voltage can be made with a ratio error less than 0.1 ppm from 1 kHz to above 1 MHz. Applications and sources of error are discussed. Experimental results leading to an optimum transformer design are given. A bridge to measure the ratio error to 0.025 ppm from 1 kHz to 1 MHz is also described.

A dual-load flow calorimeter for rf power measurement to 4 GHz, M. L. Crawford and P. A. Hudson, *J. Res. NBS*, 71C2-250, pp. 111-117 (Apr.-June 1967).

Key words: Coaxial; flow calorimeter; radio frequency power.

A new dual-load flow coaxial calorimeter power meter has been constructed at the National Bureau of Standards, Boulder Laboratories. Designed for use as a reference standard, the frequency range of the calorimeter extends up to 4 GHz and beyond. The power range extends from 2W to 100W with an error limit of 0.38 percent.

Design details, error analysis, and results of intercomparison with other standards are given.

Polymeric materials for dielectric reference specimens, A. H. Scott and J. R. Kinard, Jr., *J. Res. NBS*, 71C2-251, pp. 119-125 (Apr.- June 1967).

Key words: Dielectric constant; dissipation factor; frequency; fluorinated ethylene-propylene; humidity; polycarbonate; polyethylene; poly(1,4-cyclohexylenedimethylene terephthalate); polystyrene; poly(tetrafluoroethylene); time; reference specimens.

The results from a study of the effects of aging and humidity change on certain polymer specimens indicate it is possible to establish stable dielectric reference specimens. Specimens of polyethylene, polystyrene, polycarbonate, poly(tetrafluoroethylene) (PTFE), fluorinated ethylene-propylene polymer (FEP), and poly(1,4-cyclohexylenedimethylene terephthalate) were used in the investigation. Slow changes in the dielectric proper-

ties were observed on some specimens over a period as long as three years. Very long timed humidity runs indicate PTFE, and FEP to only a slightly less degree, are best suited for dielectric reference specimen preparation.

The sensitivity of the Dicke radiometer, D. F. Wait, *J. Res. NBS*, 71C2-252, pp. 127-152 (Apr.-June 1967).

Key words: Dicke; microwave; radiometer; sensitivity; switching.

The literature is reviewed concerning the sensitivity of the Dicke radiometer, excluding gain fluctuations. Discrepancies are pointed out and a new derivation of sensitivity using a Fourier transform method is used to resolve these discrepancies and to extend the results to radiometers with lossy switches.

Experimentally it is shown that radiometers using a half-wave square-law, linear-law, intermediate-law, or envelope detectors all have a sensitivity equal to the theoretical full-wave square-law detector (within the ±20 percent uncertainty of the experiment).

Sensitivity of a correlation radiometer, J. J. Faris, *J. Res. NBS*, 71C2-253, pp. 153-170 (Apr.-June 1967).

Key words: Correlation radiometer; differential time delay; gain fluctuations; imperfect multiplier; noise comparison; nonidentical amplifiers; sine-wave comparison signal.

The correlation radiometer is analyzed to determine the sensitivity that can be obtained under various operating conditions.

The radiometer using a sine wave comparison signal is analyzed and compared with the usual radiometer that employs a random noise for the comparison signal. It is found that the radiometer employing the sine wave comparison signal is the more sensitive of the two circuits, particularly in the case that the effective temperature of the input noise signal is greater than the effective input temperature of the amplifiers.

It is shown that if nonidentical amplifiers are used in the correlation circuit, the properties of the radiometer are determined by the portion of the amplifier response functions in the frequency interval that the two response functions overlap. The effect of amplifier gain fluctuations are considered, and although the correlation scheme reduces the effect of gain fluctuations, it is shown that they still do contribute to the output fluctuations of the radiometer.

Calculations are included showing that the effect of a differential phase shift between the two channels is a reduction in radiometer sensitivity. The same conclusion is reached concerning the effect of a differential time delay.

Finally, it is shown that if the comparison signal and the input signal have the same statistical properties, the requirements on the multiplier are less stringent than if the two signals have different statistical properties.

July-September 1967

Procedure for high precision density determinations by hydrostatic weighing, H. A. Bowman and R. M. Schoonover with Appendix by M. W. Jones, *J. Res. NBS* 71C3-254, pp. 179-198 (July-Aug. 1967).

Key words: Air density; balance; balance calibration; balance equilibrium; balance sensitivity; density; double substitution weighing; hydrostatic balance; hydrostatic weighing; silicon density; substitution balance; volumetric measurement; water density; water weighing.

There are several simplifications which can be made in the performance of the hydrostatic experiment which lead to more reproducible results. The operation of single-pan two-knife balances is discussed, and simple modifications suggested to adapt it to hydrostatic work. A data philosophy is presented which will be particularly applicable to a generation of now-developing force measuring instruments when used in hydrostatic work. A simplified formula for air density is presented and a formula for estimating day-to-day variability in the density of water. A simple balance calibration procedure is presented in an appendix, and simplified methods of fabricating suspension wires and degassing sample surfaces are described. The use of these techniques is illustrated by measurements on silicon crystals which indicate process reproducibility of a standard deviation to about one part per million.

Study of the storage stability of the barium fluoride film electric hygrometer element, F. E. Jones, *J. Res. NBS* 71C3-255, pp. 199-207 (July-Sept. 1967).

Key words: Adsorption; barium fluoride; electric hygrometer; humidity; thin films; vacuum.

A study of the aging properties of the barium fluoride film electric hygrometer element and of possible causes of the drift of calibration with time in storage has been made. It was found that exposure of aged elements to glow discharge bombardment resulted in near recovery of the prestorage calibration, indicating that the calibration drift was not irreversible and providing insight into the mechanism of aging. Based on the likelihood that aging was due, at least in part, to contamination of the barium fluoride film, production procedures were formulated which resulted in elements with significantly reduced drift. If an adjustment is made similar to the "lock-in" procedure in the operational use of radiosonde humidity elements, then the poststorage resistance values can be adjusted to correspond closely to the prestorage calibration curves. Experimental evidence supports the hypothesis that contamination of the elements by diffusion pumping fluid in the production process was a source of the calibration drift. Applications of the element as a research tool in cloud physics, atmospheric turbulence and radio refractive index structure studies, evaporation and evaporation reduction studies, water vapor flux determinations and tropospheric humidity distribution studies are mentioned.

Torsion creep of circular and noncircular tubes, L. Mordfin, *J. Res. NBS* 71C3-256, pp. 209-225 (July-Sept. 1967).

Key words: Creep; primary creep; shear; shell; stress analysis; thin wall; torsion; tube.

A torsion creep theory for noncircular tubes was developed by applying a multiaxial creep theory to a derived generalization of Bredt's equations.

A review of the literature revealed no torsion creep data on noncircular tubes. Hence, to evaluate the theory, a test program was carried out on twelve specimens of aluminum alloy structural tubing, of four configurations, at 400 °F.

Observed discrepancies between the torsion creep theory and experiment are smaller than variations in the measured creep properties of the specimen material from one tube configuration to another and are not appreciably greater than discrepancies between elastic torsion theory and experiment. Most of the observed discrepancies are consistent with measured anisotropy in the tubes, while other discrepancies are ascribed to nonhomogeneity in creep properties and a hydrostatic stress effect in multiaxial creep.

For the calculation of torsion stresses in circular tubes the thin-wall approximation is adequate for thickness-to-radius ratios up to one-tenth. For straight-sided tubes equivalent accuracy is obtained for effective ratios up to only one-twentieth. These criteria apply to creep conditions as well as to elastic conditions.

Digitized low-frequency phasemeter assembled from logic modules, J. E. McKinney, *J. Res. NBS* 71C3-257, pp. 227-238 (July-Sept. 1967).

Key words: Digital; phasemeter; logic circuit; low frequency; measurements; phase.

A digital phasemeter is described which is capable of operating from arbitrarily low frequencies to 10 kHz, for which the lower limit depends essentially upon the time available to the operator to make the measurement. The phasemeter involves a logic circuit which can be assembled easily from commercially available logic modules without the necessity of a proficiency in electronics. The output of the logic circuit is read into a conventional digital preset frequency-ratio meter. The determination is absolute and utilizes a time base. Accordingly, no calibration against a phase standard is necessary. The agreement between this phasemeter and a quality phase shifter was found to be within ±0.01° at 400 Hz, which is the accuracy specified by the manufacturer of the phase shifter. Considerable ability to ignore signal imperfections is inherent in this device.

October-December 1967

Measurements of the thermal conductivity and electrical resistivity of platinum from 100 to 900 °C, D. R. Flynn and M. E. O'Hagan, *J. Res. NBS* 71C4-258, pp. 255-284 (Oct.-Dec. 1967).

Key words: Conductivity; electrical conductivity; electrical resistivity; heat conductivity; Lorenz function; platinum; reference material; resistivity; standard; thermal conductivity.

Measurements have been made of the thermal conductivity and the electrical resistivity of commercial grade platinum (99.98% pure) in the temperature range 100 to 900 °C. The measurements have been made with a view to providing accurate data on the thermal conductivity of platinum to serve as a basis for establishing platinum as a thermal conductivity standard reference material. Two methods of measuring the thermal conductivity have been employed, one an electrical method and the other a nonelectrical method. In the electrical method, a direct current passed through a necked-down portion of the specimen and the thermal conductivity was determined in terms of the temperature and electrical potential distributions in the necked-down region. The second method was of the absolute guarded longitudinal heat flow type. The experiment was designed to permit measurements by both methods in the same apparatus and on the same specimen thereby providing as direct a comparison as possible between the methods. The data given by the two methods agree within experimental error and show the thermal conductivity of platinum to be a smoothly increasing function of temperature in the measured range. Additional measurements on samples of differing purities are necessary before platinum could be adopted as a thermal conductivity reference material.

Thermal conductivity and electrical resistivity of Armco iron, T. W. Watson, D. R. Flynn, and H. E. Robinson, *J. Res. NBS* 71C4-259, pp. 285-291 (Oct.-Dec. 1967).

Key words: Armco iron; conductivity; electrical conductivity; electrical resistivity; heat conductivity; heat transfer; iron; Lorenz function; resistivity; thermal conductivity.

New data are presented for the thermal conductivity and electrical resistivity of two samples of Armco iron. On a sample of material used in a round robin comparison between several laboratories, thermal conductivity was measured from −160 to +640 °C and electrical resistivity was measured from −195 to +1380 °C. On a sample of cold-worked Armco iron from a different lot, data are reported from −150 to +200 °C.

Heat flow in a right circular cylinder with internal heat generation: Applications to the determination of thermal conductivity, D. R. Flynn, *J. Res. NBS* 71C4-260, pp. 293-298 (Oct.-Dec. 1967).

Key words: Heat conduction; heat generation; heat transfer; neutron absorption; radioactive decay; thermal conductivity.

Expressions are developed which permit calculation of the temperature-dependent thermal conductivity of a cylindrical specimen in which heat is generated internally, e.g., by radioactive decay. The information needed consists of the experimentally determined temperature distributions on the surfaces of the cylinder, the heat flow through a central circular area at one end of the cylinder, and the rate of internal heat generation (which in general may be position-dependent). Numerical coefficients are tabulated for the case of uniform internal heat generation. The application of this calculation procedure to published methods of thermal conductivity determination is shown and an example is given.

Radiation-induced acoustic cavitation: Apparatus and some results, M. Greenspan and C. E. Tschiegg, *J. Res. NBS* 71C4-261, pp. 299-312 (Oct.-Dec. 1967).

Key words: Acoustic cavitation; alpha-particle-induced cavitation; cavitation; cavitation nucleus; cavitation threshold; fission-induced cavitation; neutron-induced cavitation; radiation-induced cavitation; threshold.

Equipment and techniques for acoustic cavitation work are described. The test liquid and its container form part of a self-sustaining programmable oscillator. Emphasis is laid on the treatment of the liquid necessary to yield reproducible results after artificial nucleation, especially by neutrons, α-recoils, and fission. With neutrons, for instance, the cavitation rate rises rapidly with acoustic (negative) pressure, and at fixed pressure is proportional to neutron flux. The cavitation events are random, and no appreciable induction or decay times are observed. Each cavitation arises from the action of a single neutron (or α-recoil, or fission). The cavitation "threshold" (roughly negative pressure below which cavitation is rare) is highly variable from liquid to liquid. Thresholds at about room temperature for liquids irradiated with 10 MeV neutrons ranged from 1 to 2 bars for *n*-pentane, ether, and freon 113 to over 50 bars for water.

Design of a new Kossel pattern generator, D. L. Vieth and H. Yakowitz, *J. Res. NBS* 71C4-262, pp. 313-318 (Oct.-Dec. 1967).

Key words: Divergent x-ray beam; instrument design; Kossel camera; Kossel method; x-ray instrumentation.

A Kossel pattern generator, designed and built at the National Bureau of Standards, is described in detail. The unit is modular and consists of an electron beam column, vacuum system, light microscope, film cassette, and Kossel camera. The camera component includes microgoniometric capabilities. The Kossel x-ray technique enables the investigator to obtain lattice spacing data precise to two or three parts per million, and orientation of crystals to 0.1° of arc. The Kossel pattern generator described permits data for such determinations to be obtained quickly and precisely.

The near-zone magnetic field of a small circular-loop antenna, F. M. Greene, *J. Res. NBS* 71C4-263, pp. 319-326 (Oct.-Dec. 1967).

Key words: Loop-antenna field strength; magnetic field-strength standard; mutual inductance of coaxial circular filaments; near-zone magnetic field; transmitting loop antenna.

An improved formula is derived for accurately computing the *near-zone* magnetic field of a small circular transmitting loop antenna. Such a field can serve as a reference standard for calibrating field-strength meters employing small receiving loop antennas in the frequency range 30 Hz to 30 MHz.

This formula includes correction terms for frequency (due to the finite time of propagation), as well as corrections for the finite radii of both the transmitting and receiving loops. Other formulas appearing in the literature often fail to include such corrections which can result in errors of up to 20 percent and more in computing standard-field values.

The NBS formula is derived by expanding the integrand of the retarded vector potential into an infinite series of spherical Hankel functions of increasing order. The resulting series expression is in error by less than 0.2 percent, is rapidly converging and simple to use without recourse to a table of functions or a computer.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 72C, JANUARY-DECEMBER 1968

January-March 1968

Acceleration due to gravity at the National Bureau of Standards, D. R. Tate, *J. Res. Nat. Bur. Stand. (U.S.)*, 72C (Eng. and Instr.), No. 1, 1-20 (Jan.-Mar. 1968).

Key words: Absolute gravity; acceleration; free-fall; gravity; Potsdam.

A determination of the absolute value of the acceleration due to gravity was completed in June 1965 at the National Bureau of Standards near Gaithersburg, Maryland. The determination resulted in a value of 980.1018 centimeters per second squared for a reference point on the first floor of the Engineering Mechanics Building. The result was published in *The Journal of Research of the National Bureau of Standards*, Vol. **70C**, No. 2, Engineering and Instrumentation, page 149, April-June 1966. The present paper describes in detail the apparatus and the techniques employed and presents the summarized data from which the value was derived.

Deflection of thin circular elastic plates under symmetrically distributed loading, A. F. Kirstein and R. M. Woolley, *J. Res. Nat. Bur. Stand. (U.S.)*, 72C (Engr. and Instr.), No. 1, 21-26 (Jan.-Mar. 1968).

Key words: Bassali's theory; deflection; elasticity; flexure; point supports; symmetrically distributed load; thin plates.

A special application of Bassali's solution for transverse flexure of thin elastic plates supported at several points is presented for the case of concentric symmetrically distributed load. Equations for deflection are presented for the case where the point supports lie within the loaded area. Under special conditions the numerical results from these equations coincide with those of Nadai's.

A dynamic method for determining the vapor pressure of carbon dioxide at 0 °C, J. L. Edwards and D. P. Johnson, *J. Res. Nat. Bur. Stand. (U.S.)* **72C** (Eng. and Instr.), No. 1, 27-32 (Jan.-Mar. 1968).

Key words: Carbon dioxide; fixed point; hypsometer; pressure standard; purification; vapor pressure.

The vapor pressure of carbon dioxide at 0 °C, or at 0.01 °C, has been used as a fixed point on the pressure scale. Comparisons between laboratories may be affected equally by pressure measurements, temperature measurements, and the purity (and possibly isotope composition) of the sample. A dynamic method for establishing this pressure is described, utilizing a device similar to those used to realize the sulfur and steam points on the International Practical Temperature Scale. Advantages of the method include rapid establishment of equilibrium conditions, and the automatic purification of the carbon dioxide. Results obtained indicate a sample-to-sample reproducibility better than one part in 25,000. The method is suggested as being suitable for general use in realizing the CO_2 point of the pressure scale. This experiment yielded a value for the vapor pressure at 0 °C of 3.48516 MN m^{-2} or 26,140.8 mm Hg; at the triple point of water, 0.01 °C, it was 3.48608 MN m^{-2} or 26,147.7 mm Hg.

An adiabatic saturation psychrometer, L. Greenspan and A. Wexler, *J. Res. Nat. Bur. Stand. (U.S.)*, 72C (Eng. and Instr.), No. 1, 33-47 (Jan.-Mar. 1968).

Key words: Adiabatic saturation; gas mixtures; humidity; hygrometer; mixing ratio; moist gas; psychrometer; psychrometric factor; saturation; thermodynamic wet-bulb temperature; vapor content; wet-bulb.

An adiabatic saturation psychrometer for measuring the humidity of gases, as well as the vapor content of vapor-gas mixtures, is described. The instrument behaves in accordance with predictions deduced solely from thermodynamic considerations. With water-air, water-hydrogen, carbon tetrachloride-hydrogen, carbon tetrachloride-oxygen and toluene-air systems, at room temperature, atmospheric pressure, and gas flow rates of 1.3 to 5.2 liters per minute, measured wet-bulb temperatures agree with calculated "thermodynamic wet-bulb temperatures" to within the accuracy of the measurements and the uncertainties in the published thermodynamic data used in the computations. For the water-air system, the systematic and random errors due to these sources are estimated at 0.027 deg C and 0.019 deg C respectively. The agreement between the calculated and measured wet-bulb temperature is 0.029 deg C, which at a dry-bulb temperature of 25 °C and an ambient pressure of 1 bar is equivalent to an uncertainty in relative humidity which varies from 1/8 to 1/4 percent. The time constant is a function of the gas flow rate; at flow rates of 3.75 to 5.2 liters per minute, the time constant is of the order of 3/4 minute.

An injection method for self-calibration of inductive voltage dividers, W. C. Sze, *J. Res. Nat. Bur. Stand. (U.S.)*, 72C (Eng. and Instr.), No. 1, 49-59 (Jan.-Mar. 1968).

Key words: Calibration; in-phase deviation; inductive voltage divider; measurements; quadrature deviation; ratio calibration; transformer; two-stage voltage transformer; voltage divider; voltage ratio.

A self-calibration or "boot-strapping" injection method for determining the voltage ratio and phase angle deviations of inductive voltage dividers utilizes specially constructed transformers for step and differential voltage injections without reference to the fundamental electrical units or standards. Construction details of transformers, derivation of equations, and systematic evaluation of uncertainties are presented. Calibration of certain ratios involving a combination of dial settings on several decades can be obtained as readily as that of a single decade. The accuracy of the results obtainable at 10 kHz is within 2×10^{-7} of input for deviations less than 10 ppm of input and within 1×10^{-6} for deviations up to 100 ppm of input. This same calibration technique can readily be used to cover a frequency range from 1 to 20 kHz.

Bolometric voltage and current (Bolovac) standard for high and microwave frequencies, M. C. Selby, *J. Res. Nat. Bur. Stand. (U.S.)*, **72C** (Eng. and Instr.), No. 1, 61-79 (Jan.-Mar. 1968).

Key words: Current measurement; measurement voltages; microwave current; microwave voltages; transmission-line voltages; voltage measurements.

A standard of voltages and currents for lumped-constant, coaxial, and other circuits operating in the TEM mode has been

developed. Its approximate potential ranges are 1 MHz to 20 GHz in frequency, 0.05 to 10 volts, and 5 microamperes to 10 amperes. The principle may be used with bolometric, thermoelectric, photoelectric or other sensing elements consisting of thin film conducting or semiconducting disks located in the transverse plane of the TEM mode. Application and advantages are described and a comprehensive error analysis is presented. Figures illustrating construction details of one of the models of the Bolovac are included.

An admittance meter technique to measure the complex permeability at VHF, A. L. Rasmussen and C. M. Allred, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 1, 81-89 (Jan.-Mar. 1968).

Key words: Admittance meter; attenuation calibration; lossy magnetic materials; magnetic measurement methods; permeability; rf magnetic materials; VHF bridge; VHF magnetic materials.

An admittance meter technique may be used in evaluating and comparing accurately and conveniently the complex permeability of magnetic materials from 30 MHz to ~ 100 MHz. The admittance meter has three coaxial lines fed from a common source at a common junction point, two lines being terminated by shorts and the third by 50Ω. The currents in the lines are detected by three electrically connected parallel loops each located close to the common junction point of the lines. The loops are adjustable to one minute of rotation and follow closely a sine law. The complex permeability of a sample is derived from measurements with a sample in and out of one of the shorted coaxial lines. The estimated error from 30 MHz to 100 MHz is from ~ 1 to ~ 10 percent for sample inductance from $3 \cdot 10^{-9}$ to 10^{-7} H and sample resistance $5 \cdot 10^{-1}$ to $10^{2}\Omega$. Error of inductance is ~ 1 percent from 30 MHz to 200 MHz for low-loss samples using calibrated sample data. Using precision 50Ω, low-contact resistance lines, the sample impedance error attainable is estimated as ~ 1 percent for the above limits of impedance and measurements can be extended to above 100 MHz. The equations for the inductance and the resistance of the sample are expressed in terms of calibrated values for the settings of two loops, the calibrated resistance value of the 50Ω termination, the calibrated or calculated impedance components of the sample line, and the inductance of an equivalent air core.

April-June 1968

Analysis and design of an oscilloscope deflection system with a calculable transfer function, D. M. Stonebraker, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 2, 117-125 (Apr.-June 1968).

Key words: Deflector; drift space; oscilloscope; standard; strip-line; transfer function.

An oscilloscope deflector is described, which has a calculable transfer function. The deflector is analyzed, leading to its transfer function, in terms of the complex frequency variables. A practical strip line deflector, usable as a pulse standard, is designed; and its frequency response, sensitivity, bandwidth, rise time, step function, and impulse response are calculated. The predicted deflection is down to 70 percent of its d-c value at 2.82 GHz, while the step-response 10 to 90 percent rise time is 148 picoseconds. The effects of a drift space on the oscilloscopic display is also discussed. Results are compared with a well-known expression for the parallel plate deflector structure.

Calculation of substitution error in barretters, S. Jarvis, Jr., and J. W. Adams, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 2, 127-237 (Apr.-June 1968).

Key words: Barretter; bolometer; microwave power measurements; substitution error.

This paper describes a mathematical analysis for determining the value of the substitution error of a bolometer with a Wollaston-wire element (barretter). The analysis reflects all significant nonlinearities in the heat flow, including some not covered before, and includes all appreciable heat transport mechanisms simultaneously.

The values of substitution error thus obtained, in conjunction with efficiency data obtained by microwave techniques, will be very useful in extending power meter calibrations to frequency ranges where extremely accurate microcalorimeters are not available.

Analysis of *n*-degree elliptical elastic rings of nonuniform cross section, R. A. Mitchell, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 2, 139-160 (Apr.-June 1968).

Key words: Curved bar analysis; elasticity; force transducer; *n*-degree elliptical ring; nonlinear programming; optimization; proving ring; structural design; theory.

A curved bar structural analysis is developed for an *n*-degree elliptical elastic ring with sinusoidally varying cross-section dimensions, where the *n*-degree ellipse is defined by $(x/a)^n + (y/b)^n = 1$, $n \geq 2.0$. A sequential grid constrained optimization method is used to search for a minimum weight design in six dimensional shape parameter space. Numerical results indicate that rings of this shape can be designed to have considerably less weight and greater flexibility than comparable circular rings with uniform cross-section dimensions.

Applications of coaxial chokes to a-c bridge circuits, D. N. Homan, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 2, 161-165 (Apr.-June 1968).

Key words: Bridge; capacitance; coaxial cable; ground loop; inductance; magnetic core; stray magnetic field.

One or more turns of coaxial cable on a magnetic core form a coaxial choke which may be used to suppress unwanted loop currents in a-c bridge circuits. A review of several applications of coaxial chokes to a-c bridge circuits is presented. These applications include suppressing ground loop currents, assuring unique definition in the measurement of small 3-terminal capacitors, reducing stray magnetic field and reducing voltage drops in leads caused by large ground capacitance current. There is also a discussion of techniques for greatly increasing the effectiveness of the coaxial choke.

Creep rupture properties of Ti-8Al-1Mo-1V alloy, W. D. Jenkins and W. A. Willard, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 2, 167-174 (Apr.-June 1968).

Key words: Creep; engineering design; high temperatures; phase changes; rupture; titanium alloy.

Creep tests were made at 600, 800, 1000, and 1200 °F (588, 699, 811, and 921 °K) on duplex-annealed Ti-8Al-1Mo-1V alloy specimens. Creep-test conditions were selected to produce creep rates ranging from 0.1 to 50,000 percent per 1,000 hours and rupture times ranging from 0.1 to about 10,000 hours. Conformance of the test data to creep theories was obtained over a limited range of stress, strain, creep rate and temperature. Creep behavior was influenced by microstructural changes during creep and by prior thermal-mechanical treatment. Engineering-design curves are included in this paper.

July-September 1968

Gas density balance design considerations, E. C. Creitz, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 3, 187-195 (July-Sept. 1968).

Key words: Chromatographic detector; density detector; gas density; gas detector.

The Nerheim gas density balance operates by measuring the flow produced by differences in density between a sample and a reference gas in the earth's gravitational field. It has been

considered theoretically in order to outline the characteristics of the gas flow system, those of the flow measuring anemometers, and the effects of detector volume on peak separation and sensitivity. It is shown that both design parameters and operating conditions affect the performance of the device, and that properly considered compromises can improve its characteristics.

Standard mismatch—the production of controlled small reflections in waveguides, L. Lewin, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 3, 197-201 (July-Sept. 1968).

Key words: Controlled small reflections; mismatch; reflector posts; waveguide.

The reflection properties of possible suitable structures, for producing small accurately controlled reflections in rectangular waveguide, are examined and a choice made of cylindrical posts for a more detailed study.

A number of sources of error due to ohmic loss, positioning and shape are investigated, and it is shown that both the inductive and capacitive post can meet reasonable specifications, but that the latter is the more suitable on almost all counts. Attention to post size and tilt is necessary, but the accuracies needed lie well within the range achievable by good engineering practice.

Viscoelastic behavior of dental amalgam, P. L. Oglesby, G. Dickson, M. L. Rodriguez, R. M. Davenport, and W. T. Sweeney, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 3, 203-213 (July-Sept. 1968).

Key words: Amalgam; creep; dental; steady-state creep; stress-strain; transient creep; viscoelastic.

Measurements made on dental amalgam in tension indicate that amalgam exhibits three types of viscoelastic phenomena: (1) instantaneous elastic strain, (2) retarded elastic strain (transient creep), and (3) viscous strain (steady-state creep). The combination of elastic plus retarded strain can be represented by an equation of the form $\epsilon = A\sigma + B^2\sigma^2$ where A and B are functions of time but not of the stress, σ. The viscous strain rate can be represented by an equation of the form $\epsilon_v = K\sigma^m$ where K and m are constants of the material. By applying a nonlinear generalization of the Boltzmann superposition principle to a general equation describing the creep behavior of amalgam, the results of creep tests can be directly related to the results of stress-strain tests.

The steady-state creep behavior of dental amalgam, G. Dickson, P. Oglesby, and R. Davenport, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 3, 215-218 (July-Sept. 1968).

Key words: Amalgam; creep; creep activation energy; dental amalgam; silver amalgam.

The steady-state creep behavior of a dental amalgam subjected to tensile stresses of 500 to 4000 psi (3.4×10^6 to 2.8×10^7 N/m^2) was investigated over the temperature range of 23 to 52 °C (296 to 325 K). It was found that the creep behavior can be represented by the equation:

$$\epsilon_v = K\sigma^m e^{-E/RT}$$

where ϵ_v is the creep rate, K and m are constants of the material, σ is the stress, E is the activation energy for the process, R is the gas constant and T is the temperature. Values of the constants determined for the dental amalgam were $K = 2.31 \times 10^9$, $m = 3.45$ and $E = 35{,}300$ cal/mol (148,000 joule/mole).

October-December 1968

Theoretical and experimental study on longitudinal impact of tapered rods, L. R. Hettche, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 4, 231-241 (Oct.-Dec. 1968).

Key words: Aluminum; experiments; longitudinal impact; numerical solution; one-dimensional; plastic-wave propagation; rate-independent theory; tapered rods.

To examine the adequacy of the one-dimensional, rate-independent theory of plastic-wave propagation for annealed, commercially pure aluminum, experimental results from the longitudinal impact of uniform and tapered rods are compared to a theoretical analysis. The theoretical description is a numerical solution which utilizes the characteristic properties of the governing equations to construct difference relations for a constant mesh spacing. Numerical evidence of convergence and stability of the solution is presented. A constant-velocity boundary condition is defined by the axial collision of identical specimens, 6 inches (152 mm) in length and tapered slope varying between ±0.03, using a 3/4-inch (19mm) bore gas gun. Strain-time profiles are measured at cross-section distances of 1, 2, and 4 inches (25, 51, and 102 mm) from the impact face with resistance gages. Quantitative agreement between theoretical prediction and experimental data, e.g., dispersive features and unloading patterns of the strain wave, show the theory and method of solution to be a reasonably accurate model of the deformation. The selection of the specimen geometry as the experimentally controllable parameter in the longitudinal impact experiment is found to be a useful testing method in investigating the dynamic response of materials.

Analytical studies of probe conduction errors in ground temperature measurements, B. A. Peavy, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 4, 243-247 (Oct.-Dec. 1968).

Key words: Earth temperature; probe conduction errors; steady periodic heat flow.

Vertical probes with temperature sensing elements placed at fixed positions along their length are commonly used for measuring earth temperature variations with time. Mainly for structural reasons, the probes are comprised of materials whose thermal properties are not the same as those of the surrounding earth, so that the temperatures as measured at a given time by the probe are not the same as that for the undisturbed earth. A mathematical analysis for steady periodic, two-dimensional heat flow in a two body composite has been made to determine the probe conduction errors in ground temperature measurements. Several examples are given to show the relative magnitude of probe conduction errors.

Nonlinear constrained optimization by a nonrandom complex method, R. A. Mitchell and J. L. Kaplan, *J. Res. Nat. Bur. Stand. (U.S.),* **72C** (Eng. and Instr.), No. 4, 249-258 (Oct.-Dec. 1968).

Key words: Curved bar analysis; discrete variables; elastic; force transducer; minimum weight; n-degree elliptical ring; nonlinear programming; nonrandom complex method; optimization; rib-stiffened plate; structural analysis.

A nonrandom complex method is described for application to optimization problems characterized by nonlinear objective and constraint functions involving continuous and/or discrete optimization variables. The method is a mutation of the "complex" method (involving a pseudo-random process) developed by M. J. Box. Application of the method is demonstrated by two minimum weight structural analysis problems: (1) an n-degree elliptical elastic ring with sinsusoidally varying cross section dimensions; and (2) a rib-stiffened, simply supported elastic plate. The ring problem has six continuous independent variables, and the plate problem has four independent variables, two of which are discrete.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 73C, JANUARY-DECEMBER 1969

January-June 1969

An interferometer for measuring gradients in both refractive index and thickness of large or small optics, J. B. Saunders, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Engr. and Instr.), Nos. 1 and 2, 1-4 (Jan.-June 1969).

Key words: Interferometer; optical homogeneity; refractive index.

A small aperture prism interferometer is described for measuring refractive index and thickness gradients between pairs of adjacent points in both small and large optics. It is relatively free from vibration problems and thermal gradients are reduced to a minimum by confining the two component beams of light to a relatively small space. Large specimens are tested by scanning them with the light beam.

A Kerr electro-optical technique for observation and analysis of high-intensity electric fields, E. C. Cassidy and H. N. Cones, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Engr. and Instr.), Nos. 1 and 2, 5-13 (Jan.-June 1969).

Key words: Dielectric liquids; electro-optical measurements; electrostatic field measurements; high voltage measurements; Kerr cell; laser applications; potential measurements; pulse measurements.

A Kerr electro-optical technique, which permits observation and analysis of high intensity electric fields in nitrobenzene-filled Kerr cells, is described. Two-dimensional visual images, similar to those achieved in photoelastic-mechanical stress analysis, of the field distribution are afforded by the fringe pattern produced by the Kerr effect when high direct voltages are applied to the cell. Analysis of the field profile, by measurement of the fringe positions, permits calibration of the system for measurement of high voltage pulses. The Kerr constant of the liquid and space-resolved determinations of relative field strength, actual field strength (in volts per centimeter), and potential are also derived.

Student-*t* deviate corresponding to a given normal deviate, B. L. Joiner, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 1 and 2, 15-16 (Jan.-June 1969).

Key words: Standard deviation; statistics; Student-*t*; table of Student-*t*; uncertainties.

A table is given of the t deviate that corresponds to a given normal deviate z in the sense that the probabilities outside the t value and outside the z value are identical. This table enables those who are accustomed to expressing uncertainties in terms of 1σ, 2σ, 3σ, or 4σ limits to give statistically equivalent limits when the standard deviation σ is not known and consequently must be estimated from small samples.

A heat loss compensated calorimeter and related theorems, S. R. Domen, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 1 and 2, 17-20 (Jan.-June 1969).

Key words: Absorbed dose; calorimeter; heat flow theorems; heat loss compensation.

A new calorimetric design and measuring technique are proposed for reducing uncertainties caused by temperature gradients. A theoretical analysis reveals a mathematical theorem concerning heat transfer and its electrical analog.

Laboratory measurements of air cavity temperature in a passenger car tire, B. G. Simson and J. Mandel, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 1 and 2, 21-24 (Jan.-June 1969).

Key words: Temperature sensitivity; tires.

The air cavity temperature of a passenger car tire, running on a test wheel, was measured for different combinations of load, speed, and pressure. An empirical function was developed to illustrate the way in which the air cavity temperature of tires can be related adequately to given values of speed, load, and inflation pressure within the range covered by this laboratory experiment. The standard deviation computed from the residuals of the fit was 5 °F ($\simeq$ 2.8 °C).

July-December 1969

Design features of a precision ac-dc converter, L. A. Marzetta and D. R. Flach, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 3 and 4, 47-55 (July-Dec. 1969).

Key words: AC; DC; operation; precision; rectifier; transfer.

With the availability today of high performance operational amplifiers and related components, it is possible to construct an instrument for ac-dc transfer work that meets the requirements of a standards laboratory. Transformation of measured average a-c values into d-c voltage is possible with a predictable accuracy of 20 parts per million up to 1 kHz. Precision of operation is assured from dc to 100 kHz.

An improved high-precision calibration procedure for reference standard hydrometers, H. A. Bowman and W. H. Gallagher, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 3 and 4, 57-65 (July-Dec. 1969).

Key words: Calibration; density; hydrometer; hydrometer calibration; reference hydrometer; specific gravity; standard hydrometer.

This paper describes a method of calibrating hydrometers which, although no more accurate than the technique used heretofore at the National Bureau of Standards, reduces calibration time from several days to a few hours. The procedure is based upon easily measured hydrometer weight, stem scale geometry, and flotation level measurements at only one liquid density. The reliability of this single level is improved by observing the hydrometer flotation under various weight loads. The calibration experiment is oriented toward automatic data reduction so the finished calibration report is of much wider applicability than the simple correction table derived from the older experiment.

The nuclear quadrupole resonance magnetometer: A new method for the precision measurement of the magnitude and direction of magnetic fields, M. Linzer, *J. Res. Nat. Bur. Stand. (U.S.),* 73C (Eng. and Instr.), Nos. 3 and 4, 67-73 (July-Dec. 1969).

Key words: Magnetometer; nuclear quadrupole resonance.

A theoretical investigation of the feasibility of a magnetometer based on the observation of the Zeeman splitting of a nuclear quadrupole resonance line is presented. With a single crystal of potassium chlorate as the sensor, an nqr magnetometer with center frequency of 28 MHz and bandwidth of 10 MHz could cover a range of 10 nT to greater than 1 T. Precision at specific crystal orientations should approach 10 nT in the magnitude of the field, at flux densities exceeding 100 μT, and (65/B) microradians in the direction of the field where B is the flux density in mT. If circularly polarized rf excitation is employed, a precision of 10 nT could be achieved at flux densities less than 100 μT. Accuracy of the flux density measurements is limited by the uncertainty in the gyromagnetic ratio of ^{35}Cl, which at the present time is approximately 1×10^{-4}. The effect of the small asymmetry parameter which characterizes the ^{35}Cl resonance in $KClO_3$ is analyzed. Various experimental arrangements are proposed to record the magnitude and direction of the field, to obtain high resolution at low fields and good linearity at high fields, to overcome the difficulties due to the presence of a small asymmetry parameter, and to make an instantaneous measurement of the Zeeman splitting frequency.

Optical FM system for measuring mechanical shock, L. D. Ballard, W. S. Epstein, E. R. Smith, and S. Edelman, *J. Res. Nat. Bur. Stand. (U.S.)*, **73C** (Eng. and Instr.), Nos. 3 and 4, 75-78 (July-Dec. 1969).

Key words: Accelerometer; calibration; Doppler; interferometer; laser; shock measuring; single-sideband.

A technique is described for calibrating shock accelerometers by measuring the Doppler shift in light frequency produced by the change in velocity of a target. The system employs a quadrature laser interferometer and a single-sideband carrier insertion circuit to distinguish between positive and negative velocities.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 74C, JANUARY-DECEMBER 1970

January-June 1970

Production of near-perfect interferograms of variable visibility, J. B. Saunders, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 1-2 (Jan.-June 1970).

Key words: Interference fringes; interferograms.

A method is given for producing interferograms of fringes that are straight and equally spaced. The intensity distribution obeys the cosine law. The visibility can be controlled over the entire range from zero to unity. The interferometer is rugged and practically free from vibration effects.

Locked nuclear quadrupole resonance spectrometer for pressure measurements, R. C. Frisch and D. L. VanderHart, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 3-8 (Jan.-June 1970).

Key words: $KClO_3$ nuclear quadrupole resonance; pressure transducer; spectrometer.

The Nuclear Quadrupole Resonance frequency of a nucleus in a solid is dependent on its local environment and can be quite sensitive to changes in temperature and pressure. A spectrometer capable of locking accurately to the center of a resonance signal is described. The feasibility of using the quadrupole resonance frequency as a transfer gage for precise pressure measurements is discussed using ^{35}Cl resonance in a $KClO_3$ polycrystalline sample. The performance of the instrument implies a limiting accuracy for pressure measurements of 0.7 bar; preliminary results are presented showing frequency versus pressure near room temperature. Uncertainties of these measurements are primarily due to inadequate temperature control and the uncertainty of the pressure measurement.

Precise continuous optical attenuator, G. Ruffino, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 9-13 (Jan.-June 1970).

Key words: Dichroic polarizers; optics; pyrometry; radiometry; relative transmittance factor.

The construction of a precision photometric attenuator is described, which uses linear birefringent polarizers. If properly calibrated, the instrument has relative error not exceeding 2.4×10^{-4} within a relative transmittance range down to 8×10^{-3}. The calibration takes into account stray light, provided the ratio of stray light intensity to total intensity remains constant and low in the whole range. The construction and calibrating procedure apply equally well to the near infrared region.

An a-c resistance thermometer bridge, R. D. Cutkosky, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 14-17 (Jan.-June 1970).

Key words: Automatic phase balance; bridge; multistage transformers; operational amplifiers; resistance bridge; resistance thermometry; temperature measurement.

A 400 Hz bridge designed specifically for measuring the resistances of platinum thermometers is described. When used in conjunction with a conventional 25 ohm thermometer, the instrument can resolve a resistance change of 2 micro-ohms or less, or about 20 microdegrees. It is believed to be in error by no more than 3 micro-ohms throughout the useful temperature range of a conventional thermometer. The instrument features an automatic phase angle balance, and extensive use is made of multistage transformers and operational amplifiers.

On the flow induced by a Maxwell-Chartoff rheometer, E. A. Kearsley, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 18-19 (Jan.-June 1970).

Key words: Normal stresses; rheology; rheometer; viscoelasticity.

The Maxwell-Chartoff rheometer does not supply the surface tractions necessary to maintain the flow customarily assumed. This can be seen from considerations of the energy balance.

Mechanical compliance measurements of single-edge-notch tension specimens, M. J. Orloski, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 20-26 (Jan.-June 1970).

Key words: Compliance; crack-toughness; fracture; single-edge-notch specimen.

This paper describes the mechanical compliance measurement of a 15×3-in single-edge-notch (SEN) specimen, effective gage length greater than twice specimen width, and a 7×3-in SEN specimen, effective gage length less than twice specimen width, both of 1/4-in-thick 7075 – T6 aluminum. The 15×3-in specimen was chosen to provide experimental values of EWG/P^2 for comparison with the theoretical stress function solutions of Srawley and Gross. Results obtained are in good agreement with the theoretical values. The 7×3-in specimen was chosen as proportional to a practical size SEN specimen that has been widely used. Comparisons of experimental values of EWG/P^2 for this specimen were made with these theoretical stress function solutions.

Effect of notch geometry and temperature on the creep-rupture behavior of titanium alloy, W. D. Jenkins and W. A. Willard, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 1 and 2, 27-37 (Jan.-June 1970).

Key words: Creep; elevated temperature; engineering design; notch geometry; stress concentration; stress-rupture; titanium alloy.

Creep-rupture tests were made on circumferentially notched Ti-8Al-1Mo-1V specimens at temperatures of 600, 800, 1000, and 1200 °F (588, 699, 811, and 921 K) with stresses to produce rupture times ranging from 1 min to several thousand hours. A comprehensive study was made to determine the effects of notch geometry (angle, depth, root radius) on creep, rupture, and ductility characteristics of the alloy. Although a limited first stage and well-defined second and third stages of creep were observed, neither rupture times nor reduction of area values were predictable from extension-time behavior. Rupture time and ductility appeared to be affected more by the initial root radius at the base of the notch than by notch depth. Differences in mechanical behavior between specimens of different notch geometries were less as the temperature was increased or the stress decreased. A limited number of tests indicated that prior strain history had a marked effect on subsequent creep-rupture behavior at 1000 °F.

Relative amounts of alpha and beta constituents, the number of observed internal cracks, and the mode of fracture were affected by notch geometry and test temperatures.

July-December 1970

Techniques for comparing four-terminal-pair admittance standards, R. D. Cutkosky, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 63-78 (July-Dec. 1970).

Key words: AC direct-reading ratio set; ac measurements; bridge; coaxial chokes; defining transformers; equal power bridge; four-pair standards; frequency-dependent bridge; quadrature bridge.

Some of the advantages of four-pair admittance standards and some of the special problems encountered in their measurement are pointed out. Detailed descriptions of three distinct types of four-pair bridges and some of their limitations are presented. These three bridges form a vital part of a very precise absolute measurement of resistance based on a calculable capacitor being undertaken at the National Bureau of Standards, but are believed to be of more general usefulness.

Some applications for series impedance elements in radio frequency immittance measurements, L. E. Huntley, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 79-85 (July-Dec. 1970).

Key words: Immittance measurement; radio frequency; series elements; two-port standards.

A series impedance element equipped with coaxial connectors may be evaluated as a two-port network. Precision connectors greatly reduce the uncertainties associated with the series connection, making practical several measurement techniques which involve series impedances. This paper discusses techniques for extending the range of immittance bridges to high values of admittance or impedance, for measuring very small admittances with incremental standards of ordinary range, and for using a bridge to measure its own reference open-circuit admittance or short-circuit impedance.

A pulse heating method for the measurement of melting point of electrical conductors (thin wires) above 2000 K, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 87-88 (July-Dec. 1970).

Key words: High-speed measurements; high temperatures; melting point; platinum.

A pulse heating method is described for the measurement of melting point of electrical conductors at high temperatures (above 2000 K) which are in the form of thin wires. The technique is checked by measuring the melting point of platinum. The results give 2044 ± 5 K on IPTS-1968.

A time-shared computer system for diffractometer control, H. A. Alperin and E. Prince, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 89-95 (July-Dec. 1970).

Key words: Automatic control; computer control; diffractometer; FORTRAN; neutron diffractometer; real-time data processing; time sharing; x-ray diffractometer.

A system is described for controlling data acquisition, and for online data reduction, on up to eight neutron and x-ray diffractometers. The system uses a medium-sized computer, with the individual instruments sharing time. Storage of programs, data, and the intermediate results of computations on a rapid-access disk makes roughly 12K of the 16K core memory available to each user in turn for computations. All users' programs are written in FORTRAN. Each user has independent access to the computer, through his own separate typewriter, for input of control parameters and output of sample results. Final output data may be recorded on magnetic tape for permanent filing or for processing offline by a large computer.

Tensile deformation of vapor-deposited copper reinforced with tungsten wires, W. D. Jenkins, W. A. Willard, and D. E. Harne, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 97-110 (July-Dec. 1970).

Key words: Composites; copper; electrical conductivity; fracture; law of mixtures; metallic bonding; tensile properties; tungsten; vapor-deposition; wires.

Short-time tensile tests were made at room temperature on sheet specimens of vapor-deposited copper containing zero to 26 volume percent continuous tungsten wires having diameters of 0.0005, 0.001, and 0.005-inch. Specimens were annealed at 25, 300, and 600 °C (298, 573, and 873 K) prior to testing. Strength, ductility, shape of the stress-strain curves, and types of fractures were influenced by volume fraction and number of layers of wires as well as by wire diameter and alinement. Strength values for the composites with 2 to 3 percent volume fractions of wires exceeded those predicted by the law of mixtures whereas at higher volume fractions, either conformance to the law was observed or lower values than those predicted were obtained. Increase in strength was accompanied by a decrease in electrical conductivity. All the properties investigated were markedly affected by increasing the annealing temperature. Tungsten wires failed in a ductile manner after considerable localized deformation ("necking") in various sections of the wires.

"Connector-pair" techniques for the accurate measurement of two-terminal low-value capacitances, A. Millea, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 111-116 (July-Dec. 1970).

Key words: Capacitance measurement; coaxial adaptor; coaxial connector; fringe capacitance; standard capacitor; two-terminal capacitor.

A method is described that allows two-terminal capacitance measurements to be performed with uncertainties of $\pm 0.0001 - 0.0002$ pF, the ultimate accuracy limit being imposed only by the repeatability performance of the connectors. This technique has been used for the calibration of coaxial capacitance standards and the measurement of the fringe capacitance of coaxial open-circuit terminations; other applications are also possible in the field of high-frequency coaxial measurements.

The use of dew-point temperature in humidity calculations, L. A. Wood, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 117-122 (July-Dec. 1970).

Key words: Antoine Equation; dew point; humidity; hygrometry; psychrometric chart; relative humidity; vapor pressure of water; wet-bulb temperature.

The dew-point temperature has a number of desirable features as a means of expressing humidity. The Antoine Equation, $\log e_w = A - B(T+C)^{-1}$, where e_w is the partial pressure and T is the temperature of saturated aqueous vapor, represents the Goff-Gratch formulation quite well over the range of temperature from 0 to 140 °F. The pressure e_w, in inches of mercury, is obtained by taking the constants $A = 6.70282$, $B = 3150.515$ (°F)$^{-1}$ and $C = 391.0$ °F, calculated from values given by Dreisbach. It is shown that the dew-point DP is related to the relative humidity RH by the relation:

$$(DP+C)^{-1} = (T+C)^{-1} + B^{-1} \log (RH)^{-1}.$$

Lines of nearly constant positive slope represent constant relative humidity values on graphs of dew-point against temperature. The value of the slope decreases from unity for $RH = 100$ percent to about 0.76 for $RH = 10$ percent, corresponding to the linear equation

$$DP = [1 + 0.1471 \log (RH)^{-1}]^{-2}(T-70) + DP_{70} \text{ where } DP_{70} = [2169 + 319 \log (RH)^{-1}]^{-1} \times 10^6 - 391.$$

Psychrometric charts showing dew-point and dry-bulb temperature as coordinates with lines representing constant relative humidity and constant wet-bulb temperature (obtained from the Ferrell Equation) are extremely useful, since given values for any two of these four variables serve to locate a point, from which the values of the other two variables can be read directly.

Bolovac application for hf and microwave power measurement and standardization, M. C. Selby, *J. Res. Nat. Bur. Stand. (U.S.)*, **74C** (Eng. and Instr.), Nos. 3 and 4, 123-133 (July-Dec. 1970).

Key words: Bolometric power standards; Bolovac power measurements; calibration of power meters; rf and microwave power measurements; standard of power through 18 GHz.

The bolometric voltage and current (BOLOVAC) standard for frequencies to 18 GHz and higher, recently developed at the National Bureau of Standards (NBS), can also be used to measure power, offering the following advantages over a number of other methods in use today: (1) It eliminates: (a) the uncertainty resulting from neglecting termination mismatch, (b) measurement of reflection coefficients and computations using complex equations, (c) "Limits-of-error" charts, thus rendering definitive results, (d) use of impedance charts, (e) dc or af calibrations of power meters, (f) need of corrections such as "effective efficiency" and "calibration factor." (2) It covers a wide frequency range (0.5 MHz to 18 GHz or wider); (3) It should result in substantial reduction of calibration time in many instances; (4) It can be applied to calibrate feed-through power measurement methods for power levels ranging into kilowatts.

In measuring power, the Bolovac (1) measures the voltage across a known resistance component of a given load, or (2) measures the voltage in any plane of a coaxial line of known characteristic impedance and known voltage distribution along the line, or (3) absorbs the rf power as any other absorption-type power mount does. In the first two cases resistance and voltage distribution measurements may be made separately or these measurements may be combined with the power measurement procedure. In the third case the rf power is absorbed in a special disk-type bolometric detector of the Bolovac and is equal to the dc- (or af) bias-power substituted in that detector; this bias power is measured with conventional power substitution bridges. Any appreciable unaccounted for power losses occur outside the Bolovac and can be determined employing conventional techniques as well as the Bolovac itself. The Bolovac needs no rf calibration. A Bolovac may have a power range of 20 dB or higher, depending on accuracy desired, and a maximum power approaching its safe power dissipation, e.g., 0.5 W or higher. This paper is limited to the application of the Bolovac to power measurements only and presents analytical and practical aspects of this application.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 75C, JANUARY-DECEMBER 1971

January-March 1971

Rotary-vane attenuator with an optical readout, W. E. Little, W. Larson, and B. J. Kinder, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 1-5 (Jan.-Mar. 1971).

Key words: Attenuator; microwave; precision; rotary vane.

A precision x-band rotary-vane attenuator has been developed that follows its theoretical cosine squared law of attenuation to within 0.002 dB to a value of 20 dB. The best available attenuation measurement techniques verify this relationship to within the accuracy of the measurements. From 20 to 50 dB, the deviation from the theoretical value slowly increases and is frequency dependent. At present, three attenuators of this type have been constructed by NBS. Two of these attenuators have excellent attenuation versus frequency characteristics in the 20 to 50 dB range (0.08 dB deviation at 50 dB) while the third has a marked degree of frequency sensitivity (0.21 dB at 50 dB).

Design and operational characteristics of a high-speed (millisecond) system for the measurement of thermophysical properties at high temperatures, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 7-18 (Jan.-Mar. 1971).

Key words: High-speed measurements; high temperatures; thermodynamics; thermophysical properties.

Design and constructional details of a high-speed system for the measurement of selected thermophysical properties of electrical conductors at temperatures above 2000 K in experiments of subsecond duration are described. Operational characteristics of such a system are given. Various phenomena that affect the design and successful operation of the system are discussed and, whenever possible, quantitative results are given. Certain experimental checks to assess the operation of the system are also described.

A new method of determining residual thiosulfate in processed photographic film, C. I. Pope, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 19-22 (Jan.-Mar. 1971).

Key words: Archival film; hypo; microfilm; permanent record film.

Chromatographic paper, saturated with ammonia, is used to extract the residual thiosulfate from the gelatin layer of processed film. The paper is treated in a silver nitrate solution and fixed in an ammonia-sodium chloride solution. Thiosulfate, if present, forms silver sulfide and the thiosulfate is determined by measuring the transmission density of the paper darkened by silver sulfide. The paper extraction method is simple, rapid, requires only a densitometer as special equipment, and is very sensitive especially when the transmission density is measured for two layers of the paper. No filters are required. The test readily reveals the uneven distribution of residual thiosulfate on the film. By selective removal of thiosulfate from the image silver by ammonia and potassium bromide solutions, it was shown that small amount of thiosulfate was absorbed on the image silver immediately after processing.

Scanning densitometer for continuous recording of spectral transmission density at low spatial contrast, W. L. McLaughlin, M. Rosenstein, E. K. Hussmann, and J. J. Lantz, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 23-27 (Jan.-Mar. 1971).

Key words: Densitometer; microdensitometer; radiochromic dye films; spectral transmission density.

A simple photoelectric transmission densitometer can be converted in the laboratory into an instrument for measuring spatial variations in spectral density of small areas of thin, nonturbid films. This is accomplished by adding relatively inexpensive components that are readily available and easily assembled. The basic instrument can be one of a number of commercial densitometers, consisting of stabilized electronics, an adjustable light source, and a photosensitive probe which has a wide range and measures spectral transmission density. For continuous scanning of relatively small sample areas, the following additions are needed: (1) narrow-bandpass filters; (2) interchangeable field illuminating slits; (3) a short-focal-length illuminating-condenser lens which compromises between a relatively large numerical aperture and a reasonable depth of focus; (4) a motor-driven stage with adjustable speeds; (5) a light diffuser and light guide; and (6) a continuous, relatively fast-response data-recording system (such as a fast-response strip-chart recorder). This instrument has been assembled and tested especially for measuring spatial variations of spectral density produced in irradiated photochromic films; and also for calibrating a train of irradiated film samples, in terms of transmission density at a given wavelength as a function of irradiance, radiation absorbed dose, or photochemical reactivity.

Rotating optical attenuator for the generation of subsecond duration sawtooth shape radiance pulses, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 29-32 (Jan.-Mar. 1971).

Key words: High-speed methods; light attenuator; photometry; radiance modulation; radiation.

A rotating attenuator for the generation of subsecond duration sawtooth shape radiance pulses is described. The attenuator disk is in the form of a cam. The geometry of the opening of a diaphragm used as the aperture stop determines the shape of the radiance pulses. Radiance is determined from the measurements with a high-speed photoelectric pyrometer. Recording of signals is made with a high-speed digital data acquisition system. The combined measuring and recording systems have a full-scale signal resolution of approximately one part in 8000 and a time resolution of 0.4 ms. Two different diaphragms are used in this study yielding radiance pulses (20 to 150 ms long) with linear and quadratic rise. The standard deviation of the experimental points from the pertinent functions describing the radiance variation is less than 0.5 percent.

Sound speed measurements in solids: absolute accuracy of an improved transient pulse method, T. M. Proctor, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 33-40 (Jan.-Mar. 1971).

Key words: Acoustical pulse; longitudinal and shear sound waves; solids sound speed accuracy; speed of sound; transient pulse-acoustical.

A modified transient pulse technique for measuring shear and longitudinal sound speeds in solids has been devised. The

technique is described and evaluated for both precision and accuracy on a variety of solids. This evaluation has been done by experiments in which the constancy of sound speed with path length is used as the prime test for accuracy. A number of variables such as transducer frequency, transducer size, choice of different coincidence points, etc., have been examined. The transducer bond problem is examined and overcome by the use of a time delay bond. Indicated accuracy of the method is found to be better than one part in 10^4. Advantageous sample geometries for accuracy testing are discussed.

Seismic response of infrasonic microphones, A. J. Bedard, Jr., *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 1, 41-45 (Jan-Mar. 1971).

Key words: Compensation; ground motion; infrasonic microphones; seismic response.

Factors affecting the (unwanted) seismic response of infrasonic microphones are indicated. Past measurements of ground motion deduced from the radiated atmospheric sound measured with infrasonic microphones are reviewed, and such measurements are compared with seismometer measurements of ground motion. Seismic motions caused by the Japanese earthquake of May 1968 are used in this example. The seismic response of the infrasonic microphone used for this measurement was experimentally determined and the results are presented. A simple method of compensating for interfering seismic effects on microphones is described.

April-June 1971

Heated air adiabatic saturation psychrometer, L. Greenspan, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 2, 69-78 (Apr.-June 1971).

Key words: Adiabatic saturation; dew point temperature; humidity; hygrometer; mixing ratio; moist gas; psychrometer; vapor pressure.

A portable self-contained heated-air adiabatic saturation psychrometer intended as a field and laboratory instrument has been developed and constructed. The instrument measures the humidity of air in the range from 0 to 50 grams of water vapor per kilogram of dry air over an ambient temperature range of − 5 to 40 °C. It samples a test gas at the rate of 4 liters per minute.

The psychrometer was compared with the NBS pressure humidity generator over the mixing ratio range of 2.5 to 19 grams of water per kilogram of dry air (equivalent to a dew-point range of − 5.4 to 24 °C at atmospheric pressure). The mixing ratio indicated by the psychrometer was higher than that produced by the generator by 0.025 g/kg + 0.24 percent of the reading with a standard deviation of 0.024 g/kg; that is, it was higher by 1.24 percent to 0.37 percent of the reading as the measured mixing ratio increased from 2.5 to 19 g/kg. In equivalent terms of dew point, the psychrometer reading was higher by 0.16 deg C to 0.06 deg C as the measured dew point increased from − 5.4 to 24.0 °C. The results are approximately those which would be expected based on an analysis of estimated errors in individual measurements.

Computation of the temperature distribution in cylindrical high-pressure furnaces, M. Waxman and J. R. Hastings, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 2, 79-83 (Apr.-June 1971).

Key words: Analytic solutions; boundary conditions; computation, temperature distribution; furnaces, high-pressure; high-pressure furnaces; high-temperature, high-pressure research; power dissipation; temperature distribution, steady-state; temperature gradients; temperature irregularities; temperature variation; thermal conductivity.

The steady-state temperature distribution in typical cylindrical high-pressure furnaces has been computed from analytic solutions for various boundary conditions. Either the temperature variation along the cylindrical heater or the power dissipation per unit length is prescribed. The results are tabulated and discussed as an aid in the design of high-pressure furnaces and in the estimation of temperature gradients. Topics considered include: (1) the reduction of temperature gradients around the center of the furnace, (2) the effect of temperature irregularities along the heater, and (3) the effect of the relative thermal conductivity of neighboring components.

Rotating adjustable transmission optical step attenuator, A. Cezairliyan, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 2, 85-88 (Apr.-June 1971).

Key words: High-speed measurements; optical attenuator; photometry; radiance.

A rotating wavelength-independent optical attenuator is described that generates four radiance steps. Radiance ratios between the steps can be continuously varied. Experiments are performed to assess the operational characteristics of the attenuator. Radiance is determined from measurements with a high-speed photoelectric pyrometer. Recording of signals is made with a high-speed digital data acquisition system. The combined measuring and recording systems have a full-scale signal resolution of approximately one part in 8000 and a time resolution of 0.4 ms. The results of several experiments on radiance ratio measurements are found to be in agreement within one part in 1000.

An improved method for microwave power calibration, with application to the evaluation of connectors, G. E. Engen, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 2, 89-93 (Apr.-June 1971).

Key words: Calibration; connectors; mismatch; power equation; power measurement.

In the procedures for microwave power calibration, which are well documented, the subject of mismatch errors (or corrections) plays a major role. In particular, the evaluation of mismatch corrections requires the measurement of complex reflection coefficients; and the accuracy of this measurement is limited, in part, by connector imperfections.

The application of recently developed "power equation" methods to this problem provides both a simplified determination of the mismatch correction (M_{gm}) and improved accuracy. In particular, the intermediate step of measuring the reflection coefficients is eliminated, and the precision connector requirement is greatly relaxed. If this new method were adopted at each level of the usual calibration hierarchy, the accuracy of disseminating measurements referenced to the primary standards at NBS would be greatly improved.

The accuracy potential was demonstrated in a series of experiments involving the Type N, GPC-7, and waveguide flange connectors. The outcome of this experimental evaluation, in which the "ordinary" Type N performed on a par with GPC-7, raises some rather serious questions relative to current trends in connector development.

Apparatus for impact-fatigue testing, R. E. Schramm, R. J. Durcholz, and R. P. Reed, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), No. 2, 95-98 (Apr.-June 1971).

Key words: Cryostat; fatigue; impact; low temperature; mechanical property equipment; stainless steel.

A standard impact machine was extensively modified to allow the measurement of the response of specimens to repeated, controlled impact pulses. This equipment enables one to vary the

mperature (76-297 K), specimen geometry (uniaxial, biaxial, iaxial stress systems), and load levels. At stress levels in the eighborhood of the yield stress, on the order of 10,000 impact ycles are needed to fatigue specimens to fracture. Strain rates chieved are moderately high, of the order of 1000 min^{-1}, which onveniently form intermediate data between tensile (max. of bout 100 min^{-1}) and explosive straining data (about 6000 in^{-1}). Contrasted to standard fatigue tests, no constraint is aced on specimen elongation and only unidirectional stresses e imposed. Typical impact-fatigue results for AISI 310 stainss steel are presented.

program in refractory metal thermocouple research, G. W. Burns and W. S. Hurst, *J. Res. Nat. Bur. Stand. (U.S.)*, **75C** (Eng. and Instr.), No. 2, 99-106 (Apr.-June 1971).

Key words: EMF-temperature relationship; furnace; high temperature; refractory metals; thermocouple; thermoelements; sensor; ultra high vacuum; W-Re alloys.

A refractory metal thermocouple research program, directed wards establishing the parameters that are necessary to hieve reliable, long term, high temperature thermocouple perrmance, is outlined. A description of special apparatus for exsing bare-wire thermoelements to high temperatures in cuum and in high purity gaseous environments is given, and e design and performance of an ultra-high-vacuum, high-temrature furnace system are described. Bare-wire W-3 percent e and W-25 percent Re thermoelements were exposed at 2400 in argon, hydrogen or vacuum, and experienced a shift in their nf-temperature relationship upon initial exposure. After the inil shift, the thermoelements exposed in the gaseous environents experienced no significant further change in their emf-mperature relationship for periods up to 1000 hours. The therbelements exposed in vacuum continually drifted in their emf-mperature relationship as a result of the preferential loss of Re evaporation.

larization measurements as related to corrosion of underground steel piling, W. J. Schwerdtfeger, *J. Res. Nat. Bur. Stand. (U.S.)*, **75C** (Eng. and Instr.), No. 2, 107-121 (Apr.-June 1971).

Key words: Corrosion; corrosion rate; disturbed soil; instantaneous rate; pit depth; pitting factor; polarization; steel piling; undisturbed soil; weight loss.

Most of this paper is devoted to the author's evaluation of larization measurements made by the Corps of Engineers ower Mississippi Valley Division) on steel pipe specimens exsed to the soil at four dam sites as related to the corrosion of el piling (underground) observed at the sites. As the polarizan measurements were made periodically on weighed ecimens for periods as long as seven years, the Corps' data ofed an excellent opportunity for evaluating the accuracy and acticability of a polarization technique for measuring corrosion es. Reasonable agreement between calculated and actual corsion on the specimens made it possible to estimate maximum icipated corrosion on the piling after 50 years of exposure.

Confidence gained in the value of polarization measurements de on short length pipe specimens led the author to make meaements on actual piling. Instantaneous corrosion rates were asured on two driven pipe piles, 72 ft (22 m) and 19 ft (5.8 m) length, both of which had been exposed for 12 years. One nth later, the short pile was extracted and examined. Relativelow corrosion rates calculated from the polarization data were ified by the appearance of the pile and by the limited extent of pitting.

July-December 1971

ermal voltage converters and comparator for very accurate AC oltage measurements, E. S. Williams, *J. Res. Nat. Bur. Stand. (U.S.)*, **75C** (Eng. and Instr.), Nos. 3 and 4, 145-153 (July-Dec. 1971).

Key words: AC-DC difference; comparator; thermoelement; transfer voltmeter, voltage measurements.

A new fourteen-range set of thermal voltage converters and a thermoelement comparator are used to measure ac-dc difference, and a-c voltages relative to external d-c standards, with 20 ppm (parts-per-million) accuracy at audio frequencies. The imprecision is less than 2 ppm. Corrections relative to the very stable middle ranges can be redetermined for every range by a seven-step intercomparison of certain adjacent ranges.

Formulation and experimental verification of an axisymmetric finite-element structural analysis, R. A. Mitchell, R. M. Woolley, and C. R. Fisher, *J. Res. Nat. Bur. Stand. (U.S.)*, **75C** (Eng. and Instr.), Nos. 3 and 4, 155-161 (July-Dec. 1971).

Key words: Axisymmetric; elastic; experiment; finite-element analysis; force transducer; stiffness matrix; structural analysis.

A finite-element structural analysis is described for application to problems in which geometry and loading are axisymmetric and material properties are isotropic elastic. An attempt to minimize restrictions imposed on the shape and orientation of the triangular finite-elements has been largely successful. This facilitates use of the analysis, with automatic finite-element mesh generation, in parameter or optimization studies. A series of laboratory tests to verify the analysis are described in which the magnitude and distribution of boundary loading was known within narrow limits.

A Burnett apparatus for the accurate determination of gas compressibility factors and second virial coefficients, and an evaluation of its capability based on some results for argon and carbon dioxide, M. Waxman and J. R. Hastings, *J. Res. Nat. Bur. Stand. (U.S.)*, **75C** (Eng. and Instr.), Nos. 3 and 4, 163-172 (July-Dec. 1971).

Key words: Adsorption, gas on metal; argon, compressibility factor of; Burnett data reduction; carbon dioxide, second virial coefficient of; compressibility factor; gas; gas, compressibility factor of; gas, *PVT* properties of; measurements; second virial coefficient.

A Burnett apparatus has been developed for the determination of the compressibility factor of gases, including corrosive halogenic gases, to an accuracy of 0.1 percent to 0.01 percent at temperatures from 0 to 225 °C and for pressures up to 250 bars. The apparatus has been used throughout this temperature and pressure range and at temperatures within 15 °C of the critical temperature of the sample gas. The apparatus features a rugged yet highly sensitive and reproducible null-type pressure transducer to isolate the sample gas without introducing a pressure uncertainty greater than the precision of the pressure measurements, which is better than 1 part in 50,000. The pressure measurements are accurate to at least 1 part in 20,000. The reduction of the data is discussed extensively. The capability of the apparatus has been evaluated in terms of the compressibility factor represented by a finite pressure or density virial expansion and derived from argon data at 25 °C and pressures up to 250 bars and in terms of the second virial coefficient of carbon dioxide based on data at 50 °C and pressures below 35 bars. The value obtained for this second virial coefficient, -102.2 ± 0.5 cm^3/mol, compares favorably with the value of -102.5 cm^3/mol obtained from a recent correlation and is in substantial disagreement with the value of -100.7 ± 0.4 cm^3/mol determined by Dadson and co-workers from the Burnett method and the piezometer method.

An extension to the sliding short method of connector and adaptor

evaluation, G. F. Engen, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), Nos. 3 and 4, 173-180 (July-Dec. 1971).

Key words: Adaptor; connector; efficiency; sliding short.

Sliding short methods represent a measurement tool of substantial potential for the measurement of small losses such as are associated with waveguide connectors or adaptors. Until recently, however, the use of these methods has been inhibited by the uncertainty of the error contribution due to non-ideal short behavior.

A recent analysis by Almassy has shown that by the use of proper techniques, the error contribution from this source is usually negligible, provided that the adaptor (or connector) is "well matched."

It is the purpose of this paper to eliminate this latter restriction, develop additional measurement methods, and describe further applications.

Accurate microwave high power measurements using a cascaded coupler method, K. E. Bramall, *J. Res. Nat. Bur. Stand. (U.S.),* **75C** (Eng. and Instr.), Nos. 3 and 4, 181-186 (July-Dec. 1971).

Key words: Accurate; calibration; directional coupler; high power; measurement; microwave.

The use of directional couplers to extend the range of low-level power meters is a well established technique. Calibration of bolometer-coupler units up to 20 dB is routine at NBS and other laboratories and allows power measurement to the 1 W level. For higher coupling ratios, however, the problems in calibration using conventional techniques becomes more difficult. This paper describes a cascade method which allows calibration of low power meter-coupler combinations for measurement up to the megawatt range.

The technique is based upon system linearity and the uncertainty limits are shown to be 1 percent to 1.5 percent using NBS low power standards. By using the NBS calibration services and commercially available equipment, the above power levels can be measured with uncertainty limits less than 2.7 percent. The method can also be adapted to measurement of large coupling ratios (20-80 dB).

Results are given for power (200 watts in WR-90 waveguide) and coupling ratio (40 dB coaxial coupler) measurements.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 76C, JANUARY-DECEMBER 1972

Effective with this issue, this Section was discontinued.

January-June 1972

ational Bureau of Standards one kilogram balance (NBS No. 2), H. E. Almer, *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 1-10 (Jan.-June 1972).

Key words: Arrestment; balance; beam; buoyant; case; constant-load; equilibrium; knife; one-pan; short arm; two-knife.

The balance described is a one-pan, two-knife, short arm, 1 kg lance. The fulcrum flat and the suspension support elements mounted on a bed plate supported by three posts attached to base. The weight handling mechanism is mounted on a center lumn attached to the base. The balance has two modes of ar-tment, the constant load mode and the full arrest mode. A uble case encloses the structure.

There are positions for six weights inside the balance. These ights can be compared with each other, according to an ap-ppriate weighing design, without opening the balance case. e operation of the balance and the weight changing are ough control elements outside the balance case. The indicat-, elements for the instruments measuring the pressure, tem-rature, and relative humidity within the balance are located in-e the balance.

The standard deviation of the balance developed by a series of asurements in the National Bureau of Standards Experimen-Mass Laboratory was approximately 4μg.

ll and cylinder interferometer, J. B. Saunders, Sr., *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 11-20 (Jan.-June 1972).

Key words: Density standards; interferometer; volume of spheres.

An interferometer is described that permits the comparison of meters of balls and cylinders with an etalon. The specimen is ated in the cavity of the etalon. Interference is produced by t reflected from each surface of the etalon and the adjacent face of the specimen. The two pairs of interfering beams of t (one pair from each side of the etalon) are received by the e eyepiece or camera. A shutter permits alternate viewing of two interferograms. Magnification and contrast of the fringes obtained by a suitable choice of power and separations of nponents of the system. After the prime dimension of the lon is determined, it can be subsequently rechecked with the gle mode (stabilized) laser, used with this interferometer, hout removing the etalon from the assembly. A method is pro-ed for analyzing the results of this interferometer.

cision reference specimens of surface roughness: Some characteristics of the Cali-Block, R. D. Young and F. E. Scire, *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 1-23 (Jan.-June 1972).

Key words: Arithmetic Average roughness; Cali-Block; calibration; roughness.

The distribution of Arithmetic Average values of surface ghness across the 120 and 20 micro-inch patches of NBS Cali-Block "B" have been measured. It is shown that each distribution can be described in terms of its mean value and standard deviation. The observed systematic distribution of *AA* values strongly suggests that the user select several widely spaced regions at random on the patch when calibrating a roughness measuring instrument.

Absorption of sound in liquids by the resonator-decay technique: A critique, M. Greenspan, *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 25-32 (Jan.-June 1972).

Key words: Acoustic impedance; acoustic materials; acoustic parameters; acoustics.

(1) The resonator-decay and the reverberation methods for measurement of the absorption of sound in liquids are in wide use, but their theoretical foundation has not hitherto been investigated. The basic assumptions are in fact invalid, but under most practical conditions the errors are tolerable, at least for three common geometries. (2) The very large excess losses always observed at the lower-order modes are identified with anelastic effects in the envelope, for the most part, and with viscous boundary-layer effects to a lesser, but very substantial extent. For modes of sufficiently high order these become negligible.

Ductile fracture by development of surfaces of unstable cavity expansion, C. A. Berg, *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 33-39 (Jan.-June 1972).

Key words: Ductile fracture; plasticity; void growth.

A model of fracture of a ductile metal in which surfaces of unstable microcavity expansion occur is proposed. It is shown that such surfaces can occur only in locally plane incremental strain. The hardening conditions required for the development of these surfaces are considered. It is shown that in a material possessing an equivalent yield stress (Y) which depends upon the total plastic dilatation (Δ) and equivalent distortional strain (ϵ), the minimum ratio of dilatational softening ($\partial\gamma/\partial\Delta < 0$) to distortional hardening ($\partial\gamma/\partial\epsilon > 0$) under which an unstable surface of a dilatation may form is $-2/3$. A possible explanation, based upon the model, for the lack of correlation between plane strain ductility and ductility as measured in a tensile test is offered. Also, the pertinence of the model to fracture of glassy polymers and environmental stress cracking of crystalline polymers is discussed.

Friction and wear of graphite fiber composites, C. A. Berg, S. Batra, and J. Tirosh, *J. Res. Nat. Bur. Stand. (U.S.)*, 76C (Eng. and Instr.), Nos. 1 and 2, 41-52 (Jan.-June 1972).

Key words: Composites; friction; graphite fiber; wear.

Friction and wear of two different types of graphite fiber composites were studied in a pin-disk sliding contact wear machine. Composites reinforced (62% by volume) with low modulus, high strength circular fiber (Modmor 11) exhibited very high resistance to wear [a threshold wear load of ~ 20 N, a maximum bearing load of ~ 50 N, and a wear coefficient of ~ 10^{-6}] when worn by hardened steel pins. However, the composite produced extreme abrasion on the steel counterface. Composites rein-

forced (62% by volume) with high modulus, lower strength, non-circular fiber (GY70) also exhibited high resistance to wear (a threshold wear load of ~ 25 N, a maximum bearing capacity of ~ 20 N, and a wear coefficient of ~ 10^{-6}) when worn by hardened steel, but these composites developed a surface film which prevented abrasional damage to the steel counterface.

Potential applications of the two different types of composites in bearings are discussed. The advantages of these composites in bearings subject to corrosion, vibration, loss of lubrication, or impact damage are noted.

A note on construction of the equivalent plastic strain increment, C. A. Berg, *J. Res. Nat. Bur. Stand. (U.S.)*, **76C** (Eng. and Instr.), Nos. 1 and 2, 53-54 (Jan.-June 1972).

Key words: Equivalent strain; hardening; plasticity; strain hardening; work hardening.

Strain hardening plastic deformation of a material possessing a yield locus which may be written as a homogeneous function of the stress components, and which obeys the classical associated flow rule for metals is considered. The material may be anisotropic and may display plastic dilatation. A method is given for constructing the equivalent plastic strain increment in such a way that the increment of plastic work is always equal to the product of the equivalent plastic strain increment and the equivalent yield stress. The method is implied in classical treatments of hardening but seems not to have been given explicitly heretofore.

.4. PAPERS FROM THE JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA, VOLUME 1, JANUARY-DECEMBER 1972

This journal is published quarterly by the American Chemical ociety and the American Institute of Physics for the National ureau of Standards. The objective of the Journal is to provide ritically evaluated physical and chemical property data, fully ocumented as to the original sources and the criteria used for valuation. Critical reviews of measurement techniques, whose im is to assess the accuracy of available data in a given technical tea, are also included. The principal source for the Journal is the lational Standard Reference Data System (NSRDS). The Jour- al is not intended as a publication outlet for original experimen- al measurements such as are normally reported in the primary esearch literature, nor for review articles of a descriptive or rimarily theoretical nature.

Volume 1, No. 1

aseous diffusion coefficients, T. R. Marrero and E. A. Mason, *J. Phys. Chem. Ref. Data* **1,** No. 1, 3-118 (1972).

Key words: binary gas mixtures; critically evaluated data; diffusion; diffusion coefficients; gases; transport properties.

Diffusion coefficients of binary mixtures of dilute gases are omprehensively compiled, critically evaluated, and correlated y new semi-empirical expressions. There are seventy-four ystems for which the data are sufficiently extensive, consistent nd accurate to allow diffusion coefficients to be recommended ith confidence. Deviation plots are given for most of these ystems. Almost every gaseous diffusion coefficient which was xperimentally determined and reported prior to 1970 can be ob- ained from the annotated bibliography and table of gas pairs.

A detailed analysis of experimental methods is given, and in- ercomparison of their results helps establish reliability limits for ne data, which depend strongly on temperature. Direct mea- urements are supplemented by calculations based on knowledge f intermolecular forces derived from independent ources – molecular beam scattering for high temperatures, and ondon dispersion constants for low temperatures. In addition, iffusion coefficients for several mixtures are obtained from ex- erimental data on mixture viscosities and thermal diffusion fac- ors. Combination of all these results gives diffusion coefficients ver a very extensive temperature range, from very low tempera- ures to 10 000 K.

All data are corrected for composition dependence and for uantum effects. New semi-empirical equations are derived for aking such corrections easily.

elected values of critical supersaturation for nucleation of liquids from the vapor, G. M. Pound, *J. Phys. Chem. Ref. Data* **1,** No. 1, 119-133 (1972).

Key words: critical supersaturation; data evaluation; homogeneous nucleation; phase change.

Selected values of critical supersaturation for homogeneous ucleation of droplets from the vapor and for heterogeneous ucleation of droplets on the natural stationary concentration of aseous ions are tabulated and plotted, and a rationale is given r selection of these data.

elected values of evaporation and condensation coefficients for simple substances, G. M. Pound, *J. Phys. Chem. Ref. Data* **1,** No. 1, 135-146 (1972).

Key words: condensation coefficients; data evaluation; evaporation coefficients; phase change.

Tables of selected data on the coefficients of evaporation and condensation far from equilibrium for simple substances are presented, together with a rationale for the exclusion or choice of data and an estimate of the precision measure.

Atlas of the observed absorption spectrum of carbon monoxide between 1060 and 1900 Å, S. G. Tilford and J. D. Simmons, *J. Phys. Chem. Ref. Data* **1,** No. 1, 147-188 (1972).

Key words: absorption spectra; carbon monoxide; electronic transitions; identification atlas; potential energy curves; rotational and vibrational constants.

This atlas summarizes the results of a recent investigation of the carbon monoxide absorption spectrum between 1060 and 1900 Å. Twelve electronic transitions are observed in this region; four electric dipole allowed electric transitions from the ground state X $^1\Sigma^+$ to the A $^1\Pi$, B $^1\Sigma^+$, C $^1\Sigma^+$, and E $^1\Pi$ states, and eight forbidden transitions to the a' $^3\Sigma^+$, e $^3\Sigma^-$, a $^3\Pi$, D $^1\Delta$, d $^3\Delta_i$, I $^1\Sigma^-$, j $^3\Sigma^+$, and c $^3\Pi$ states. The following items are presented in the atlas: (1) A photograph of the spectrum with band assignments; (2) a table of band head measurements and assignments arranged by wavelength; (3) a summary of the spectroscopic constants and potential curve for each electronic state; (4) a line list, arranged by wavelength, of the observed rotational lines of the allowed transitions.

Tables of molecular vibrational frequencies. Part 5, T. Shimanouchi, *J. Phys. Chem. Ref. Data* **1,** No. 1, 189-216 (1972).

Key words: fundamental frequencies; infrared spectra; polyatomic molecules; Raman spectra; vibrational frequencies.

The compilations of fundamental vibrational frequencies of molecules previously published as NSRDS-NBS-6, NRSD-NBS-11, NSRDS-NBS-17, and NSRDS-NBS-39, are extended to 58 additional molecules. Selected values of the fundamental vibrational frequencies are given for each molecule, together with observed infrared and Raman spectral data and citations to the original literature. The selection of vibrational fundamentals has been based on careful studies of the spectral data and comprehensive normal-coordinate analyses. An estimate of the accuracy of the selected values is included. The tables provide a convenient source of information for those who require vibrational energy levels and related properties in molecular spectroscopy, thermodynamics, analytical chemistry, and other fields of physics and chemistry.

Volume 1, No. 2

Selected values of heats of combustion and heats of formation of organic compounds containing the elements C, H, N, O, P, and S, E. S. Domalski, *J. Phys. Chem. Ref. Data* **1,** No. 2, 221-277 (1972).

Key words: CHNOPS compounds; heat of combustion; heat of formation; selected values.

Selected values of the heats of combustion and heats of forma-

tion of 719 organic compounds are reported here. The data tabulated pertain to compounds containing the elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur (CHNOPS). The information is arranged according to classes of compounds and within each class, compounds are arranged by empirical formula. The general classes covered are: hydrocarbons, alcohols, phenols, polyols, ethers, aldehydes, ketones, acids, acid anhydrides, esters, steroids, lactones, carbohydrates, heterocyclic oxygen compounds, amines, amides, urea derivatives, guanidine derivatives, amino acids, peptides, alkaloids, heterocyclic nitrogen compounds, porphyrins, organic sulfur compounds, and organic phosphorus compounds. When a selection was made from among several investigators, commentary is provided to indicate the choice, and usually some relevant data. The number of references cited is 596. An alphabetical compound index is provided which gives the name, page number, empirical formula, and the Wiswesser Line Notation (WLN), for each compound.

Thermal conductivity of the elements, C. Y. Ho, R. W. Powell, and P. E. Liley, *J. Phys. Chem. Ref. Data* **1**, No. 2, 279-421 (1972).

Key words: conductivity; critically evaluated data; data compilation; elements; reference data; thermal conductivity; transport properties.

This is the abridged version of a comprehensive volume on the thermal conductivity of the elements. It contains recommended reference values resulting from critical evaluation, analysis, and synthesis of all the available data. It also gives estimated values for those elements for which no thermal conductivity data are available. Thus, the work provides recommended or estimated thermal conductivity values for all the elements over the full temperature ranges where experimental data are available or reliable extrapolations or estimations can be made. The results on each element are presented in both graphical and tabular forms. Summary graphs arranged by group in the periodic table are also given.

The spectrum of molecular oxygen, P. H. Krupenie, *J. Phys. Chem. Ref. Data* **1**, No. 2, 423-534 (1972).

Key words: critical review; electronic spectrum; molecular oxygen; potential energy curves; rotational spectrum; spectroscopic constants.

This is a critical review and compilation of the observed and predicted spectroscopic data on O_2 and its ions O_2^-, O_2^+, and O_2^{2+}. The ultraviolet, visible, infrared, Raman, microwave, and electron paramagnetic resonance spectra are included. Each electronic band system is discussed in detail, and tables of band origins and heads are given. The microwave and EPR data are also tabulated. Special subjects such as the dissociation energy of O_2, perturbations, and predissociations are discussed. Potential energy curves are given, as well as *f*-values, Franck-Condon integrals, and other intensity factors. A summary table lists the molecular constants for all known electronic states of O_2 and O_2^+. Electronic structure and theoretical calculations are also discussed.

A critical review of the gas-phase reaction kinetics of the hydroxyl radical, W. E. Wilson, Jr., *J. Phys. Chem. Ref. Data* **1**, No. 2, 535-573 (1972).

Key words: activation energy; chemical kinetics; combustion; rate constant; review.

The literature pertinent to reactions of the hydroxyl radical has been reviewed. An extensive discussion is given for reactions of the hydroxyl radical with itself and with CO, H_2, and CH_4. These four reactions are: (1) $OH + OH \rightarrow H_2O + O$; (2) $CO + OH \rightarrow CO_2 + H$; (3) $H_2 + OH \rightarrow H_2O + H$; (4) $CH_4 + OH \rightarrow CH_3 + H_2O$.

Values are recommended for k_1 and k_2 and for the ratio k_3/k_2 and k_4/k_2. These rate ratios are used with the previously established value of k_2 to obtain recommended values for k_3 and k_4.

The recommended values in $cm^3\ mol^{-1} \cdot s^{-1}$, the temperature range, and the uncertainty are:

$$k_1 = 1.55 \times 10^{12}, 300\ \text{K}, \log k \pm .5^1$$

$$k_2 = 3.1 \times 10^{11} \exp(-300/T), 300\text{-}2000\ \text{K}, \log k \pm .3$$

$$k_3/k_2 = 73 \exp(2300/T), 300\text{-}2000\ \text{K}, \log k_3/k_2 \pm .3$$

$$k_3 = 3.8 \times 10^{13} \exp(-2600/T), 300\text{-}2000\ \text{K}, \log k \pm .3$$

$$k_4/k_2 = 92 \exp(2200/T), 300\text{-}2000\ \text{K}, \log k_3/k_2 \pm .3$$

$$k_4 = 2.85 \times 10^{13} \exp(-2500/T), 300\text{-}2000\ \text{K}, \log k \pm .7.$$

Rate expressions are also recommended for a number of other hydroxyl reactions whose rates are less well established.

Volume 1, No. 3

Molten salts: Volume 3, nitrates, nitrites, and mixtures. Electrical conductance, density, viscosity, and surface tension data, G. J. Janz, U. Krebs, H. F. Siegenthaler, and R. P. T. Tomkins, *J. Phys. Chem. Ref. Data* **1**, No. 3, 581-746 (1972).

Key words: data compilation; density; electrical conductance; molten salt mixtures; nitrates; nitrites; standard reference data; surface tension; viscosity.

Data on the electrical conductance, density, viscosity, and surface tension of nitrate-nitrate, nitrite-nitrite, and nitrite-nitrate mixtures have been systematically collected and evaluated. Results are given for some 71 binary mixtures over a range of compositions and temperatures. Values of the above properties for the single salts have been updated in accord with previously advanced recommendations.

High temperature properties and decomposition of inorganic salts. Part 3. Nitrates and nitrites, K. H. Stern, *J. Phys. Chem. Ref. Data* **1**, No. 3, 747-772 (1972).

Key words: nitrates; nitrites; thermal decomposition; thermodynamic functions.

The literature dealing with the high-temperature behavior of inorganic nitrates and nitrites has been critically reviewed. Values of $(G_T^\circ - H_{298}^\circ)/T$ of the reactants and products of the decomposition reactions were calculated and have been tabulated from 298 K up to as high a temperature as possible. Equilibrium constants and partial pressures were tabulated. Auxiliary data on phase transitions and densities have also been included. Qualitative information about the thermal decomposition of the salts is reviewed.

High-pressure calibration. A critical review, D. L. Decker, W. A. Bassett, L. Merrill, H. T. Hall, and J. D. Barnett, *J. Phys. Chem. Ref. Data* **1**, No. 3, 773-836 (1972).

Key words: calibration of pressure scales; critically evaluated data; high pressure; high pressure phase changes; pressure measurement.

A critical review of experimental technique for measuring high pressures has been made. The broad coverage includes discussions relating to (a) the establishment of a primary pressure scale using the free-piston gage, (b) the selection and precise measurement of identifiable phase changes as fixed pressure points, and (c) the use of interpolation and extrapolation techniques such as resistance gages, equations of state, and optical changes. The emphasis is on static pressure measurements above 10 kbar, but shock measurements are also considered for completeness. The pressure values to be associated with the fixed points have been analyzed in detail. Temperature measurement in the high pres

ure environment is also reviewed. The accuracy with which ressures can be measured has been carefully considered; the aximum accuracies now obtainable are considered to be of the rder of 0.02 percent at 8 kbar, 0.25 percent at 25 kbar, 2 percent 50 kbar, and 4 percent at 100 kbar.

Volume 1, No. 4

he surface tension of pure liquid compounds, J. J. Jasper, *J. Phys. Chem. Ref. Data* **1**, No. 4, 841-1010 (1972).

Key words: evaluated data; liquids; surface tension; thermodynamics of liquids.

The surface tension tables presented herein are the result of a erature survey, evaluation, and compilation of data of some 200 pure liquid compounds, 226 of which were reported for a ngle temperature. These are arranged with related compounds the increasing order of their molecular weights. As far as ssible the method of measurement, nature of atmosphere to hich the liquid was exposed during measurements, and the esti- ated accuracy are given for each liquid. The tabulated values ere calculated from the derived results of directly measured uantities reported in the literature of many countries from about 374 to 1969. Preliminary plots of the experimentally measured uantities indicated that the surface tensions of the liquid com- ounds are linear functions of the temperature over the reported erational range. The principle of least squares was applied to perimental surface tension values to establish the regression urves and their equations. The constants of the equations (slope nd intercept), together with the standard deviations are given r each compound. The selection factors establishing criteria of uality of surface tension data are discussed. These include (a) ethod of measurement, (b) purity of compound, (c) quality of pparatus and assembly, (d) experimental procedure (experimen- tion), (e) reliability of measurements (most probable values), (f) perience of investigator, and (g) availability of data. There are 74 references listed alphabetically.

icrowave spectra of molecules of astrophysical interest. I. Formaldehyde, formamide, and thioformaldehyde, D. R. Johnson, F. J. Lovas, and W. H. Kirchhoff, *J. Phys. Chem. Ref. Data* **1**, No. 4, 1011-1046 (1972).

Key words: formaldehyde; formamide; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; thioformaldehyde.

The available data on the microwave spectra of formaldehyde, rmamide, and thioformaldehyde are critically reviewed for in- rmation applicable to radio astronomy. Molecular data such as tational constants, centrifugal distortion parameters, dipole oments, hyperfine coupling constants, and structural parame- rs are tabulated. Observed rotational transitions are presented r the astronomically interesting isotopic forms of these olecules when available. Detailed centrifugal distortion calcu- tions have been carried out for the most abundant isotopic forms of these molecules, namely, $H_2{}^{12}C^{16}O$, $H_2{}^{13}C^{16}O$, $^{14}NH_2{}^{12}CH^{16}O$, and $H_2{}^{12}C^{32}S$. Transitions have been predicted and tabulated for the frequency ranges

1 MHz to 300 GHz for $H_2{}^{12}C^{16}O$,

100 MHz to 300 GHz for $H_2{}^{13}C^{16}O$,

500 MHz to 180 GHz for $^{14}NH_2{}^{12}CH^{16}O$,

and

100 MHz to 300 GHz for $H_2{}^{12}C^{32}S$.

All predicted transitions include 95 percent confidence limits; measured transition error limits have been reproduced from the original literature. References are given for all data included.

Osmotic coefficients and mean activity coefficients of uni-univalent electrolytes in water at 25 °C, W. J. Hamer and Y.-C. Wu, *J. Phys. Chem. Ref. Data* **1**, No. 4, 1047-1100 (1972).

Key words: activity coefficients; critically evaluated data; excess Gibbs energy for electrolytes; osmotic coefficients.

This paper gives values for the osmotic coefficients and mean activity coefficients of uni-univalent electrolytes in aqueous solutions at 25 °C. The values are expressed on the molality or weight basis. The data available in the literature have been corrected to the presently accepted scales of atomic weights (1969) and temperature (IPST 1968) and, where necessary, to the absolute electrical units of 1969 and the fundamental constants of 1963. The selected values of osmotic coefficients and mean activity coefficients for individual electrolytes have been made internally consistent thermodynamically. In some cases estimated values are given; in other cases, references only are given when the data are sparse or unsuited to critical evaluation. Values of the osmotic coefficients and mean activity coefficients of 79 compounds are given together with the standard deviation, variance, and normalized standard deviation of their fit to equations which express these quantities as functions of electrolyte concentration. Finally, literature references are given to data on 51 additional uni-univalent electrolytes.

The viscosity and thermal conductivity coefficients of gaseous and liquid fluorine, H. J. M. Hanley and R. Prydz, *J. Phys. Chem. Ref. Data* **1**, No. 4, 1101-1114 (1972).

Key words: critically evaluated data; fluorine; kinetic theory; modified Enskog theory; thermal conductivity; viscosity.

Tables of values for the viscosity and thermal conductivity of fluorine are presented in the range 70-300 K for pressures up to 200 atmospheres. Experimental results were reviewed but were judged to be unreliable. Accordingly, dilute gas values were determined from kinetic theory using the m-6-8 potential, and dense gas and liquid values were obtained from the modified Enskog theory. The critical point anomaly in the thermal conductivity coefficient is also discussed.

PAPERS FROM THE JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA, VOLUME 2, JANUARY-DECEMBER 1973

Volume 2, No. 1

Microwave spectra of molecules of astrophysical interest. II. Methylenimine, W. H. Kirchhoff, D. R. Johnson, and F. J. Lovas, *J. Phys. Chem. Ref. Data* 2, No. 1, 1-10 (1973).

Key words: hyperfine structure; interstellar molecules; methylenimine; microwave spectra; molecular parameters; radio astronomy; rotational transitions.

The available data on the microwave spectrum of methylenimine are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion parameters, hyperfine coupling constants, and dipole moments are tabulated. A detailed centrifugal distortion calculation has been carried out for the most abundant isotopic form of this molecule, H_2 ^{12}C ^{14}NH. Transitions have been predicted and tabulated for the frequency range 100 MHz to 300 GHz. All predicted transitions include 95 percent confidence limits; error limits have been reported for all measured transitions.

Analysis of specific heat data in the critical region of magnetic solids, F. J. Cook, *J. Phys. Chem. Ref. Data* 2, No. 1, 11-24 (1973).

Key words: critical exponents; critical phenomena; data analysis; magnetic solids; nonlinear least-squares; phase transitions; specific heat; static scaling.

A detailed analysis of specific heat data in the critical region of magnetic solids is presented. An inverse power law, whose strength is measured by the exponent α, is used to describe the temperature dependence of the magnetic specific heat. Other parameters used include the power law coefficient A, the critical temperature T_c, and a constant background term B. Advanced techniques of data analysis suitable for estimation of nonlinear parameters and their errors under conditions of realistically weighted experimental data were used to obtain the dependence of α, T_c, A, and B on the range of data points included in the fit. Those exponents and parameters that provide the best overall fit to the data have been found. Literature references to 49 experiments from 1935 to 1971 are given. We present in tabular form the values of α, A, and B for 24 different magnetic crystals. With some exceptions, the best fits to the data suggest that in the temperature range studied the magnetic specific heat is not symmetric; the exponent α depends on the range of data included in the fit, varies widely from material to material, and in many cases is definitely negative below the critical temperature; and that there is little evidence that the asymptotic region is being adequately sampled by experiment. These results have the implication that until such time as we can adequately account for departures from the expected sharp peak in the data at T_c (data rounding) and corrections to asymptotic scaling, then comparisons between magnetic specific heat experiments and lowest order scaling predictions are to this date still tenuous.

Evaluated chemical kinetic rate constants for various gas phase reactions, K. Schofield, *J. Phys. Chem. Ref. Data* 2, No. 1, 25-84 (1973).

Key words: activation energies; evaluation; gaseous reactions; radical reactions; rate constants; review; sulfur chemistry; tables.

The available information, up to mid-1972, for the rate constants of a series of gas phase chemical reactions has been evaluated critically. For each reaction, relevant thermodynamic data are presented and values for the equilibrium constant expressed in mathematical form. Kinetic data are presented in tabular and graphical form together with a discussion of the pertinent details. Recommended rate constant values are presented wherever possible with suggested error limits. The reactions considered involve the species H, O, C, N, S, OH, HS, S_2, CS, SO, HSO_2, NH_2, NH_3, NO, N_2O, NO_2, N_2O_4, N_2, O_2, O_3, H_2, H_2O, SO_2, SO_3, CS_2, OCS, H_2S, and CO. Particular emphasis is given to reactions involving sulfur chemistry. The best available data for these reactions have been summarized in a table at the end of the paper. An appendix discussing the available evaluations and review articles published since 1960 also has been included to publicize these sources of either evaluated data or of extensive reference bibliographies.

Atomic transition probabilities for forbidden lines of the iron group elements. (A critical data compilation for selected lines) M. W. Smith and W. L. Wiese, *J. Phys. Chem. Ref. Data* 2, No. 1, 85-120 (1973).

Key words: chromium; cobalt; forbidden transitions; iron; manganese; nickel; transition probabilities; vanadium.

Atomic transition probabilities for about 750 forbidden spectral lines for elements of the iron group, specifically V, Cr, Mn, Fe, Co, and Ni, have been critically evaluated and compiled using all available literature sources. The selection of the spectra and elements has been made primarily according to their astrophysical importance. The data are presented in separate tables for each element and stage of ionization, and for each ion the data are arranged according to multiplets. For each line within a multiplet the transition probability for spontaneous emission is listed along with the standard spectroscopic designation, the wavelength, the statistical weights, and the energy levels of the upper and lower states. In addition, the estimated accuracy and the source are indicated. In short introductions which precede the individual tables for the ions the main justifications for the choice of the adopted data and for the accuracy rating are discussed. A general introduction contains a detailed discussion of the critical factors entering into the calculations. It also includes detailed comparisons of calculated data with astrophysical observations and a few laboratory results, which serve as a valuable indication for the validity of the estimated accuracies.

Tables of molecular vibrational frequencies. Part 6, T. Shimanouchi, *J. Phys. Chem. Ref. Data* 2, No. 1, 121-161 (1973).

Key words: fundamental frequencies; infrared spectra; polyatomic molecules; Raman spectra; vibrational frequencies.

The compilations of fundamental vibrational frequencies of molecules previously published in the NSRDS-NBS publication series and in this journal are here extended to 55 additional molecules. Selected values of the fundamental vibrational frequencies are given for each molecule, together with observed infrared and Raman spectral data and citations to the original literature. The selection of vibrational fundamentals has been based on careful studies of the spectral data and comprehensive normal-coordinate analyses. An estimate of the accuracy of the selected values is included. The tables provide a convenient source of information for those who require vibrational energy levels and related properties in molecular spectroscopy, ther

nodynamics, analytical chemistry, and other fields of physics nd chemistry.

ompilation of energy band gaps in elemental and binary compound semiconductors and insulators, W. H. Strehlow and E. L. Cook, *J. Phys. Chem. Ref. Data* **2**, No. 1, 163-199 (1973).

Key words: band gaps; binary compounds; electronic properties; insulators; semiconductors.

Energy band gaps are tabulated for elemental and binary compound semiconductors and insulators reported in 723 references. he method of measurement, transition, type of sample, and ther pertinent information are included for each entry. The eterminations believed to be the most reliable are indicated.

Volume 2, No. 2

licrowave spectra of molecules of astrophysical interest. III. Methanol, R. M. Lees, F. J. Lovas, W. H. Kirchhoff, and D. R. Johnson, *J. Phys. Chem. Ref. Data* **2**, No. 2, 205-214 (1973).

Key words: internal rotation; interstellar molecules; methanol; microwave spectra; molecular parameters; radio astronomy; rotational transitions; torsion.

The available data on the microwave spectrum of methanol are itically reviewed for information applicable to radio astrono- ay. Molecular data such as moments and product of inertia, tor- ional potential constants, centrifugal distortion and torsion-rota- ion interaction constants, dipole moment, and structural arameters are tabulated. Observed rotational transitions are resented for the astronomically interesting isotopic forms of ethanol when available. Detailed centrifugal distortion and tor- ion-rotation interaction calculations have been carried out for he most abundant isotopic form of methanol. Transitions are abulated for the frequency range from 500 MHz to 200 GHz. leasured transition error limits have been reproduced from the riginal literature. References are given for all data included.

licrowave spectra of molecules of astrophysical interest. IV. Hydrogen sulfide, P. Helminger, F. C. De Lucia, and W. H. Kirchhoff, *J. Phys. Chem. Ref. Data* **2**, No. 2, 215-223 (1973).

Key words: hydrogen sulfide; hyperfine structure; interstellar molecules; microwave spectra; molecular parameters; radio astonomy; rotational transitions.

The available data on the microwave spectrum of hydrogen ulfide are critically reviewed for information applicable to radio stronomy. Molecular data such as rotational constants, cen- ifugal distortion constants, hyperfine coupling parameters, and pole moments are tabulated. A detailed centrifugal distortion alculation has been carried out for the most abundant isotopic rm of this molecule, $H_2{}^{32}S$, as well as for $HD^{32}S$. Transitions ave been predicted and tabulated for the frequency range 1 Hz to 1000 GHz for $H_2{}^{32}S$ and 1 MHz to 700 GHz for $HD^{32}S$. ll predicted transitions include 95 percent confidence limits; stimated error limits have been reported for all measured transi- ons. Observed transitions of $H_2{}^{32}S$ and $H_2{}^{34}S$ are also listed.

ables of molecular vibrational frequencies. Part 7, T. Shimanouchi, *J. Phys. Chem. Ref. Data* **2**, No. 2, 225-256 (1973).

Key words: fundamental frequencies; infrared spectra; polyatomic molecules; Raman spectra; vibrational frequencies.

The compilations of fundamental vibrational frequencies of olecules previously published in the NSRDS-NBS publication ries and in this journal are here extended to 50 additional olecules. Selected values of the fundamental vibrational equencies are given for each molecule, together with observed frared and Raman spectral data and citations to the original literature. The selection of vibrational fundamentals has been based on careful studies of the spectral data and comprehensive normal-coordinate analyses. An estimate of the accuracy of the selected values is included. The tables provide a convenient source of information for those who require vibrational energy levels and related properties in molecular spectroscopy, thermodynamics, analytical chemistry, and other fields of physics and chemistry.

Energy levels of neutral helium (^{4}He I), W. C. Martin, *J. Phys. Chem. Ref. Data* **2**, No. 2, 257-265 (1973).

Key words: atomic energy levels; atomic spectra; autoionization; electron scattering; fine structure; helium; photoionization resonances; photon absorption.

This compilation of all identified levels is based on the most accurate available observations. It includes 48 levels above the He II 1^2S limit (two-electron excitation).

Survey of photochemical and rate data for twenty-eight reactions of interest in atmospheric chemistry, R. F. Hampson, Ed., W. Braun, R. L. Brown, D. Garvin, J. T. Herron, R. E. Huie, M. J. Kurylo, A. H. Laufer, J. D. McKinley, H. Okabe, M. D. Scheer, W. Tsang, and D. H. Stedman, *J. Phys. Chem. Ref. Data* **2**, No. 2, 267-311 (1973).

Key words: atmospheric chemistry; chemical kinetics; data evaluation; gas phase reactions; optical absorption coefficients; photochemistry; quantum yields; rate constants.

Photochemical and rate data have been evaluated for 28 gas phase reactions of interest for the chemistry of the stratosphere. The results are presented on data sheets, one per reaction. For each reaction, the available data are summarized. Where possible there is given a preferred value for the rate constant or, for the photochemical reactions, preferred values for primary quantum yields and optical absorption coefficients.

Compilation of the static dielectric constant of inorganic solids, K. F. Young and H. P. R. Frederikse, *J. Phys. Chem. Ref. Data* **2**, No. 2, 313-409 (1973).

Key words: dielectric constant; dielectric loss; permittivity; static dielectric constant.

This compilation contains values of the static dielectric constant of more than 300 inorganic solids. The temperature and frequency of the measurements are listed and the magnitude of the loss tangent is indicated if known. For ninety materials – including most ferroelectrics and antiferroelectrics and several oxides and halides – additional information is presented in the form of graphs depicting the temperature dependence of the dielectric constant. In a few cases the frequency and pressure dependences are also shown. The basic principles and formulas pertinent to the field of dielectrics are reviewed in a short introduction. This part also mentions several measuring techniques and indicates the criteria used for data selection.

Soft x-ray emission spectra of metallic solids: Critical review of selected systems, A. J. McAlister, R. C. Dobbyn, J. R. Cuthill, and M. L. Williams, *J. Phys. Chem. Ref. Data* **2**, No. 2, 411-426 (1973).

Key words: alloys; critical review; emission spectra; intermetallic compounds; metals; soft x-ray; spectra.

Theory and experimental practice in the field of soft x-ray emission from metallic solids are briefly reviewed, and measurements on a number of systems (Al, Al in $AuAl_2$, Al and Mg in Al-Mg, Cu, Cu and Ni in Cu-Ni, Li, Mg, Na, and Ni) are critically evaluated and compared with the results of other techniques and theory, with a view to establishing the pertinence of the soft x-ray measurements and indicating specific guidelines for enhancing their value.

Ideal gas thermodynamic properties of ethane and propane, J. Chao, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **2,** No. 2, 427-437 (1973).

Key words: critically evaluated data; enthalpy; enthalpy function; enthalpy of formation; entropy; equilibrium constant of formation; ethane; Gibbs energy function; Gibbs energy of formation; heat capacity; ideal gas thermodynamic properties; internal rotation barrier height; internal rotation energy levels; propane; torsional frequencies.

The thermodynamic properties ($C_p°$, $S°$, $H°-H_0°$, $(H°-H_0°)/T$, $-(G°-H_0°)/T$, $\Delta Hf°$, $\Delta Gf°$ and log Kf) for ethane and propane in the ideal gaseous state in the temperature range from 0 to 1500 K and at 1 atm were calculated by statistical thermodynamic methods based on a rigid-rotor harmonic-oscillator model. The internal rotation contributions to thermodynamic functions were evaluated by using a partition function formed by summation of internal rotation energy levels. The calculated heat capacities and entropies compare favorably with available experimental data.

Volume 2, No. 3

An analysis of coexistence curve data for several binary liquid mixtures near their critical points, A. Stein and G. F. Allen, *J. Phys. Chem. Ref. Data* **2,** No. 3, 443-466 (1973).

Key words: binary liquid mixtures; coexistence curve; consolute point; critically evaluated data; critical point; critical point exponent; diameter; power law; statistical analysis.

Experimental data on the coexistence curves for nine binary liquid systems, which meet strict criteria of precision, purity of components, and experimental method, are analyzed in the neighborhood of the critical point. The data are examined in terms of a general equation of state which is nonanalytic at the critical point. The results of the computer analysis using weighted non-linear least squares procedures present evidence that some symmetry features of classical equations of state remain; and within the experimental errors in the data all systems are consistent with the critical exponent $\beta = 0.34$. The asymptotic behavior of the diameter is examined and evidence is provided for a curved diameter in some cases; however, it is concluded that the available data are not extensive enough to make a firm conclusion concerning the shape of the diameter. Experimental methods are briefly criticized and mention is made of the experimental direction that future work should take. Special attention is given to estimating the reliability of the conclusions that may be drawn from a given set of data.

Rate constants for the reactions of atomic oxygen (O ^3P) with organic compounds in the gas phase, J. T. Herron and R. E. Huie, *J. Phys. Chem. Ref. Data* **2,** No. 3, 467-518 (1973).

Key words: atomic oxygen; chemical kinetics; compilation; critical evaluation; gases; organic compounds; rate constants.

Rate constants for the reactions of atomic oxygen (O ^3P) with organic compounds in the gas phase are compiled and critically evaluated. Data are given here as originally reported in the literature for a total of 107 organic reactants. From a critical evaluation of the data, recommended values for rate constants are given over specified temperature intervals, and where possible at 298 K and 1000 K. Estimated error limits are assigned to all recommended values.

First spectra of neon, argon, and xenon 136 in the 1.2-4.0 μm region, C. J. Humphreys, *J. Phys. Chem. Ref. Data* **2,** No. 3, 519-530 (1973).

Key words: argon; extraphotographic region; infrared emission spectra; intensities; neon; wavelengths; wavelength standards; wave numbers; xenon.

Descriptions of the first spectra of neon, argon, and xenon 136, comprising calculated wavelengths, calculated wave numbers, relative intensities, and classifications, are presented. The calculated values are derived from currently best established energy levels, obtained mostly from interferometric observations and adopted as standards by the International Astronomical Union. All listed lines have actually been observed. This paper makes available a compilation of all results previously presented in fragmentary or relatively inaccessible reports with intensities normalized to as nearly a uniform scale as the various observations permit.

Elastic properties of metals and alloys. I. Iron, nickel, and iron-nickel alloys, H. M. Ledbetter and R. P. Reed, *J. Phys. Chem. Ref. Data* **2,** No. 3, 531-618 (1973).

Key words: bulk modulus; compressibility; elastic constant; Debye temperatures; iron; iron alloys; Lamé constants; nickel; nickel alloys; Poisson's ratio; shear modulus; single-crystal elastic coefficients; Young's modulus.

A comprehensive compilation is given of elastic properties of iron-nickel alloys. When sufficient data exist, preferred values are recommended. This compilation covers, besides pure iron and pure nickel, the entire binary composition range, both b.c.c. and f.c.c. phases. Elastic constants included are: Young's modulus, shear modulus, bulk modulus (reciprocal compressibility), Poisson's ratio, and single-crystal elastic stiffnesses, both second-order and higher-order. Data are compiled for variation of elastic constants with composition, temperature, pressure, magnetic field, mechanical deformation, annealing, and crystallographic transitions. An overview is given from the vantage points of the electron theory of metals, elasticity theory, and crystallographic theory. Also included are discussions of isothermal and adiabatic elastic constants, interrelationships among engineering elastic constants, computation of the latter from single-crystal elastic stiffnesses, and similar topics. Where key data have not been measured, they were generated if possible from existing data using standard formulae. Other gaps, both theoretical and experimental, in the elastic properties of iron-nickel alloys are indicated. A few theoretical results are included where experimental data are nonexistent or scarce. A semantic scheme is proposed for distinguishing elastic constants of solids.

The viscosity and thermal conductivity coefficients of dilute argon, krypton, and xenon, H. J. M. Hanley, *J. Phys. Chem. Ref. Data* **2,** No. 3, 619-642 (1973).

Key words: dilute gas; kinetic theory; m-6-8 potential function; rare gases; thermal conductivity coefficient; viscosity coefficient.

The viscosity and thermal conductivity coefficients of dilute argon, krypton, and xenon are reviewed and tables of recommended values presented. The tables were generated using the appropriate kinetic theory expressions with the m-6-8 potential. The temperature range covers from about one-half critical temperature to 2000 K for each gas. A general estimate of the accuracy is one percent increasing to one and three-quarters percent for temperatures above 1000 K.

Diffusion in copper and copper alloys. Part I. Volume and surface self-diffusion in copper, D. B. Butrymowicz, J. R. Manning and M. E. Read, *J. Phys. Chem. Ref. Data* **2,** No. 3, 643-65(1973).

Key words: copper; diffusion; electromigration; liquid copper diffusion; nuclear magnetic resonance and diffusion; pressure effects on diffusion; self-diffusion; sintering; surface diffusion; thermo-migration.

A survey, comparison, and critical analysis is presented of data compiled from the scientific literature concerning copper self-diffusion. Topics include volume diffusion, dislocation pipe diffusion, surface diffusion, sintering, electromigration, the

momigration, pressure effect on diffusion, strain-enhanced diffusion, nuclear magnetic resonance measurements of solid state diffusion and diffusion in molten copper. An extensive bibliography is presented along with figures, tabular presentation of data, and discussion of results.

Volume 2, No. 4

The 1973 least-squares adjustment of the fundamental constants, E. R. Cohen and B. N. Taylor, *J. Phys. Chem. Ref. Data* **2**, No. 4, 663-734 (1973).

Key words: data analysis; fundamental constants; least-squares adjustments; quantum electrodynamics.

This paper is a summary of the 1973 least-squares adjustment of the fundamental physical constants carried out by the authors under the auspices of the CODATA Task Group on Fundamental Constants. The salient features of both the input data used and its detailed analysis by least-squares are given. Also included is the resulting set of best values of the constants which is to be recommended for international adoption by CODATA, a comparison of several of these values with those resulting from recent past adjustments, and a discussion of current problem areas in the fundamental constants field requiring additional research.

The viscosity and thermal conductivity coefficients of dilute nitrogen and oxygen, H. J. M. Hanley and J. F. Ely, *J. Phys. Chem. Ref. Data* **2**, No. 4, 735-756 (1973).

Key words: critically evaluated data; dilute polyatomic gas; kinetic theory of polyatomic molecules; *m*-6-8 potential; nitrogen; nonspherical interactions; oxygen; second virial coefficient; thermal conductivity coefficient; thermal diffusion factor; viscosity coefficient.

The viscosity and thermal conductivity coefficients of dilute oxygen and nitrogen are discussed and tables of values are presented for temperatures between 80 and 2000 K. The oxygen viscosity tables are estimated to be accurate to two percent for temperatures up to 400 K and four percent above that temperature; the nitrogen viscosity tables are estimated to be reliable to one percent in the range 100-1000 K, increasing to two percent above 1000 K and below 100 K. The error assigned to the thermal conductivity is three percent below 400 K and five percent above 400 K for both gases. The tables were calculated from the appropriate kinetic theory equations using the *m*-6-8 model potential with nonspherical contributions. The approximations to the equations are discussed. It is emphasized that the available data for oxygen viscosity are generally poor and that the thermal conductivity data for both oxygen and nitrogen cannot be considered reliable at high temperatures. No oxygen data exist for temperatures above 1500 K.

Thermodynamic properties of nitrogen including liquid and vapor phases from 63 K to 2000 K with pressures to 10,000 bar, R. T. Jacobsen and R. B. Stewart, *J. Phys. Chem. Ref. Data* **2**, No. 4, 757-922 (1973).

Key words: critically evaluated data; critical point; density; enthalpy; entropy; equation of state; heat capacity; ideal gas properties; latent heat; nitrogen; second virial coefficient; vapor pressure; velocity of sound.

Tables of thermodynamic properties of nitrogen are presented for the liquid and vapor phases for temperatures from the freezing line to 2000 K and pressures to 10,000 bar. The tables include values of density, internal energy, enthalpy, entropy, isochoric heat capacity (C_v), isobaric heat capacity (C_p), velocity of sound, the isotherm derivative $(\partial P/\partial \rho)_T$, and the isochor derivative $(\partial P/\partial T)_\rho$. The thermodynamic property tables are based on an equation of state, $P = P(\rho, T)$, which accurately represents liquid and gaseous nitrogen for the range of pressures and temperatures covered by the tables. Comparisons of property values calculated from the equation of state with measured values for P-ρ-T, heat capacity, enthalpy, latent heat, and velocity of sound are included to illustrate the agreement between the experimental data and the tables of properties presented here. The coefficients of the equation of state were determined by a weighted least squares fit to selected P-ρ-T data and, simultaneously, to C_v data determined by corresponding states analysis from oxygen data, and to data which define the phase equilibrium criteria for the saturated liquid and the saturated vapor. The vapor pressure equation, melting curve equation, and an equation to represent the ideal gas heat capacity are also presented. Estimates of the accuracy of the equation of state, the vapor pressure equation, and the ideal gas heat capacity equation are given. The equation of state, derivatives of the equation, and the integral functions for calculating derived thermodynamic properties are included.

Thermodynamic properties of helium 4 from 2 to 1500 K at pressures to 10^8 Pa, R. D. McCarty, *J. Phys. Chem. Ref. Data* **2**, No. 4, 923-1042 (1973).

Key words: critically evaluated data; critical point; enthalpy; entropy; equation of state; helium; internal energy; Joule-Thomson coefficient; lambda line; melting line; P-V-T; specific heat; speed of sound; vapor pressure; virial coefficient.

Tabular values of density, internal energy, enthalpy, entropy, heat capacity, and speed of sound for liquid and gaseous helium are presented for temperatures from 2 to 1500 kelvin at pressures from 1.0×10^4 to 1.0×10^8 pascals. Diagrams of temperature vs. entropy are also given. The properties presented are calculated from an equation of state which was fitted to experimental P-V-T and other thermodynamic data from the world's literature. The equation of state was fitted to these data in three separate regions of pressure and temperature. The regional equations are forced to join smoothly at the preconceived boundaries. Extensive comparisons between the equation of state and experimental data have been made, and deviation plots are presented. A particularly careful determination of the second virial coefficient over the full temperature range 2-1500 kelvin is presented. The Joule-Thomson inversion curve has been calculated and comparisons made with other sources. Equations for the density of the saturated liquid and vapor are included as well as an equation which represents the 1958 helium vapor pressure temperature scale.

PAPERS FROM THE JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA, VOLUME 3, JANUARY-DECEMBER 1974

Volume 3, No. 1

Molten salts: Volume 4. Part I. Fluorides and mixtures. Electrical conductance, density, viscosity, and surface tension data, G. J. Janz, G. L. Gardner, U. Krebs, and R. P. T. Tomkins, *J. Phys. Chem. Ref. Data* **3**, No. 1, 1-115 (1974).

Key words: data compilation; density; electrical conductance; fluorides; molten salt mixtures; standard reference data; surface tension; viscosity.

Data on the electrical conductance, density, viscosity, and surface tension of fluoride mixtures have been systematically collected and evaluated. Results are given for 44 binary mixtures over a range of compositions and temperatures. Values of the above properties for the single salts have been updated in accord with previously advanced recommendations.

Ideal gas thermodynamic properties of eight chloro- and fluoromethanes, A. S. Rodgers, J. Chao, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **3**, No. 1, 117-140 (1973).

Key words: chloromethane; critical evaluation of thermodynamic properties; fluoromethane; ideal gas thermodynamic properties.

The structural data, vibrational assignments, enthalpies of vaporization and formation for chloromethane, dichloromethane, trichloromethane, tetrachloromethane, fluoromethane, difluoromethane, trifluoromethane, and tetrafluoromethane were critically reviewed. Based on the selected best values, the thermodynamic properties for each of these eight chloro- and fluoromethanes were calculated by statistical thermodynamic methods using the rigid-rotor harmonic-oscillator approximations. The derived entropies and heat capacities are compared with the available third law entropies and vapor heat capacities. The calculated values of $C_p°$, $S°$, and $\Delta Hf°$ at 298.15 and 700 K are compared with those reported in the other major compilations.

Ideal gas thermodynamic properties of six chloroethanes, J. Chao, A. S. Rodgers, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **3**, No. 1, 141-162 (1973).

Key words: chloroethane with a symmetry top; ideal gas thermodynamic properties; internal rotation; internal rotation barrier heights; torsional fundamental.

The thermodynamic properties: $C_p°$, $S°$, $H° - H_0°$, $-(G° - H_0°)/T$, $\Delta Hf°$, $\Delta Gf°$, and log K_f for chloroethane, 1,1-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, pentachloroethane, and hexachloroethane in the ideal gaseous state in the temperature range from 0 to 1500 K and at 1 atm were evaluated by statistical thermodynamic methods based on a rigid-rotor harmonic-oscillator model. The internal rotation contributions to thermodynamic functions were calculated by using a partition function formed by summation of internal rotation energy levels. The internal rotation barrier heights (in kcal mol^{-1}) employed for generation of the energy levels for each of the above six chloroethanes are: 3.69, 3.54, 5.08, 10.38, 14.43, and 14.7, respectively. The calculated heat capacities and entropies are compared with available experimental data. The derived values of $C_p°$, $S°$, and $\Delta Hf°$ at 298.15 and 700 K are compared with those reported in the other major compilations.

Critical analysis of heat-capacity data and evaluation of thermodynamic properties of ruthenium, rhodium, palladium, iridium, and platinum from 0 to 300 K. A survey of the literature data on osmium, G. T. Furukawa, M. L. Reilly, and J. S. Gallagher, *J. Phys. Chem. Ref. Data* **3**, No. 1, 163-209 (1974).

Key words: calorimetry; critically evaluated data; Debye temperature (θ); electronic coefficient of heat capacity (γ); enthalpy; entropy; Gibbs energy; heat capacity; iridium; osmium, palladium; platinum; rhodium; ruthenium; thermodynamic properties.

The literature sources of heat-capacity data on ruthenium, rhodium, palladium, osmium, iridium, and platinum have been compiled and the data critically analyzed. Except for osmium where data are lacking, best values of themodynamic properties have been evaluated between 0 and 300 K from the analyses. The literature values of heat capacity, the electronic coefficient of heat capacity (γ), and the zero K limiting Debye characterstic temperature ($\theta_D(0)$) are compared. The sources of data are tabulated chronologically along with the temperature range of measurements, purity of sample, and the pertinent experimental procedures used. A bibliography of the references is listed.

Microwave spectra of molecules of astrophysical interest. V. Water vapor, F. C. De Lucia, P. Helminger, and W. H. Kirchhoff, *J. Phys. Chem. Ref. Data* **3**, No. 1, 211-219 (1974).

Key words: hyperfine structure; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; water.

The available data on the microwave spectrum of water vapor are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion constants, hyperfine coupling parameters, and dipole moments are tabulated. A detailed centrifugal distortion calculation has been carried out for the most abundant isotopic form of this molecule $H_2\,{}^{16}O$, as well as for $H_2\,{}^{18}O$ and HD ^{16}O. Transitions have been predicted and tabulated for the frequency range 1 MHz to 800 GHz. All predicted transitions include 95 percent confidence limits; estimated error limits have been reported for all measured transitions. Observed transitions of $H_2\,{}^{17}O$ are also listed.

Microwave spectra of molecules of astrophysical interest. VI. Carbonyl sulfide and hydrogen cyanide, A. G. Maki, *J. Phys. Chem. Ref. Data* **3**, No. 1, 221-244 (1974).

Key words: carbonyl sulfide; hydrogen cyanide; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; spectra.

All available data on the microwave spectra of carbonyl sulfide and hydrogen cyanide are critically reviewed and tabulated. Molecular data such as rotational constants, centrifugal distortion constants, dipole moments, hyperfine coupling constants, and structural parameters are also tabulated. All rotational transitions from 100 MHz to 300 GHz that are deemed likely to be of interest to radio astronomers are calculated and tabulated along with their estimated 95 percent confidence limits. Microwave measurements are tabulated for most isotopic species and for many of the lower vibrational states. For both carbonyl sulfide and hydrogen cyanide a bibliography is given which includes nearly all the spectroscopic work reported in the literature. For each molecule a bibliography of related astrophysical papers is also given.

Microwave spectra of molecules of astrophysical interest. VII. Carbon monoxide, carbon monosulfide, and silicon monoxide, F. J. Lovas and P. H. Krupenie, *J. Phys. Chem. Ref. Data* **3**, No. 1, 245-257 (1974).

Key words: carbon monosulfide; carbon monoxide; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; silicon monoxide.

The available data on the microwave spectra of carbon monoxide, carbon monosulfide, and silicon monoxide are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion parameters, dipole moments, hyperfine coupling constants, and structure are tabulated. Observed rotational transitions are presented for all measured isotopic forms of these molecules. All of the available data has been analyzed in order to predict all rotational transitions of these molecules up to 300 GHz. Error limits have been taken from the original literature for each measured transition frequency. All predicted transition frequencies are given with estimated uncertainties which represent the 90 percent confidence limit.

Microwave spectra of molecules of astrophysical interest. VIII. Sulfur monoxide, E. Tiemann, *J. Phys. Chem. Ref. Data* **3**, No. 1, 259-268 (1974).

Key words: interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; spectra; sulfur monoxide.

The available data on the microwave spectrum of sulfur monoxide (SO) is critically reviewed and tabulated. Molecular data such as rotational constants, hyperfine coupling constants, electric dipole moment, and magnetic g-factors are given. All rotational transitions up to 350 GHz for the isotopic species $^{32}S^{16}O$, $^{34}S^{16}O$, and $^{32}S^{18}O$ in the ground vibrational state are calculated and tabulated along with their estimated 95 percent confidence levels. The line strengths of all tabulated transitions have been determined. A bibliography of SO is given which includes results from microwave spectroscopy as well as from electron paramagnetic resonance.

Tables of molecular vibrational frequencies. Part 8, T. Shimanouchi, *J. Phys. Chem. Ref. Data* **3**, No. 1, 269-308 (1974).

Key words: fundamental frequencies; infrared spectra; polyatomic molecules; Raman spectra; vibrational frequencies.

The compilations to fundamental vibrational frequencies of molecules previously published in the NSRDS-NBS publication series and in this journal are here extended to 49 additional molecules. Selected values of the fundamental vibrational frequencies are given for each molecule, together with observed infrared and Raman spectral data and citations to the original literature. The selection of vibrational fundamentals has been based on careful studies of the spectral data and comprehensive normal-coordinate analyses. An estimate of the accuracy of the selected values is included. The tables provide a convenient source of information for those who require vibrational energy levels and related properties in molecular spectroscopy, thermodynamics, analytical chemistry, and other fields of physics and chemistry.

Volume 3, No. 2

JANAF Thermochemical Tables, 1974 supplement, M. W. Chase, J. L. Curnutt, A. T. Hu, H. Prophet, A. N. Syverud, and L. C. Walker, *J. Phys. Chem. Ref. Data* **3**, No. 2, 311-480 (1974).

Key words: critically evaluated data; enthalpy; entropy; equilibrium constant of formation; free energy of formation; Gibbs energy function; heat capacity; heat of formation; thermochemical tables.

The thermodynamic tabulations previously published as NSRDS-NBS-37 are extended by 154 new and revised tables. The JANAF Thermochemical Tables cover the thermodynamic properties over a wide temperature range with single phase tables for the crystal, liquid, and ideal gas state. The properties given are heat capacity, entropy, Gibbs energy function, enthalpy, enthalpy of formation, Gibbs energy of formation, and the logarithm of the equilibrium constant for formation of each compound from the elements in their standard reference states. Each tabulation lists all pertinent input data and contains a critical evaluation of the literature upon which these values are based. Literature references are given.

High temperature properties and decomposition of inorganic salts. Part 4. Oxy-salts of the halogens, K. H. Stern, *J. Phys. Chem. Ref. Data* **3**, No. 2, 481-526 (1974).

Key words: bromates; bromites; chlorates; chlorites; critically evaluated data; iodates; iodites; perbromates; perchlorates; periodates; thermal decomposition; thermodynamic functions.

The literature dealing with the high-temperature behavior of inorganic oxygen-containing salts of chlorine, bromine and iodine has been critically reviewed. Values of $(G°_T - H°_{298})/T$ of the reactants and products of the decomposition reactions were calculated and have been tabulated from 298 K up to as high a temperature as possible. Equilibrium constants and partial pressures were tabulated. Auxiliary data on phase transitions and densities have also been included. Qualitative information about the thermal decomposition of the salts is reviewed.

Diffusion in copper and copper alloys. Part II. Copper-silver and copper-gold systems, D. B. Butrymowicz, J. R. Manning, and M. E. Read, *J. Phys. Chem. Ref. Data* **3**, No. 2, 527-602 (1974).

Key words: alloy diffusion; copper; diffusion; electromigration; gold; grain boundary diffusion; impurity diffusion; liquid metal diffusion; silver; surface diffusion; thermomigration.

A survey, comparison, and critical analysis is presented of data compiled from the scientific literature concerning diffusion in copper-silver and copper-gold systems. Here the term "copper alloy system" is interpreted in the broadest sense. For example, the review of diffusion in the Cu-M system reports all diffusion situations which involve both copper and element M, including diffusions of Cu in M or in any binary, ternary or multicomponent alloy containing M: diffusion of M in Cu or in any alloy containing Cu; and diffusion of any element in any alloy containing both Cu and M. Topics include volume diffusion, surface diffusion, grain boundary diffusion, tracer diffusion, alloy interdiffusion, electromigration, thermomigration, strain enhanced diffusion, and diffusion in molten metals. An extensive bibliography is presented along with figures, tabular presentation of data and discussion of results.

Volume 3, No. 3

Microwave spectral tables. I. Diatomic molecules, F. J. Lovas and E. Tiemann, *J. Phys. Chem. Ref. Data* **3**, No. 3, 609-770 (1974).

Key words: diatomic molecules; dipole moments; hyperfine structure; internuclear distance; molecular spectra; rotational constants; rotational spectral lines.

All of the rotational spectral lines observed and reported in the open literature for 83 diatomic molecules have been tabulated. The isotopic molecular species, assigned quantum numbers, observed frequency, estimated measurement uncertainty, and

reference are given for each transition reported. In addition to rectifying a number of misprints and errors in the literature cited, the spectral lines for approximately 20 molecules have been reanalyzed to produce a comprehensive and consistent analysis of all the data extracted from various literature sources. The derived molecular properties, such as rotational constants, hyperfine structure constants, electric dipole moments, rotational g-factors and internuclear distances are listed with one standard deviation uncertainties for all species.

Ground levels and ionization potentials for lanthanide and actinide atoms and ions, W. C. Martin, L. Hagan, J. Reader, and J. Sugar, *J. Phys. Chem. Ref. Data* **3**, No. 3, 771-780 (1974).

Key words: actinide elements; atomic data; atomic ground levels; ionization energies; ionization potentials; lanthanide elements.

Values of the first four ionization potentials of the lanthanides ($Z = 57 - 71$) and of Hf have been compiled. All except the value for neutral Hf are based on spectroscopic data. The spectroscopic designations of the ground levels of the neutral through triply ionized atoms ($Z = 57 - 72$) are also tabulated. A similar compilation for the actinides ($Z = 89 - 103$) lists Sugar's recent values for the first ionization potentials through No ($Z = 102$). Accurate spectroscopic ionization potentials have been determined for only two of the actinide ions (Ac^{+} and Th^{3+}). The ground-level designations for the neutral through triply ionized actinides are given where they are known or can be predicted with near certainty. A selection of references to the most complete and most recent work on the analyses of the optical spectra of the neutral through triply ionized lanthanide and actinide elements is included.

Behavior of the elements at high pressures, J. F. Cannon, *J. Phys. Chem. Ref. Data* **3**, No. 3, 781-824 (1974).

Key words: critically evaluated data; crystal structures; elements; high pressure; melting curves; phase diagrams; polymorphism.

Data on polymorphic phase changes and variation of melting temperature of the elements with pressure have been compiled and critically evaluated. Emphasis has been placed on work done at pressures exceeding 1 kbar. Pressure-temperature phase diagrams showing first-order solid-solid phase boundaries and/or melting curves derived from the best available data are given for 58 elements. Information on the crystal structures of high-pressure polymorphs is also reviewed. Those elements that exist in the gaseous state at room temperature and pressure are not included.

Volume 3, No. 4

Reference wavelengths from atomic spectra in the range 15 Å to 25000 Å, V. Kaufman and B. Edlén, *J. Phys. Chem. Ref. Data* **3**, No. 4, 825-896 (1974).

Key words: optical spectra, atomic; reference wavelengths; standard wavelengths; vacuum ultraviolet.

This is a compilation of atomic lines with accurately known wavelengths covering the range from 15 Å to 25000 Å. The tables are a fairly complete record of available spectrum lines that meet the requirements for useful references with regard to wavelength accuracy and intensity. In general, wavelength uncertainties range from 0.0001 Å to 0.0002 Å. Section 1, $\lambda >$ 2000 Å, gives λ_{air} and λ_{vac} for 3341 lines belonging to thirteen different spectra of ten elements. Section 2, $\lambda <$ 2000 Å, contains 2091 lines belonging to 59 different spectra of 28 elements. The lines of section 2 are listed both by spectrum (i.e., element and ionization stage) and in a finding list arranged in order of decreasing wavelength. Detailed explanations of the data and the sources used for the compilation are included.

Elastic properties of metals and alloys. II. Copper, H. M. Ledbetter and E. R. Naimon, *J. Phys. Chem. Ref. Data* **3**, No. 4, 897-936 (1974).

Key words: bulk modulus; compressibility; copper; elastic constants; Poisson's ratio; shear modulus; single-crystal elastic coefficients; Young's modulus.

The elastic properties of copper have been compiled and reviewed. Polycrystalline elastic constants included are: Young's modulus, the shear modulus, the bulk modulus, and Poisson's ratio. Single-crystal constants of second-, third-, and fourth-order are included. Over 200 references to the experimental literature are given. A few theoretical numbers are included. When sufficient data exist, best values are recommended together with their standard errors. Effects on the elastic constants of temperature, pressure, and mechanical (plastic) deformation are included. The Cauchy (central-force) relationships and the single-crystal–polycrystal relationship are also discussed.

A critical review of H-atom transfer in the liquid phase: Chlorine atom, alkyl, trichloromethyl, alkoxy, and alkylperoxy radicals, D. G. Hendry, T. Mill, L. Piszkiewicz, and J. A. Howard, *J. Phys. Chem. Ref. Data* **3**, No. 4, 937-978 (1974).

Key words: chlorine atom reactions; hydrogen transfer reactions; liquid phase; organic molecules; organic radical reactions; rate constants; reference data.

This review covers hydrogen-atom transfer from carbon-hydrogen bonds in organic compounds to chlorine atom, methyl, ethyl, trichloromethyl, t-butoxy and alkylperoxy radicals in the liquid phase. Rate constant data are presented in 38 tables. Literature is covered through most of 1972. The review is divided into six sections; an introduction plus five sections each dealing with specific radicals. Hydrogen-atom transfer to chlorine atom are presented as relative rate constants. For hydrogen-atom transfer to methyl, ethyl, trichloromethyl, and t-butoxy radicals, both relative and absolute rate constants are tabulated. For alkylperoxy radicals only absolute rate constants are listed. Each absolute rate constant has a tabulated set of rate parameters where A has been assigned and E derived from the Arrhenius equation.

The viscosity and thermal conductivity coefficients for dense gaseous and liquid argon, krypton, xenon, nitrogen, and oxygen, H. J. M. Hanley, R. D. McCarty, and W. M. Haynes, *J. Phys. Chem. Ref. Data* **3**, No. 4, 979-1018 (1974).

Key words: argon; correlation; critical data evaluation; critical point; dense gas and liquid; excess transport property functions; krypton; nitrogen; oxygen; tables; thermal conductivity coefficient; transport property; viscosity coefficient; xenon.

Data for the viscosity and thermal conductivity coefficients of argon, nitrogen, and oxygen have been critically evaluated. A functional form to represent the data has been proposed. The function is basically the same for both coefficients if the contribution of the viscosity coefficient at high densities is considered as a separate effect. The critical point enhancement in the thermal conductivity coefficient is also treated separately. Transport properties of krypton and xenon are calculated by means of the principle of corresponding states. Tables of values are presented in the range from about the triple point temperature to 500 K for pressures up to 100 MPa. Care has been taken to ensure that the calculated values are consistent with reliable equation-of-state data and also with dilute gas transport coefficients previously determined. The uncertainties of the tabulated coefficients are assessed as follows: Viscosity: argon, nitrogen and oxygen, ±2 percent; krypton and xenon, ±5 percent. Thermal conductivity: argon, nitrogen, and oxygen, ±4 percent increasing to ±15 percent in the critical region and to 8 percent

above 200 K; krypton and xenon, ± 8 percent again increasing to ± 15 percent in the critical region. The correlation further serves to clarify the state of the art concerning transport data and experiment and to emphasize gaps in data coverage.

PAPERS FROM THE JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA, VOLUME 4, JANUARY-DECEMBER 1975

This journal is published quarterly by the American Chemical Society and the American Institute of Physics for the National Bureau of Standards. The objective of the Journal is to provide critically evaluated physical and chemical property data, fully documented as to the original sources and the criteria used for evaluation. Critical reviews of measurement techniques, whose aim is to assess the accuracy of available data in a given technical area, are also included. The principal source for the Journal is the National Standard Reference Data System (NSRDS). The Journal is not intended as a publication outlet for original experimental measurements such as are normally reported in the primary research literature, nor for review articles of a descriptive or primarily theoretical nature.

Volume 4, No. 1

JANAF Thermochemical Tables, 1975 supplement, M. W. Chase, J. L. Curnutt, H. Prophet, R. A. McDonald, and A. N. Syverud, *J. Phys. Chem. Ref. Data* **4**, No. 1, 1-176 (1975).

Key words: critically evaluated data; enthalpy; entropy; equilibrium constant of formation; free energy of formation; Gibbs energy function; heat capacity; heat of formation; thermochemical tables.

The thermodynamic tabulations previously published in NSRDS-NBS-37 and the 1974 Supplement (J. Phys. Chem. Ref. Data 3, 311 [1974]) are extended by 158 new and revised tables. The JANAF Thermochemical Tables cover the thermodynamic properties over a wide temperature range with single phase tables for the crystal, liquid, and ideal gas state. The properties given are heat capacity, entropy, Gibbs energy function, enthalpy, enthalpy of formation, Gibbs energy of formation, and the logarithm of the equilibrium constant for formation of each compound from the elements in their standard reference states. Each tabulation lists all pertinent input data and contains a critical evaluation of the literature upon which these values are based. Literature references are given.

Diffusion in copper and copper alloys. Part III. Diffusion in systems involving elements of the groups IA, IIA, IIIB, IVB, VB, VIB, and VIIB, D. B. Butrymowicz, J. R. Manning, and M. E. Read, *J. Phys. Chem. Ref. Data* **4**, No. 1, 177-250 (1975).

Key words: alloy diffusion; beryllium; cerium; cesium; chromium; copper; diffusion; electromigration; europium; grain boundary diffusion; hydrogen; impurity diffusion; interdiffusion; lanthanum; liquid metal diffusion; lithium; lutetium; magnesium; manganese; molybdenum; niobium; plutonium; potassium; praseodymium; promethium; rhenium; rubidium; sodium; surface diffusion; tantalum; terbium; ternary diffusion; thermomigration; thulium; titanium; tungsten; uranium; vanadium; zirconium.

A survey, comparison, and critical analysis is presented of data compiled from the scientific literature concerning diffusion in copper alloy systems involving elements in Groups IA, IIA, IIIB, IVB, VB, VIB, and VIIB. Here the term "copper alloy system" is interpreted in the broadest sense. For example, the review of diffusion in the Cu-M system reports all diffusion situations which involve both copper and element M, including diffusion of Cu in M or in any binary, ternary or multicomponent alloy containing M; diffusion of M in Cu or in any alloy containing Cu; and diffusion of any element in any alloy containing both Cu and M. Topics include volume diffusion, surface diffusion, grain boundary diffusion, tracer diffusion, alloy interdiffusion, electromigration, thermomigration, dislocation-pipe diffusion, and diffusion in molten metals. An extensive bibliography is presented along with figures, tabular presentation of data and discussion of results.

Ideal gas thermodynamic properties of ethylene and propylene, J. Chao and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **4**, No. 1, 251-261 (1975).

Key words: critically evaluated data; enthalpy; enthalpy function; enthalpy of formation; entropy; equilibrium constant of formation; ethylene; Gibbs energy function; Gibbs energy of formation; heat capacity; ideal gas thermodynamic properties; internal rotation; internal rotation barrier height; propylene; torsional frequency.

The ideal gas thermodynamic properties [$H° - H_0°$, $(G° - H_0°)/T$, $(H° - H_0°)/T$, $S°$, $C_p°$, $\Delta Hf°$, $\Delta Gf°$, and log K_f] for ethylene and propylene in the temperature range 0 to 1500 K and at 1 atm have been calculated by the statistical thermodynamic method employing the most recent fundamental and molecular spectroscopic constants. The internal rotational contributions to thermodynamic properties for propylene were generated based on an internal rotation partition function formed by summation of internal rotation energy levels. The energy levels were derived from the potential function $V(cm^{-1}) = 349.2\ (1 - \cos 3\theta) - 6.5\ (1 - \cos 6\theta)$. The calculated heat capacities and entropies were compared with the available experimental values.

Volume 4, No. 2

Atomic transition probabilities for scandium and titanium. (A critical data compilation of allowed lines), W. L. Wiese and J. R. Fuhr, *J. Phys. Chem. Ref. Data* **4**, No. 2, 263-352 (1975).

Key words: allowed transitions; line strengths; oscillator strengths; scandium; titanium; transition probabilities.

Atomic transition probabilities for about 1500 allowed spectral lines of the elements scandium and titanium through all stages of ionization have been critically evaluated and compiled. All available literature sources have been utilized. The data are presented in separate tables for each element and stage of ionization and are arranged according to multiplets and, when appropriate, also to transition arrays and increasing quantum numbers. For each line the transition probability for spontaneous emission, the absorption oscillator strength, and the line strength are given along with the spectroscopic designation, the wavelength, the statistical weights, and the energy levels (when available) of the upper and lower atomic states. In addition the estimated accuracy and the literature reference is indicated. In short introductions, which precede the tables for each spectrum, the main justifications for the choice of the adopted data and for the accuracy rating are discussed. A general introduction contains some more details on our evaluation procedure.

Energy levels of iron, Fe I through Fe XXVI, J. Reader and J. Sugar, *J. Phys. Chem. Ref. Data* **4**, No. 2, 353-440 (1975).

Key words: atomic energy levels; atomic spectra; iron.

The energy levels of the iron atom in all of its stages of ionization, as derived from the analyses of atomic spectra, have been compiled. In cases where only line classifications are given in the literature, level values have been derived. The percentages for the two leading components of the calculated eigenvectors of the levels are given where available. Ionization energies are also given.

Ideal gas thermodynamic properties of six fluoroethanes. S. S. Chen, A. S. Rodgers, J. Chao, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **4**, No. 2, 441-456 (1975).

Key words: barrier height to internal rotation; fluoroethanes with a symmetric top; ideal gas thermodynamic functions; reduced and principal moments of inertia; standard heat of formation; structural parameters; torsional mode; vibrational fundamentals.

The molecular structural parameters, the vibrational fundamentals, the potential barrier height to internal rotation, and the standard enthalpy of formation for each of the six fluoroethanes in which at least one of the internally rotating groups is a symmetric top have been extensively studied and recommended values selected. Chemical thermodynamic properties of molecules in the ideal gas state at temperatures from 0 to 1500 K have been calculated with the rigid-rotor harmonic-oscillator approximation. The calculated values are in a very good agreement with the existing third-law entropies.

Ideal gas thermodynamic properties of the eight bromo- and iodomethanes. S. A. Kudchadker and A. P. Kudchadker, *J. Phys. Chem. Ref. Data* **4**, No. 2, 457-470 (1975).

Key words: bromomethanes; critically evaluated data; ideal gas thermodynamic properties; iodomethanes.

The available molecular parameters, fundamental frequencies, and enthalpy of formation for eight bromo- and iodomethanes have been critically evaluated and recommended values selected. This information has been utilized to calculate the ideal gas thermodynamic properties, $C_p°$, $S°$, $H° - H_0°$, $(G° - H_0°)/T$, $\Delta Hf°$, $\Delta Gf°$, and log Kf from 0 to 1500 K using the rigid rotor-harmonic oscillator approximation.

Volume 4, No. 3

Atomic form factors, incoherent scattering functions, and photon scattering cross sections. J. H. Hubbell, W. J. Veigele, E. A. Briggs, R. T. Brown, D. T. Cromer, and R. J. Howerton, *J. Phys. Chem. Ref. Data* **4**, No. 3, 471-538 (1975).

Key words: atomic form factor; Compton scattering; cross sections; gamma rays; incoherent scattering function; photons; Rayleigh scattering; tabulations; x rays.

Tabulations are presented of the atomic form factor, $F(x,Z)$, and the incoherent scattering function, $S(x,Z)$, for values of x (= $\sin(\theta/2)/\lambda$) from 0.005 Å^{-1} to 10^9 Å^{-1}, for all elements $A = 1$ to 100. These tables are constructed from available state-of-the-art theoretical data, including the Pirenne formulas for $Z = 1$, configuration-interaction results by Brown using Brown-Fontana and Weiss correlated wavefunctions for $Z = 2$ to 6 nonrelativistic Hartree-Fock results by Cromer for $Z = 7$ to 100, and a relativistic K-shell analytic expression for $F(x,Z)$ by Bethe and Levinger for $x > 10$ Å^{-1} for all elements $Z = 2$ to 100. These tabulated values are graphically compared with available photon scattering angular distribution measurements. Tables of coherent (Rayleigh) and incoherent (Compton) total scattering cross sections, obtained by numerical integration over combinations of $F^2(x,Z)$ with the Thomson formula and $S(x,Z)$ with the Klein-Nishina formula, respectively, are presented for all elements $Z = 1$ to 100, for photon energies 100 eV ($\lambda = 124$ Å) to 100 MeV (0.000124 Å). The incoherent scattering cross sections also include the radiative and double-Compton corrections as given by Mork. Similar tables are presented for the special cases of terminally-bonded hydrogen and for the H_2 molecule, interpolated and extrapolated from values calculated by Stewart et al. and by Bentley and Stewart using Kolos-Roothaan wavefunctions.

Binding energies in atomic negative ions. H. Hotop and W. C. Lineberger, *J. Phys. Chem. Ref. Data* **4**, No. 3, 539-576 (1975).

Key words: ab initio calculations; atomic negative ions; binding energy; electron affinity; excited states; experimental methods; fine structure splitting; recommended values; semiempirical calculations.

A survey of the electron affinity determinations for the elements up to $Z = 85$ is presented, and based upon these data, a set of recommended electron affinities is established. Recent calculations of atomic electron affinities and the major semiempirical methods are discussed and compared with experiment. The experimental methods which yield quantitative electron binding energy data are described and intercompared. Based primarily upon extrapolation techniques, fine structure splittings for these ions and excited state term energies are given.

A survey of electron swarm data. J. Dutton, *J. Phys. Chem. Ref. Data* **4**, No. 3, 577-856 (1975).

Key words: electrical breakdown of gases; electrical discharges; electron attachment coefficient; electron detachment coefficient; electron diffusion coefficient; electron drift velocity; electron excitation coefficient; electron ionization coefficient; electron-ion recombination coefficient; electron swarm; electron transport coefficients; ionized gases.

An electron swarm consists of a small number density n of electrons in a gas of much higher number density N. The mean energy and energy distribution of such a swarm are determined by the value of E/N, where E is the electric field. At any given value of E/N the swarm may be characterized by the values of eight parameters, viz: drift velocity, diffusion coefficient, (diffusion coefficient)/mobility, excitation coefficient, electron attachment coefficient, electron detachment coefficient, ionization coefficient, recombination coefficient. In this survey, data on these parameters obtained by a variety of experimental techniques are collected, discussed, and compared graphically. Also included on the graphs are computed values of the parameters obtained in many cases from cross sections and energy distributions chosen to give the best fit with the swarm data. Selected tabulations of the data are also given except in cases for which the accuracy of the data is not sufficient to warrant numerical presentation. The mean energy of the electron swarms ranges from thermal to several electron volts and the gases for which data are given are the rare gases, the common molecular gases (H_2, N_2, O_2, CO, NO, CO_2, NO_2) and air. The survey also contains an extensive bibliography which includes references (i) to publications on electron swarms in a much wider range of gases than those for which data are given and (ii) to papers concerned with energy distributions, conductivity, and ionization coefficients in crossed electric and magnetic fields in addition to those relating to the eight parameters listed above.

Volume 4, No. 4

Ideal gas thermodynamic properties and isomerization of *n*-butane and isobutane. S. S. Chen, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **4**, No. 4, 859-870 (1975).

Key words: equilibrium compositions; heat of isomerization; ideal gas thermodynamic properties; isobutane; *n*-butane; potential barrier to internal rotation.

Reported values of structural parameters, vibrational fundamentals, and potential energy functions for internal rotation of *n*-butane and isobutane are reviewed. The selected values were used to calculate the thermodynamic properties ($C_p°$, $S°$, $(H° - H_0°)/T$, $(G° - H_0°)/T$) in the temperature range of 0 to 1500 K by the usual statistical thermodynamic methods using the rigid-rotor and harmonic-oscillator model. Contributions of internal rotation were evaluated by the direct sum of terms containing energy levels which were calculated with a one-dimensional potential model. For internal rotation about the central C–C bond in *n*-butane, energy levels were approximated by two procedures. A unique potential function was assumed for each methyl rotor of *n*-butane or of isobutane. Top-top interactions in isobutane were approximated by the potential parameter V_6 which was determined empirically by comparison with thermodynamic data. The calculated and observed values of heat capacities and entropies agree well within experimental uncertainties. Standard enthalpies of formation at 298.15 K for the ideal gaseous state were selected from measured values of heats of combustion and third-law enthalpies for isomerization. Corresponding values of $\Delta Hf°$, $\Delta Gf°$ and log Kf are tabulated over the same temperature range.

Molten salts: Volume 4, part 2, chlorides and mixtures. Electrical conductance, density, viscosity, and surface tension data, G. J. Janz, R. P. T. Tomkins, C. B. Allen, J. R. Downey, Jr., G. L. Gardner, U. Krebs, and S. K. Singer, *J. Phys. Chem. Ref. Data* **4**, No. 4, 871-1178 (1975).

Key words: chlorides; data compilation; density; electrical conductance; molten salt mixtures; standard reference data; surface tension; viscosity.

Data on the electrical conductance, density, viscosity, and surface tension of chloride mixtures have been systematically collected and evaluated. Results are given for 124 binary mixtures over a range of compositions and temperatures. Values of the above properties for the single salts have been updated in accord with previously advanced recommendations.

PAPERS FROM THE JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA, VOLUME 5, JANUARY-DECEMBER 1976

This journal is published quarterly by the American Chemical Society and the American Institute of Physics for the National Bureau of Standards. The objective of the Journal is to provide critically evaluated physical and chemical property data, fully documented as to the original sources and the criteria used for evaluation. Critical reviews of measurement techniques, whose aim is to assess the accuracy of available data in a given technical area, are also included. The principal source for the Journal is the National Standard Reference Data System (NSRDS). The Journal is not intended as a publication outlet for original experimental measurements such as are normally reported in the primary research literature, nor for review articles of a descriptive or primarily theoretical nature.

Volume 5, No. 1

Scaled equation of state parameters for gases in the critical region, J. M. H. L. Sengers, W. L. Greer, and J. V. Sengers, *J. Phys. Chem. Ref. Data* 5, No. 1, 1-52 (1976).

Key words: air constituents; critical region parameters; ethylene; heavy noble gases; helium; linear model; methane; NBS equation; scaling laws; statistical analysis; steam; universality.

The anomalous thermodynamic behavior of fluids near the critical point can be described in terms of scaling laws. In this paper we consider two critical region equations of state, to be referred to as the NBS equation and the Linear Model parametric equation, that satisfy the scaling laws. A complete formulation of the thermodynamic properties in terms of the two equations is given. The statistical methods used for fitting these equations to experimental data are described. Each of the equations is fitted to experimental equation of state data for six fluids, namely He^3, He^4, Xe, CO_2, O_2, and H_2O. An evaluation of the recorded experimental material is included. We find that the two equations represent the experimental data in the range $|T-T_c|/T_c<0.03$ and $|\rho-\rho_c|\sqrt{\rho_c}<0.25$ equally well and that the exponents and amplitudes of the power laws deduced from the two equations agree closely. The optimum critical exponents appear to vary little from substance to substance. Moreover, a restricted version of the Linear Model with only two freely adjustable constants, in addition to the critical point parameters and the critical exponents, fits the data well in most cases, in agreement with expectations based on universality of critical behavior. The principle of universality is discussed and applied to predict critical region parameters for nine additional fluids, including several for which only limited experimental information is available. These additional fluids are Ar, Kr, N_2, H_2, CH_4, C_2H_4, SF_6, NH_3, and D_2O. We thus conclude with a single universal equation for the critical region of all fifteen fluids considered in this paper.

Microwave spectra of molecules of astrophysical interest. IX. Acetaldehyde, A. Bauder, F. J. Lovas, and D. R. Johnson, *J. Phys. Chem. Ref. Data* 5, No. 1, 53-78 (1976).

Key words: acetaldehyde; internal rotation; interstellar molecules; microwave spectrum; radio astronomy; rotational transitions.

The microwave spectrum of acetaldehyde is critically reviewed and augmented through calculations which include the effects of internal rotation and centrifugal distortion. Since the primary objective of this review is to provide microwave spectral transitions applicable to radio astronomy studies, the review encompasses only the ground state rotational spectrum of the most abundant isotopic form of acetaldehyde, $^{12}CH_3{}^{12}CH^{16}O$. While all measured transitions are included, the predicted transition frequencies were limited to $J\leqq 12$ in the range of 900 MHz to 250 GHz. In addition to this spectral information, the review includes the rotational constants, centrifugal distortion constants, inertial rotation parameters, electric dipole moment, structural data, moments of inertia, and constants relating to the barrier to internal rotation.

Microwave spectra of molecules of astrophysical interest. X. Isocyanic acid, G. Winnewisser, W. H. Hocking, and M. C. L. Gerry, *J. Phys. Chem. Ref. Data* 5, No. 1, 79-102 (1976).

Key words: isocyanic acid; interstellar molecules; microwave spectra; molecular parameters; rotational transitions; radio astronomy.

The available data on the microwave spectrum of isocyanic acid are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion parameters, dipole moments, hyperfine coupling constants, and structural parameters are tabulated. Detailed centrifugal distortion calculations have been carried out for all isotopic forms of this molecule, including DNCO. Transitions have been predicted for the parent molecule for the frequency range 160 MHz-300 GHz. All predicted transitions include error limits. The quoted uncertainties represent one standard deviation. A 95 percent confidence limit is obtained by using approximately twice the calculated standard deviation. Estimated error limits for the measured transitions are discussed. References are given for all data included.

Diffusion in copper and copper alloys. Part IV. Diffusion in systems involving elements of group VIII, D. B. Butrymowicz, J. R. Manning, and M. E. Read, *J. Phys. Chem. Ref. Data* 5, No. 1, 103-200 (1976).

Key words: alloys; cobalt; copper; diffusion; electromigration; iron; nickel; palladium; platinum; rhodium; ruthenium; thermomigration.

A survey, comparison, and critical analysis is presented of data compiled from the scientific literature concerning diffusion in copper alloy systems involving elements in Group VIII (Co, Fe, Ni, Pd, Pt, Rh, Ru). Here the term "copper alloy system" is interpreted in the broadest sense. For example, the review of diffusion in the Cu-M system reports all diffusion situations which involve both copper and element M, including diffusion of Cu in M or in any binary, ternary or multicomponent alloy containing M; diffusion of M in Cu or in any alloy containing Cu; and diffusion of any element in any alloy containing both Cu and M. Topics include volume diffusion, surface diffusion, grain boundary diffusion, tracer diffusion, alloy interdiffusion, electromigration, thermomigration, dislocation-pipe diffusion, and diffusion in molten metals. An extensive bibliography is presented along with figures, tabular presentation of data and discussion of results.

Volume 5, No. 2

A critical review of the Stark widths and shifts of spectral lines from non-hydrogenic atoms, N. Konjevic and J. R. Roberts, *J. Phys. Chem. Ref. Data* **5**, No. 2, 209-258 (1976).

Key words: experimental; neutral atom; review; shift; Stark broadening; width.

A critical review of all available data on the Stark broadening and shifts of spectral lines of neutral elements has been undertaken. Over 200 papers compiled by the NBS Data Center on Atomic Line Shapes and Shifts have been evaluated, and of these, 68 were chosen as having reviewable data. Only those papers with properly determined critical factors, such as electron density, temperature, spatial homogeneity, optical depth, and instrument function deconvolution, were selected.

Experimental Stark widths and shifts for non-hydrogenic spectral lines of ionized atoms. (A critical review and tabulation of selected data), N. Konjevic and W. L. Wiese, *J. Phys. Chem. Ref. Data* **5**, No. 2, 259-308 (1976).

Key words: critically evaluated data; experimental; ionized spectra; Stark broadening parameters; Stark shifts; Stark widths.

A critical review of all available data on the Stark widths and shifts for lines of non-hydrogenic ionized spectra has been carried out. The relevant literature compiled by the NBS Data Center on Atomic Line Shapes and Shifts was critically evaluated, and from this evaluation 54 papers were found to satisfy all requirements and thus selected for this review. The most important factors determining the quality of plasma sources, diagnostic techniques, and line profile and shift determinations are discussed in detail in the first part of this review. In the second part the data tables containing the selected experimental Stark broadening parameters are presented. The data are arranged according to spectra and elements, and these are presented in alphabetical order. The accuracy of the experimental data is estimated on the basis of guidelines developed during the review, and comparisons with theoretical results are made whenever possible.

Atlas of the absorption spectrum of nitric oxide (NO) between 1420 and 1250 Å, E. Miescher and F. Alberti, *J. Phys. Chem. Ref. Data* **5**, No. 2, 309-318 (1976).

Key words: absorption spectrum; identification atlas; nitric oxide; Rydberg series.

This atlas presents the absorption spectrum between 1420 and 1250 Å of cold (−180 °C) nitric oxide gas, both $^{14}N^{16}O$ and $^{15}N^{16}O$, photographed in first order of a 10.5 m vacuum spectrograph. The spectral region comprises the Rydberg series (*s*-, *p*-, *d*-, and *f*-) of the molecule, including their limits of v=0, 1, and 2 of the ground state of the ion NO^+. In addition it shows some valence bands. To each band are assigned quantum numbers. The assignment is based on the detailed study of the fine structure of the bands, measured on spectral plates obtained in high order of the same instrument. Accurate numerical results of these measurements are tabulated for 140 molecular levels. A short survey on the NO absorption spectrum is given.

Ideal gas thermodynamic properties of propanone and 2-butanone, J. Chao and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **5**, No. 2, 319-328 (1976).

Key words: enthalpy; entropy; equilibrium constant of formation; Gibbs energy of formation; heat capacity; ideal gas thermodynamic properties; internal rotational barrier height; propanone (acetone); torsional frequencies; 2-butanone (methyl ethyl ketone).

The ideal gas thermodynamic properties ($C_p°$, $S°$, $H°-H_0°$, $(H°-H_0°)/T$, $-(G'-H_0°)/T$, $\Delta Hf°$, $\Delta Gf°$, and log Kf) for propanone and 2-butanone in the temperature range from 0 to 1500 K and at 1 atm were calculated by statistical mechanical procedures, using rigid-rotor and harmonic-oscillator approximations. The internal rotation contributions to thermodynamic properties were evaluated by use of a partition function formed by summation of internal rotation energy levels. The calculated heat capacities and entropies are in agreement with the available experimental values.

Refractive index of alkali halides and its wavelength and temperature derivatives, H. H. Li, *J. Phys. Chem. Data* **5**, No. 2, 329-528 (1976).

Key words: alkali halides; optical constants; refractive index; temperature coefficient of refractive index.

Refractive index data for 20 alkali halides are exhaustively surveyed, compiled, and analyzed. The most probable values at 293 K for the transparent region are generated for the materials for which experimental data are sufficiently abundant and reliable. Provisional values are also provided for the wavelength regions where available data are insufficient or missing. Reasonable estimations of refractive index for the very scantily measured materials were made by incorporating the dielectric constants and wavelengths of absorption peaks into a simplified dispersion equation. Temperature derivatives of refractive index for most of the alkali halides were unavailable. However, using the existing data for the five most commonly used alkali halides, novel empirical facts were discovered and dn/dT formulas were constructed for all of the alkali halides. The calculated dn/dT values agree remarkably well with the existing experimental data.

Volume 5, No. 3

Tables of critically evaluated oscillator strengths for the lithium isoelectronic sequence, G. A. Martin and W. L. Wiese, *J. Phys. Chem. Ref. Data* **5**, No. 3, 537-570 (1976).

Key words: *f*-values; isoelectronic sequence; lithium sequence; oscillator strengths; relativistic effects; spectral series; systematic trends.

Oscillator strengths for the lithium isoelectronic sequence have been critically evaluated and compiled by means of a new generalized analysis which makes use of several types of systematic trends and fundamental spectroscopic constraints. Relativistic effects have also been considered. The data are presented in separate tables for each ion of the sequence from Li I through Ni XXVI, and are arranged within each table according to spectral series. Separate tables are presented for the 2*s*-2*p* and 2*s*-3*p* transitions, with both relativistic and nonrelativistic *f*-values listed for all ions of the sequence through Ni XXVI, as well as for a few selected ions of higher nuclear charge. The general tables contain transitions of the type *ms-np*, *mp-ns*, and *mp-nd*, with $2 \leq m \leq 4$ (m is the lower principal quantum number) and $3 \leq n \leq 7$. Since most recommended data were determined from a nonrelativistic analysis, hydrogenic relativistic considerations were applied to estimate when the data would be significantly altered by the inclusion of relativistic effects, and such *f*-values were excluded from the tabulation.

Ideal gas thermodynamic properties of six chlorofluoromethanes, S. S. Chen, R. C. Wilhoit, and B. J. Zwolinski, *J. Phys. Chem. Ref. Data* **5**, No. 3, 571-580 (1976).

Key words: chlorofluoromethanes; ideal gas thermodynamic functions; principal moments of inertia; standard enthalpy of formation; vibrational fundamentals.

Spectroscopic and thermal data were reviewed. The selected values for the principal moments of inertia, the vibrational fundamentals, and the standard enthalpy of formation at 298.15 K for each of the six chlorofluoromethanes were used to derive the chemical thermodynamic properties of molecules from 0 to 1500 K, based on the rigid-rotor harmonic-oscillator approximation. The calculated values are in accord with experimental heat capacities and entropies.

Survey of superconductive materials and critical evaluation of selected properties, B. W. Roberts, *J. Phys. Chem. Ref. Data* **5,** No. 3, 581-822 (1976).

Key words: bibliography; composition; critical fields; critical temperature; crystallographic data; low temperature; superconductive materials; superconductivity.

This publication includes all data on superconductive materials intercepted through March 1975. Data on the bulk elements have been critically evaluated, and values on alloys, compounds, and other forms have been selected and condensed to indicate the probable value and spread of values observed. Proven nonsuperconductors have been noted. Conflict in data values has been noted. All data have been keyed to the literature in one or more of the tables. Special subdivisions are presented for superconductive materials with organic constituents and for those based on semiconductive materials. The properties presented are superconductive critical temperature, critical magnetic fields, material state and composition including crystal-structure type where noted, a key to thin-film forms, and the presence of thermodynamic data (generally the electronic specific heat, γ, and Debye θ). High-magnetic-field superconductors are noted with listing of H_{c1}, H_c, H_{c2}, and H_{c3} plus the temperature of observation T_{obs}.

Volume 5, No. 4

Nuclear spins and moments, G. H. Fuller, *J. Phys. Chem. Ref. Data* **5,** No. 4, 835-1092 (1976).

Key words: evaluated data; nuclear electric hexadecapole moments; nuclear electric quadrupole moments; nuclear magnetic dipole moments; nuclear magnetic octupole moments; nuclear spins.

A summary of nuclear-moment values and an index, arranged by Z and A, is presented. The summary value is based on the experimentally determined values of the nuclear moments which have been listed in tables according to the techniques used. Each table is preceded by a short introduction describing the experimental technique involved and the method of calculating the moment from the measured quantities. References are given for all data quoted. The date for the last systematic literature search is included with each table. This tabulation supplements and revises the earlier tables which appeared in Nuclear Data Tables, Volume A5, 433-612 (1969).

Nuclear moments and moment ratios as determined by Mössbauer spectroscopy, J. G. Stevens and B. D. Dunlap, *J. Phys. Chem. Ref. Data* **5,** No. 4, 1093-1122 (1976).

Key words: Mössbauer; nuclear electric quadrupole moments; nuclear magnetic dipole moments.

Values are given for Mössbauer effect measurements of nuclear magnetic moments, spectroscopic quadrupole moments, ratios of moments between low lying excited states and the ground state of the same isotope, and ratios of moments between states of different isotopes. Adopted values for moments, obtained by direct selection of specific results or by an averaging process, are presented. The literature has been covered through December 1974.

Rate coefficients for ion-molecule reactions I. Ions containing C and H, L. W. Sieck and S. G. Lias, *J. Phys. Chem. Ref. Data* **5,** No. 4, 1123-1146 (1976).

Key words: chemical kinetics; data evaluation; gas phase; hydrocarbons; ion-molecule reactions; mass spectrometry; rate coefficients.

A compilation is presented of experimentally determined bimolecular and third order rate coefficients for the reactions of hydrocarbon ions with neutral molecules in the vapor phase. The literature covered is from 1960 to the present, and both positive and negative ions are considered. Four hundred and fifty-eight separate reaction-pairs are tabulated, and the ionic reaction products and experimental conditions are specified wherever possible. Preferred values are suggested for a number of these processes.

Microwave spectra of molecules of astrophysical interest. XI. Silicon Sulfide, E. Tiemann, *J. Phys. Chem. Ref. Data* **5,** No. 4, 1147-1156 (1976).

Key words: interstellar molecules; microwave spectra; radio astronomy; rotational transitions; silicon sulfide; spectra.

The available data on the microwave spectrum of silicon sulfide are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, electric dipole moment and hyperfine coupling constant are tabulated. Observed rotational transitions are presented for all measured isotopic forms of SiS. These data have been analyzed in order to predict rotational transition of the ground vibrational state up to 300 GHz. From the given rotational constants transition frequencies in excited vibrational states can be calculated with little loss in accuracy.

Error limits have been taken from the original literature for each measured frequency. The predicted transition frequencies are given with uncertainties which represent the 90 percent confidence limit.

3.5. DIMENSIONS/NBS (Formerly Technical News Bulletin), ARTICLE TITLES ONLY

This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS.

DIMENSIONS/NBS highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, DIMENSIONS/NBS reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing. Issued monthly.

January 1973

TNB 57, No. 1, 1-24 (1973).

Key words: Measures for air quality; metric chart; rf measurements; runway capacities; semiconductor materials test; speed of light.

Superconducting Sensor Advances RF Metrology

Determining Runway Capacities and Delays

Nondestructive Test of Semiconductor Materials

The Environment and the Economy: Joint Progress or Parochial Negativism

Measures for Air Quality

Insert-NBS Measurement Seminars, 1973 Series

Experimental Measurement of Optical Frequency

New Value for Speed of Light

NSRDS News

Publications of the National Bureau of Standards

Prices Revised on Standard Reference Materials

February 1973

TNB 57, No. 2, 25-52 (1973).

Key words: Cancer detection; city games; temperature scale; truck noise; waste incineration.

Cancer Detected in Living Animals Using Nuclear Magnetic Resonance

City Games People Play

NBS Measurements Show Significant Temperature Scale Differences

Optical Radiation News

The Metric System – A Changeover is Under Way

Brief History of Measurement Systems with a Chart of the Modernized Metric System

NBS Helps with Problems of Waste Incineration

NSRDS News

OIML Meeting

Publications of the National Bureau of Standards

March 1973

TNB 57, No. 3, 53-76 (1973).

Key words: Electrical engineering units; electron recombination reactions; heat pipe oven; lead-based paints; popular metric chart; tribo-ellipsometry.

Electron Recombination Reactions

New NBS Director – Dr. Richard W. Roberts

New Oven Constrains Corrosive Vapors

Lower Temperatures Recommended for Ranges

Electrical Engineering Units and Constants Cards

Performance Standards for X-Ray Systems

NBS Aids U.S. Railroad System

NSRDS News

All You Will Need to Know About Metric

New Reference Tables for Low-Temperature Thermocouples Available

Using Tribo-Ellipsometry to Study Stress Corrosion Cracking

Standard Reference Material for Analyzing Lead-Based Paints Available

TV Time Petitions Sent to FCC

Publications of the National Bureau of Standards

April 1973

TNB 57, No. 4, 77-100 (1973).

Key words: Electrical power; insulation of buildings; inventor; kitchen range standards; Shirley Highway bus project; superconductive fixed-point device.

NBS Evaluates Express Bus Project

Transition Temperatures Certified Using Superconductive Fixed- Point Device

Environmental Testing of Full Size Buildings

Optical Radiation News

New Kitchen Range Standards

Shunt Reactor Power Loss

NBS and the Inventor

NBS Signals Aid Power Companies

NBS Aids Hospital Designers

NSRDS News

Publications of the National Bureau of Standards

May 1973

TNB 57, No. 5, 101-128 (1973).

Key words: Disaster losses; energy systems; flammable fabrics (FFACTS); metric; nuclear activation analysis; roofing systems; tooth decay.

The Metric Changeover

Recommendations to Cut Disaster Losses

The Ultimate Contribution of Nuclear Activation Analysis

Foam Polyurethane Roofing Systems

FFACTS

A New Theory of Tooth Decay

Matrix Isolation Studies of Reactive Species

Research Associate Develops Fire Test

A Look at Total Energy Systems

The NSRDS

Proposed Standard for Dense Numeric Representations

Publications of the National Bureau of Standards

June 1973

TNB 57, No. 6, 139-152 (1973).

Key words: Child-proof matches; hydrogen arc radiometry; impact of Federal science; MHD materials research; musical foghorn; postal automation.

Postal Automation Commemorated

NBS Analyzes Human Factors in Post Office Operations

NBS Seeking "Child-Proof" Matches

SRM Benefits in "SOAP" Far Exceed Costs

NBS and the Return of the Musical Foghorn

Proceedings of the 5th Temperature Symposium Published

NBS Policy for Usage of SI Units

Golden Anniversary of WWV

Ongoing Magnetohydrodynamic (MHD) Materials Research

Hydrogen Arc Radiometry Applied to Fusion Effort

Research Associate Programs Continue Active

Impact of Federal Science on the National Economy (Abstract)

Optical Radiation News

Publications of the National Bureau of Standards

July 1973

TNB 57, No. 7, 153-176 (1973).

Key words: Antenna performance; COBOL; environmental buoy cables; highway repair costs; incentives program; innovators; paper degradation; smoke test.

NBS Uses Laser to Detect Free Radicals

ASTM/NBS Symposium on Spreading Resistance Measurements

Initiation of Government-Wide Compiler Testing for COBOL

Bureau Studies VHF Antenna Performance Under Snow Conditions

New Technology Incentives Program Launched

Top Innovators Meet to Discuss Causes and Remedies

Accident Analysts: NBS Failure Sleuths Pick Up Pieces

Improved Atomic Frequency Standard Undergoing Tests

NBS Finds Way to Reduce U.S. Highway Repair Costs

New Environmental Buoy Cables Tested

NBS Smoke Test Gains Acceptance

NBS Finds Causes of Paper Degradation

Publications of the National Bureau of Standards

August 1973

DIM/NBS 57, No. 8, 177-200 (1973).

Key words: Cryogenics; energy conservation; energy generation; household appliance energy labels; motor vehicles using dual-fuel systems; optical radiation news; standard gases.

To Our Readers

Energy and NBS

Energy Conservation in Buildings

Household Appliance Energy Labels

Energy Generation and Transmission

Liquefied Natural Gas and NBS

Comparative Performance of Motor Vehicles Operated on Gasoline, Compressed Natural Gas, and Propane

Three States Receive Weights and Measures Standards

Current Awareness in Cryogenics

Atomic Data Aid U.S. Fusion Efforts

Standard Gases for Automotive Emissions Analysis Now Available

Optical Radiation News

Highlights

Fabric Flammability Test to be Studied

Publications of the National Bureau of Standards

September 1973

DIM/NBS 57, No. 9, 201-224 (1973).

Key words: Art; clinical chemistry; fire services; high-accuracy mass spectrometry; materials failure; night vision; precision; surface roughness.

October 1973

DIM/NBS 57, No. 10, 225-252 (1973).

Key words: Air pollution; air quality; auto emissions; clean air and water; environmental quality; metal contaminants; occupation-related air pollutants; oil spills; radioactive pollutants; stratospheric air pollution; water quality; water pollution.

November 1973

DIM/NBS 57, No. 11, 253-276 (1973).

Key words: Clinical SRM's; distance to moon; energy; fire technology; invisible moonlight; iodine stabilized lasers; sensor progress.

December 1973

DIM/NBS 57, No. 12, 277-300 (1973).

Key words: Air pollutants; automation technology; computer software; computer standards; computer utilization; electron spectroscopy; humidity facility; international trade; shortest path studies.

DIMENSIONS/NBS (Formerly Technical News Bulletin), ARTICLE TITLES ONLY

This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS.

DIMENSIONS/NBS highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, DIMENSIONS/NBS reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumention, and automatic data processing. Issued monthly.

January 1974

DIM/NBS 58, No. 1, 1-24 (1974).

Key words: air conditioners; clean air; drunk drivers; energy labeling; fundamental constants; irradiated foods; metric computer program; migrant camps; thermestesiometer.

Specifications in the Physical World

Catalysis for Clean Air

Bureau Tackles Energy Problem

Air Conditioners Will be Energy Labeled First

Highlights

A Look at Sanitary Conditions in Migrant Camps

When is Hot Pot Hot?

Taking the Drunk Driver's Measure

Irradiated Foods—Safe at Home?

Computer Program for Metric Conversion

Publications

February 1974

DIM/NBS 58, No. 2, 25-48 (1974).

Key words: Alaskan baseline study; consumer goods; door security; ferrite measurement; health hazards; industry incentives; international program; law enforcement; measurement system; weights and measures.

How Safe Are Consumer Goods?

Industry Incentives Program Underway

Scientific Cross-Fertilization

Highlights

Scientists Fight Chilblains and the Clock in Alaskan Oil Baseline Study

Measuring the National Measurement System

That Equity May Prevail

NBS Contributes to Ferrite Measurement in Stainless Welds and Castings

Reducing the Health Hazards of Poor Radioactivity Measurement

Burglars Beware!

Publications

March 1974

DIM/NBS 58, No. 3, 49-72 (1974).

Key words: atomic timekeeping; building technology; disaster studies; energy-saving building construction; energy squeeze; insulation; measuring energy utilization; miners (communications).

Facing the Energy Squeeze

Without Insulation Your Dollars Slip Away

Office Building to Slash Fuel Use

Measurement of Energy Utilization—An Instrumentation Challenge

NBS Helps Design Energy-Saving School

Home Energy Saving Tips from NBS

Where From Here?

Architects of Survival

Highlights

New "Voice" for Trapped Miners

Atomic Timekeeping 25 Years Later

Publications

April 1974

DIM/NBS 58, No. 4, 74-96 (1974).

Key words: aircraft failure; Copernicus; corrosion; length standard; lens calibration; police helmets; satellite time; sprinkler systems.

Aircraft Failure: Reconstructing the Event

Man and Cosmos Lecture Series

Police Helmets: How Safe?

Highlights

Dark Corners of Corrosion

Nursing Homes ... and a Fire Connection

Toward a New Standard of Length

Through a Glass, Clearly

At the Signal ... Via Satellite Time

Publications

May 1974

DIM/NBS 58, No. 5, 97-120 (1974).

Key words: blood banking; bone cement; clinical lab; clinical SRM's; dental research; health research; implant materials; lead paint poisoning; MUMPS; protein adsorption; thermometry.

Accuracy of Clinical Lab Tests is Upgraded

SRM's Help Improve Health Measurements

They Don't Take Temperature Like They Used To

Solving the Lead Paint Problem

The NBS Reactor: Tool for Health Research

Getting It Together Polymerically

New Computer Language Standard Aids Medicine

Study on Blood Banking Bears Interest

NBS Marks 55 Years of Dental Research

Protein Adsorption Applied to Blood Compatibility

Highlights

Publications

June 1974

DIM/NBS 58, No. 6, 121-142 (1974).

Key words: effects of metrication; environmental data; fire research (history of); fire retardants; flammability; frequency measurements; housing industry; Josephson junction; nitric oxide; synchrotron; ultraviolet machine.

New Fire Research Building

A Look at Fire Research

NBS Research Goes Back More Than 70 Years

Flammability: A New Look at an Age-Old Problem

From Thales to Josephson

Highlights

Effects of Metrication on the U.S. Economy

Metrication and the Housing Industry

NBS Develops Nitric Oxide Monitor

Latest Publications on Fire Research

New Ultraviolet Machine Will Outshine the Sun

Validation of Environmental Data

Publications

July 1974

DIM/NBS 58, No. 7, 145-168 (1974).

Key words: bus experiment; charcoal grill safety; computer privacy and security; computer standards proposed; electroexplosive devices; energy monitored; jerry-can standard; materials conservation; noise pollution; voltage transfer.

Privacy and Security: Twin Challenges to Computer Technology

Edward Uhler Condon

Sounds That Hurt

Noise Pollution Grows

Waste Not, Want Not

NBS Programs Promote Materials Durability

Highlights

NBS Urges Charcoal Grill Safety

Bus Experiment Aids Commuter, Energy Conservation, Environment

New Voltage Transfer Technique

Stray Energy Monitored

New Computer Standards Proposed

JILA Fellows Named

Jerry-Can Standard Approved

Two Standards Under Review

Publications

August 1974

DIM/NBS 58, No. 8, 169-192 (1974).

Key words: Big G; bolometer calibration; earthquake prediction; frequency standard systems; heat-pipe ovens; Hoover; liquefied natural gas; magnetometer; mechanical failure; microwaves; oscillator calibration.

Making the Most of a Limited Resource

Getting Through with Microwaves

How Big is G

Hoover at Commerce: "Satisfying Years"

Mechanical Failure—A Material Matter

Highlights

NBS Automates Bolometer Calibrations

Magnetic Eye Spots Weak Tanks

More Versatile Heat-Pipe Ovens Developed

Magnetometer May Help Predict Earthquakes

Guide to Courtroom Systems Prepared

Color TV Used to Calibrate Oscillators

Frequency Standard Systems Compare Atomic Time Scales

Publications

September 1974

DIM/NBS 58, No. 9, 193-215 (1974).

Key words: auto paint; chlorine monitor; color measurements; color use; postdoctoral appointments; retroreflectors; semiconductor technology; thermocouple data; video tape; warning lights; weights and measures.

Standardization for Measuring Color

Greater Visibility Sought for Warning Lights

Collection of Auto Paint Colors Prepared for Forsenic Use

NBS Publishes Book on Color Use

October 1974

November 1974

December 1974

DIMENSIONS/NBS (Formerly Technical News Bulletin), ARTICLE TITLES ONLY

This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS.

DIMENSIONS/NBS highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, DIMENSIONS/NBS reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing. Issued monthly.

January 1975

DIM/NBS 59, No. 1, 1-24 (1975).

Key words: computers; energy research; ethylene; fabric flammability; glass standards; household fires; jet engines; measurement seminars; metric; protecting nuclear fuels.

Computers Automate Jet Engine Tuneups

NBS Camera Keeps Eye on Nuclear Fuels

Crime Labs Aided by NBS Glass Standard

Survey Results in New Data on Household Fires

Energy Research: The Long-Term Perspective

Highlights

NBS to Hold Measurement Seminars

Survey Shows Schools Going Metric

NBS Strengthens Consumer Programs

NBS, Industry to Join in Ethylene Study

New Flammability Standard for Sleepwear

Publications

February 1975

DIM/NBS 59, No. 2, 25-48 (1975).

Key words: energy conservation; fires; gasoline consumption; glass SRM; hazardous chemicals; leap second; playground equipment safety; scientific data; silicon devices; time.

NBS, FEA Help Homeowners Make the Most of Their Energy Conservation Dollars

Estimating Gas Consumption

Good Science, Bad Data

Assessing the Hazard Potential of Chemical Substances

Safety of Playground Equipment

Highlights

New Time Rules

1975 Arrived Late

Fifty Glass Standard Reference Materials Available

Facts on High Rise Fires

Workshop on Surface Finish of Silicon Devices

Publications

March 1975

DIM/NBS 59, No. 3, 49-72 (1975).

Key words: accelerator facilities; computers; court records; fire safety; forensic science; law enforcement; methane; metric; police protection; safer streets; security systems; WWV/WWVH.

The Law Enforcement Standards Laboratory

Safer Streets Through Improved Communication

Guidelines for Keeping Better Court Records

Helping Improve Police Protection

Toward More Objective Evidence

Investigating the Performance of Security Systems

Patrolcar Performance and Safety Studied

Highlights

New Flowchart Template for Federal Computer Users

Call for Papers Issued for NBS/ANSI Symposium

Proceedings of Fire Safety Research Symposium Available

Metric Kit Published

New Data on Methane

Particle Accelerator Facilities Upgraded

WWV/WWVH Users Queried

April 1975

DIM/NBS 59, No. 4, 73-96 (1975).

Key words: buildings; computers; computer codes; computer networks; copyrights; energy; epoxies; hazard; metric conversion; piezoelectric accelerometers; sun.

Computer Networks Are Here

There's More to Comfort Than Hot Air

Laser-Induced Photochemical Enrichment of Isotopes

NBS Tests Epoxies to Protect Bridges

Harnessing the Sun

Highlights

Managing Information as a Resource

Effects on Piezoelectric Accelerometers Determined

NBS to Study Computers and Copyrights

New Standards for Computer Codes and Controls

Revised Bill for Voluntary Metric Conversion Submitted to Congress

Natural Hazard Evaluation of Existing Buildings

Publications

May 1975

DIM/NBS 59, No. 5, 97-120 (1975).

Key words: air pollution; camera guidelines; computerized elections; dental fillings; metre; ozone problem; police communications; water pollution; x rays.

NBS Proposes Guidelines for Computerized Elections

New Air Pollution Standards Developed by NBS

The Treaty of the Metre 1875-1975

Beyond X-Rays

A Look at the Ozone Problem

Highlights

ETIP, Utility Commissions and Policy Experiments

Instrument Evaluates Wear of Dental Filling Materials

Surveillance Camera Guideline to Help Cut Thefts

NBS Tests "Little Box" That Speeds Police Communications

New NBS Mercury Standards Will Aid Water Pollution Studies

Publications

June 1975

DIM/NBS 59, No. 6, 121-144 (1975).

Key words: air conditioners; appliance; bone cement; computer; energy; energy labels; fire fatalities; hydrogen fuel; magnetohydrodynamics; metric changeover; safety.

More on the Metric Changeover

New Insights on the Causes of Fire Fatalities

Magnetohydrodynamics – An Old Idea with More Power to It

You, the Computer and Our Society in the Next Two Decades

Mobile Home Safety, Durability Studied

Highlights

Bone "Cement" Characterized

Major Appliance Manufacturers Support Energy Efficiency Program

Hydrogen Fuel Topics Published

Check Energy Labels on Room Air Conditioners

Publications

July 1975

DIM/NBS 59, No. 7, 145-168 (1975).

Key words: air conditioners; buses, subway cars; centennial; electric power; environment; ethane data; facilities; fire research; fire safety; graffiti; product standards; programming language.

Banking the Environment

NBS Studies Ways to Prevent and Remove Graffiti

Monitoring Electric Power Network for Dollar Savings and Quality Control

NBS Tests Buses, Subway Cars for Fire Safety

Product Standards for a Summer Afternoon

Highlights

Centennial Volume Published

Equipment, Facilities for Shared Use

Fire Research Programs Outlined

Computer Symposium Planned

New Air Conditioners Save Energy, Money

Ethane Data Available

Standard for APT Programming Language

Publications

August 1975

DIM/NBS 59, No. 8, 169-192 (1975).

Key words: auto fuels; energy; highway safety; lead; pressure transducer; railway safety; silicon devices; water heaters; windowless buildings.

Working for Railway Safety

A New Look at the View From Within

NBS Brightens the Way for Highway Safety

Making the Most of Your Energy Dollars

Highlights

Surface Analysis for Silicon Devices

Energy-Efficient Water Heaters to Save Money

Pressure Transducer Service Available

Measuring Lead in Auto Fuels

Publications

September 1975

DIM/NBS 59, No. 9, 193-216 (1975).

Key words: computer; cryogenic; cryptography; data; energy labeling; energy needs; fluid safety; materials; NBS, GSA experiment; optical spectra; plastic pipes; thermal conductivity.

Data Protection Through Cryptography

Determining the Effect of Weather on Building Materials

Plastic Pipes, Pros and Cons

October 1975

November 1975

December 1975

DIMENSIONS/NBS, ARTICLE TITLES ONLY

This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS.

DIMENSIONS/NBS highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, DIMENSIONS/NBS reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing. Issued monthly.

January 1976

DIM/NBS 60, No. 1, 1-24 (1976).

Key words: computer; energy measurement; EPIC; FIPS; kitchen ranges; mercury; metal fires; metric; safety; WWV/WWVH.

NBS Develops New Mercury Monitor
An EPIC Undertaking: Out of the Classroom, Into the Plant
Metal Fires – Science and Safety
Government Primes the Industrial Pump
WWV/WWVH User's Guide Published by NBS
DOC-GSA Cooperate in Purchase of More Efficient Kitchen Ranges
NBS Makes Computer Network Access Easier
Complete Set of FIPS Available from NBS
NBS, EPRI Sign Cooperative Agreement on Energy Measurement Technology
NBS Establishes Speakers Bureau for Metric Information

February 1976

DIM/NBS 60, No. 2, 1-25 (1976).

Key words: computer systems; environmental; fire; glass door; lead nitrate; mercury thermometers; metric; nuclear power; police radars; solar energy; SRM's.

The Unseen Menace: A Glass Door
America Joins a Metric World
Computer Systems of the 1980's
Mercury Thermometers – Are They Becoming Antiques?
Highlights
Evaluating Economic Performance of Solar Energy Systems
Papers Solicited for Major Environmental Conference
Lead Nitrate SRM Now Available
Lag Time for Nuclear Power Plant Standards
Fire Symposium Scheduled as 75th Anniversary Event
Simple Calibration System for Police Radars Developed by NBS

March 1976

DIM/NBS 60, No. 3, 1-24 (1976)

Key words: batteries; dental materials; industry; integrated utilities system; mass spectrometry; motorized criminal; ozone puzzle; portable transceiver batteries; RF power meter; utilities system.

Catching the Motorized Criminal Scientifically
Another Piece of the Ozone Puzzle
Better Dental Materials Mean Fewer Trips to the Dentist
NBS RAPS With Industry
Highlights
University of Florida, Gainesville, Selected to Test Integrated Utilities System Concepts

NBS Issues Privacy Act Index
New Publication Available on Secondary Ion Mass Spectrometry
Standard Issued for Police Portable Transceiver Batteries
New RF Power Meter Design Available to Manufacturers
Publications

April 1976

DIM/NBS 60, No. 4, 1-24 (1976).

Key words: cryogenic fluid; door locks; energy; EPIC supplement; high winds; home security; nondestructive evaluation; research associate program; school systems; smoke detectors; teaching metric.

Houses vs. High Winds
Life-Saving Investments – Smoke Detectors for the Home
NBS Nondestructive Evaluation Program
Home Security Starts at Your Door
Highlights
Metric Activity Continues to Accelerate in Nation's School Systems
Successes in Teaching Metric Described in Publication
Supplement to Energy Saving Handbook, EPIC, Available
NBS Issues Aids for COBOL Program Conversion
Key to Data on Cryogenic Fluid Mixtures Published
New Research Associate Program for Metal SRM's
Publications

DIM/NBS 60/Suppl., Anniversary Issue, 1-32 (1976).

Key words: computer age; data system; materials research; measurement challenge; science and technology; sea of data; standard reference data system.

"Let Us Raise a Standard to Which the Wise and Honest Can Repair"
Meeting the Measurement Challenge
NBS Through the Years
75 Years of Progress Through Materials Research
Science and Technology for People
Standards for a Computer Age
Staying Afloat in a Sea of Data: National Standard Reference Data System

May 1976

DIM/NBS 60, No. 5, 1-24 (1976).

Key words: building collapse; corrosion; energy; environmental; frequency standards; hearing aids; high-rise buildings; metals; radiation safety; standards laboratory; synchrotron.

Listen Closely – Testing Hearing Aids for Veterans
A Sage of Radiation Safety

June 1976

DIM/NBS 60, No. 6, 1-24 (1976).

Key words: air conditioners; attic fans; basic research; chemical thermodynamics; door security; Elliot Richardson; energy conservation; engineering; fashion; flammability; laser measurement; science.

July 1976

DIM/NBS 60, No. 7, 1-24 (1976).

Key words: bike regulations; bomb disarmament; computer auditing; energy options; explosive vapor detectors; firebug; impulse generators; MHD electrode materials; optical standards; safety wheels.

August 1976

DIM/NBS 60, No. 8, 1-24 (1976).

Key words: architectural heritage; fire; guardrail; high-capacity; mathematics; mercury; performance standard; pressure transducers; SRM; surgical implants; testing; thermal transients.

September 1976

DIM/NBS 60, No. 9, 1-24 (1976).

Key words: computer; consumer; drugs; electrical pulses; environmental standards; friction measurement; lead poisoning; LNG data; optical; standard reference materials; thermophysical properties symposium; waste heat.

October 1976

DIM/NBS 60, No. 10, 1-24 (1976).

Key words: building industry; calibration system; centigrade/celsius; computer; electrical industries; environments; glass standards; government intervention; heating/cooling; lead-paint; metric; pressure transducers; thermal comforts; weights and measures.

November 1976

DIM/NBS 60, No. 11, 1-24 (1976).

Key words: computer power; computer standard; corrosion; environment; health care; housing production; I-R 100 awards; NIKE missile; papers available; stereology; toy safety; x-ray units.

December 1976

DIM/NBS 60, No. 12, 1-24 (1976).

Key words: air; building codes; computer tapes; energy; fire; helmets; mobile homes; phase diagrams; tire pressure.

3.6. MONOGRAPHS

Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities. Until July 1959 most of this type of material was published in the Circular series. The abbreviation for the Monograph Series was changed from Mono. to Monogr. in 1968.

Mono. 25, Section 5. **Standard x-ray diffraction powder patterns. Section 5.-Data for 80 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, and E. H. Evans, NBS Mono. 25, Section 5 (Aug. 31, 1967).

Key words: Constants; crystal; lattice; measurements; powder-patterns; reference-intensities; standard; structure; x-ray diffraction.

Standard x-ray diffraction powder patterns are presented for 80 substances. Thirty-nine of these patterns represent experimental data and 41 are calculated. The experimental x-ray powder diffraction patterns are made with a Geiger counter x-ray diffractometer, using samples of high purity. All d-values were assigned Miller indices determined by comparison with theoretical interplanar spacings and from consideration of space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were obtained from published crystal structure data. The reported peak height intensities for calculated patterns were converted from integrated intensities.

Reference intensity values based upon the strongest line of corundum (113) in a 50 percent weight mixture are given for 73 materials.

Monogr. 25, Section 6. **Standard x-ray diffraction powder patterns, Section 6.-Data for 60 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, and E. H. Evans, Nat. Bur. Stand. (U.S.), Monogr. 25, Sec. 6, 101 pages (June 1968).

Key words: Constants; crystal; lattice; measurements; powder-patterns; reference-intensities; standard; structure; x-ray diffraction.

Standard x-ray diffraction powder patterns are presented for 60 substances. Fifty-four of these patterns represent experimental data and 6 are calculated. The experimental x-ray powder diffraction patterns are made with a Geiger counter x-ray diffractometer, using samples of high purity. All d-values were assigned Miller indices determined by comparison with theoretical interplanar spacings and from consideration of space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were obtained from published crystal structure data. The reported peak height intensities for calculated patterns were converted from integrated intensities.

Reference intensity values based upon the strongest line of corundum (113) in a 50 weight percent mixture are given for 98 materials.

Monogr. 25, Section 7. **Standard x-ray diffraction powder patterns, Section 7.-Data for 81 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, and E. H. Evans, Nat. Bur. Stand. (U.S.), Monogr. 25, Sec. 7 (Sept. 1969).

Key words: Crystal structure; integrated intensities; latttice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction powder patterns are presented for 81 substances. Forty-five of these patterns represent experimental data and 36 are calculated. The experimental x-ray powder diffraction patterns were obtained with a Geiger or proportional counter x-ray diffractometer, using samples of high purity. All d-values were assigned Miller indices determined by comparison with computed interplanar spacings and consideration of space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr. 25, Section 8. **Standard x-ray diffraction powder patterns, Section 8. – Data for 81 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, and E. H. Evans, Nat. Bur. Stand. (U.S.), Monogr. 25, Sec. 8, 171 pages (Sept. 1970).

Key words: Crystal structure; integrated intensities; lattice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 81 substances. Fifty-three of these patterns represent experimental data and 28 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer, using samples of high purity. All d-values were assigned Miller indices determined by comparison with computed interplanar spacings consistent with space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities were reported for the calculated patterns.

Monogr. 25, Section 9. **Standard x-ray diffraction powder patterns. Section 9. – Data for 63 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, E. H. Evans, and B. Paretzkin, Nat. Bur. Stand. (U.S.), Monogr. 25 – Sec. 9, 128 pages (Dec. 1971).

Key words: Crystal structure; integrated intensities; lattice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 63 substances. Forty of these patterns represent experimental data and 23 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer. All *d*-values were assigned Miller indices determined by comparison with computer interplanar spacings consistent with space group extinctions. The densities and lattice constants were calculated and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr. 25, Section 10. **Standard x-ray diffraction powder patterns. Section 10 – Data for 84 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, E. H. Evans, B. Paretzkin, J. H. deGroot, and S. J. Carmel, Nat. Bur. Stand. (U.S.), Monogr. 25, Sec. 10, 161 pages (Nov. 1972).

Key words: Crystal structure; integrated intensities; lattice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 84 substances. Forty-seven of these patterns represent experimental data and 37 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer. All d-values were assigned Miller indexes determined by comparison with computed interplanar spacings consistent with space group extinctions. The densities and lattice constants were calculated, and the refractive indexes were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr. 25, Section 11. **Standard x-ray diffraction powder patterns. Section 11-data for 70 substances,** H. E. Swanson, H. F. McMurdie, M. C. Morris, E. H. Evans, B. Paretzkin, J. H. de Groot, and S. J. Carmel, Nat. Bur. Stand. (U.S.), Monogr. 25-Sec. 11, 134 pages (Feb. 1974) SD Catalog No. C13.44:25/Sec. 11.

Key words: crystal structure; integrated intensities; lattice constants; peak intensities, powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 70 substances. Fifty-two of these patterns represent experimental data and 18 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer. All d-values were assigned Miller indices determined by comparison with computer interplanar spacings consistent with space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr. 25, Section 12. **Standard x-ray diffraction powder patterns. Section 12-data for 57 substances,** H. F. McMurdie, M. C. Morris, E. H. Evans, B. Paretzkin, J. H. de Groot, C. R. Hubbard, and S. J. Carmel, Nat. Bur. Stand. (U.S.), Monogr. 25-Sec. 12, 90 pages (Feb. 1975) SD Catalog No. C13.44:25/Sec. 12.

Key words: crystal structure; integrated intensities; lattice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 57 substances. Twenty-five of these patterns represent experimental data and 32 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer. All d-values were assigned Miller indices determined by comparison with computed interplanar spacings consistent with space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr. 25, Section 13. **Standard x-ray diffraction powder patterns. Section 13—Data for 58 substances,** M. C. Morris, H. F. McMurdie, E. H. Evans, B. Paretzkin, J. H. de Groot, C. R. Hubbard, and S. J. Carmel, *Nat. Bur. Stand. (U.S.), Monogr. 25, Sec. 13,* 114 pages (June 1976) SD Catalog No. C13.44:25/Sec. 13.

Key words: crystal structure; integrated intensities; lattice constants; peak intensities; powder patterns; reference intensities; standard; x-ray diffraction.

Standard x-ray diffraction patterns are presented for 58 substances. Thirty-one of these patterns represent experimental data and 27 are calculated. The experimental x-ray powder diffraction patterns were obtained with an x-ray diffractometer. All d-values were assigned Miller indices determined by comparison with computed inter-planar spacings consistent with space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were computed from published crystal structure data. Both peak height and integrated intensities are reported for the calculated patterns.

Monogr.27 & all Supplements superseded by Special Publication 373.

Monogr.32. Pts. 1 & 2 superseded by Monograph 145.

Mono. 61. **The solar spectrum 2935 Å to 8770 Å. Second revision of Rowland's preliminary table of solar spectrum wavelengths,** C. E. Moore, M. G. J. Minnaert, and J. Houtgast. NBS Mono. 61 (Dec. 1966).

Key words: Elements in sun; equivalent widths of solar lines; identification of solar lines; molecules in sun; solar spectrum; wavelengths of solar lines.

The present compendium of solar spectrum wavelengths and intensities is essentially a second revision of Rowland's Table, corrected and supplemented by material from the Utrecht Photometric Atlas. Approximately 24,000 lines are listed. In a number of cases new wavelengths were determined. Measured equivalent widths from the Atlas records replace the Rowland estimated line intensities recorded in the 1928 revision. From these directly measured equivalent widths have been derived reduced widths, which, if necessary, were corrected for disturbing influences. The intensity behavior of atomic lines in the spot spectrum as compared with the spectrum of the solar disk is indicated by letters denoting strengthening, weakening, and the like. Atomic lines present only in the spot spectrum are, also, included, 223 in all.

Revised identifications of the lines, as to chemical origin, are given for both atomic and molecular lines. For classified atomic lines the lower excitation potential and multiplet number are listed. For molecular lines the rotation branch and quantum number, and the vibration band are indicated. Note numbers refer to notes in which the complete designation of the band is given.

An introductory text gives a detailed description of each column of the solar ledger. Figures are included to illustrate the procedure used to derive the observed equivalent widths $\Delta\lambda$(mÅ) and the reduced widths $\Delta\lambda/\lambda$(F).

Tables include counts of lines of each spectrum recorded in the identification column, leading lines in the first and second spectra, and summaries of molecules and elements present in the sun. About 73 percent of the lines are wholly or partially identified. Sixty-three elements are recorded as present. A number need further study. The number of molecules identified in the sun totals 11.

Monogr. 70, Volumes I and II. See Nat. Bur. Stand. (U.S.), Misc. Publ. Suppl. to 240, 757 pages (Apr. 1967).

Monogr. 70, Volume III. **Microwave spectral tables. Volume III. Polyatomic molecules with internal rotation,** P. F. Wacker, M. S. Cord, D. G. Burkhard, J. D. Petersen, and R. F. Kukol, Nat. Bur. Stand. (U.S.), Monogr. 70, Vol. III, 275 pages (June 1969).

Key words: Barrier height; centrifugal distortion constant; coherent radiation technique; dipole moment; hindered rotation; internal rotation; microwave spectra; molecular spectra; polyatomic molecules; quadrupole coupling constants; rotational constant; spectral lines.

Measured frequencies, assigned molecular species, and assigned quantum numbers are given for about 9,000 spectral lines of polyatomic molecules with internal rotation observed by coherent radiation techniques. Molecular data, such as rotational constants, dipole moments, and various coupling constants, determined by such techniques, are also tabulated. References are given for all included data.

Monogr. 70, Volume IV. **Microwave spectral tables. Volume IV. Polyatomic molecules without internal rotation,** M. S. Cord, J. D. Petersen, M. S. Lojko, and R. H. Haas, Nat. Bur. Stand. (U.S.), Monogr. 70, Vol. IV, 429 pages (Oct. 1968).

Key words: Centrifugal distortion constant; coherent radiation technique; dipole moment; l-doubling; microwave spectra; molecular spectra; polyatomic molecules; quadrupole coupling constants; rotational constant; spectral lines.

Measured frequencies, assigned molecular species, and assigned quantum numbers are given for about 14,000 spectral lines of polyatomic molecules without internal rotation observed by coherent radiation techniques. Molecular data, such as rotational constants, dipole moments, and various coupling constants, determined by such techniques, are also tabulated. References are given for all included data.

Monogr. 70, Volume V. **Microwave spectral tables. Volume V. Spectral line listing,** M. S. Cord, M. S. Lojko, and J. D. Petersen, Nat. Bur. Stand. (U.S.), Monogr. 70, Vol. V, 538 pages (June 1968).

Key words: Diatomic molecules; hyperfine; microwave spectra; molecular spectra; polyatomic molecules; rotational quantum numbers; spectral lines.

This volume is a listing of the spectral lines reported in Volumes I, III, and IV of the Microwave Spectral Tables. These lines are listed according to ascending magnitude of frequency and should provide a ready reference.

Mono. 75. **Colors of signal lights: Their selection, definition, measurement, production, and use,** F. C. Breckenridge, NBS Mono. 75 (Apr. 3, 1967).

Key words: Colors; lights; signal lights.

This Monograph is intended to serve as a reference work for all those concerned with the selection, specifications, and use of signal-light colors. It discusses the nature of the problem, and the mathematical representation, recognition, production, control, and use of such colors. The characteristics of different types of chromaticity boundaries and the purpose and effect of the requirement for similarity of chromaticity characteristics are given special consideration. The treatment is varied according to the intended use. The discussion of the control of colors and the section on the use of colors are nontechnical, whereas the section on the production of signal colors is designed for the colorimetrist who is faced with the problem of selecting limit filters or drafting a specification.

Mono. 88. **Heat treatment and properties of iron and steel,** T. G. Digges, S. J. Rosenberg, and G. W. Geil, NBS Mono. 88 (Nov. 1, 1966).

Key words: Annealing; case hardening; chemical composition; hardening; heat treatment; Ni-maraging steels; normalizing; stainless steels; structural steels; surface hardening; tempering; tool steels.

This Monograph is a revision of the previous NBS Monograph 18. Its purpose is to provide an understanding of the heat treatment of iron and steels, principally to those unacquainted with this subject. The basic principles involved in the heat treatment of these materials are presented in simplified form. General heat treatment procedures are given for annealing, normalizing, hardening, tempering, case hardening, surface hardening, and special treatments such as austempering, ausforming, martempering and cold treatment. Chemical compositions, heat treatments, and some properties and uses are presented for structural steels, tool steels, stainless and heat-resisting steels, precipitation-hardenable stainless steels and nickel-maraging steels. (Supersedes NBS Circ. 495 and NBS Mono. 18).

Mono. 97. **Microwave attenuation measurements and standards,** R. W. Beatty, NBS Mono. 97 (Apr. 3, 1967).

Key words: Microwave; attenuation; measurements; standards; tutorial.

A comprehensive and commentarial review of microwave attenuation measurement methods and standards is presented. In addition, a relatively new and more precise way of representing and analyzing an attenuation measurement is presented. This in turn permits more rigorous definitions and error analyses than were previously possible. Expressions for both mismatch and connector errors are presented.

The referral of microwave attenuation measurements to standards operating at lower frequencies is discussed with particular attention to the errors in the referral processes as well as the errors in the standards themselves. Standards operating at d-c, audio frequencies, and higher frequencies are included in this discussion which covers waveguide-below-cutoff attenuators and rotary vane attenuators.

Desirable characteristics are listed for attenuators which are suitable for calibration, and examples of these are given.

Measurement methods are classified and described, giving greatest emphasis to the intermediate-frequency substitution method using a waveguide-below-cutoff standard attenuator, and to d-c substitution techniques. Methods for measurement of small attenuations as well as methods not requiring reference to any standard attenuators are covered.

Comments are made on the accuracy and convenience of various methods, and references are given which cover most of the basic and important research in this field.

Mono. 98. **Abscissas and weights for Gaussian Quadrature for N=2 to 100, and N=125, 150, 175, and 200,** C. H. Love, NBS Mono. 98 (Dec. 28, 1966).

Key words: Integration; Gaussian; Quadrature.

The abscissas and weights for Gaussian Quadrature of order N=2 to 100 and N=125, 150, 175 and 200 are given. The abscissas are given to twenty-four places and the error is estimated to be no more than one unit in the last place. The weights are given to twenty-three places and the error is estimated to be no more than one unit in the last place.

Mono. 99. **Automatic typographic-quality typesetting techniques: A state-of-the-art review,** M. E. Stevens and J. L. Little, NBS Mono. 99 (Apr. 7, 1967).

Key words: Automated type composition; computerized typesetting; graphic arts; photocomposition; printing and publication.

This report describes the current state-of-the-art in automation of graphic arts composition, starting from either of two sources: (1) keyboard entry of manuscript material, or (2) mechanized input in the form of available perforated tapes or magnetic tapes. The gamut is covered from one extreme in which a skilled keyboard operator performs all of the compositor functions required to operate a typesetting machine, to the other extreme in which the input merely provides text whether or not including designation of desired font changes, followed by a high degree of automation through all operations leading to type set for printing. Intermediate automation aids for the compositor functions, including characteristics of special-purpose digital computers and functions performed by typography programs for general-purpose digital computers, are reviewed.

Characteristics of automatically operated typesetting mechanisms, including hot metal casting machines and photocomposers, slow, medium and high speed, are outlined. Applications of new techniques for typographic-quality automated composition that are of interest in scientific and technical information centers, libraries and other documentation operations include sequential card camera listings, computer-generated KWIC indexes, photocomposition of technical journals, automatic composition of books containing both computer-produced tabular data and natural language texts, and the incorporation of mechanized processes throughout the publication cycle from the author's original manuscript preparation to the final printing. A bibliography of 363 references is included.

Mono. 100. **Trace characterization. Chemical and physical,** Editors, W. W. Meinke and B. F. Scribner, NBS Mono. 100 (April 28, 1967).

Key words: Electrochemical methods; electron and optical microscopy; nuclear methods; optical spectroscopy; symposium on trace characterization; trace characterization; x-ray spectroscopy.

A symposium on Trace Characterization, Chemical and Physical was held at the National Bureau of Standards October 3-7, 1966. This volume contains the texts of invited lectures, and summaries by the rapporteurs of the contributed papers and discussion sessions. Topics covered include trace characterization and the properties of materials; electrical measurements; electrochemical methods; optical and x-ray spectroscopy; x-ray diffraction; optical methods; chemical spectrophotometry; nuclear methods; mass spectroscopy; preconcentration; sampling and reagents; and electron and optical microscopy.

Mono. 101. **Low-temperature mechanical properties of copper and selected copper alloys. A compilation from the literature,** R. P. Reed and R. P. Mikesell, NBS Mono. 101 (Dec. 1, 1967).

Key words: Compilation; copper; copper alloys; low temperature; mechanical properties.

In the past 60 years considerable data has accumulated concerning the mechanical properties of copper and its alloys. It was felt that there was a great need to adequately document these results in one publication. Therefore a unique type of compilation is presented. The compilation is divided into four parts. The first section is intended for quick reference use for those who are interested in average values. The second section includes data from most of the investigators who have published results on the mechanical properties of copper and its alloys. The third section is composed of tables classifying the investigations which were not included in section two. These usually involve investigations in which data were obtained only at one temperature, such as room temperature. The fourth section lists, in alphabetical order, all references used.

Mono. 102. **Effects of finite lattice heat capacity on spin-lattice relaxation. Theory and numerical analysis,** R. L. Peterson, NBS Mono. 102 (Aug. 1, 1967).

Key words: Spin-lattice relaxation; phonon bottleneck; phonon-boundary scattering; spin-phonon interactions.

The transient magnetic behavior of a paramagnetic substance, after an initial disturbance, is considered theoretically for a variety of situations in which the lattice temperature rises as a result of energy flow from the magnetic (electron spin) system. The relaxation mechanisms considered are the direct process, involving interaction between spins and the resonant-phonon modes, and a T^9 Raman process, involving the remaining phonon modes. It is first assumed that the resonant and remaining modes are strongly coupled to each other, and that the helium bath has been removed (helium temperatures are assumed). The resulting transient behavior typically does not differ much from exponential relaxation (the rate increases somewhat during the relaxation), but the difference should be experimentally observable, particularly if the resonance line is inverted initially.

Next, the opposite extreme is considered--that in which the resonant and remaining modes are totally uncoupled; the helium bath is again assumed to have been removed. Two dramatic effects can then occur, depending upon initial conditions. One is the rapid decay to saturation from initial inversion, due to an avalanching creation of resonant phonons by the spins. The second is the pronounced inhibition of the subsequent decay, with the spins remaining near saturation. This decay rate is typically very much slower than the Raman rate, and is due to the flow of the resonant-phonon energy back into the spin system as the spin energy flows into the remaining lattice. Eventually the rate increases to the Raman rate characteristic of the final lattice temperature. Because of inelastic phonon scattering at crystal boundaries, which couples the phonon modes together, this effect of inhibited decay may be difficult to observe.

Finally, we consider the case of spins coupled only to the resonant phonons, which in turn are coupled to a constant temperature bath, whether this be the helium or the remaining modes. Recent phonon avalanche experiments are discussed in this context. It is pointed out that such experiments, performed in the absence of a bath, may provide a reliable measurement of inelastic phonon-boundary scattering.

Mono. 103. **Realistic uncertainties and the mass measurement process. An illustrated review,** P. E. Pontius and J. M. Cameron, NBS Mono. 103 (Aug. 15, 1967).

Key words: Accuracy; mass measurement; measurement; measurement process; precision; statistical control; uncertainty.

This paper gives a review of the concepts and operations involved in measuring the mass of an object. The importance of viewing measurement as a production process is emphasized and methods of evaluating process parameters are presented. The use of one of the laboratory's standards as an additional unknown in routine calibration provides an accuracy check and, as time goes on, the basis for precision and accuracy statements.

Monogr. 104. **Colorimetry,** I. Nimeroff, Nat. Bur. Stand. (U.S.), Monogr. 104, 50 pages (Jan. 1968).

Key words: Color dictionaries; color vision; colorimeters; photoelectric tristimulus; spectrophotometric colorimetry; visual colorimetry.

The definition of color, as a characteristic of light, and the basic principles of its measurement are given. The reduction of spectrophotometric data to three chromaticity coordinates by means of the three-function CIE standard observer system for colorimetry is described. Various methods of direct colorimetry, and visual and photoelectric methods of colorimetry by differences from material standards are treated. The most useful collections of material color standards are described and the most widely used one-dimensional color scales are explained. The limitations of several colorimetric methods: spectrophotometric, photoelectric, and visual, are discussed. (Supersedes NBS Circ. 478).

Monogr. 105. **Acid-base behavior in aprotic organic solvents,** M. M. Davis, Nat. Bur. Stand. (U.S.), Monogr. 105, 156 pages (Aug. 1968).

Key words: Acid-base behavior; acidity and basicity scales; aprotic organic solvents; hydrogen bonding; titrations.

A unified picture of acid-base behavior in aprotic organic solvents is presented, based on an extensive survey of the literature and experimental results of the author and associates. Evidence given to support this picture includes data pertaining to colligative properties of acids, bases, and salts and also conductance, dielectric constants, distribution between immiscible solvents, and spectral absorption in the infrared, visible, and ultraviolet. The acids upon which attention is centered are proton-donor compounds that are measurably ionized in water, such as aliphatic and aromatic carboxylic acids, substituted phenols, and mineral acids. The bases of principal interest are likewise compounds capable of forming ions in water, for example, aliphatic and aromatic amines and derivatives of guanidine or pyridine. The solvents emphasized are hydrocarbons and halohydrocarbons, but data for dipolar aprotic solvents (for example, acetone, acetonitrile, and nitrobenzene) are included. Contrasts in acid-base behavior and in acidity and basicity scales in aprotic and water-like solvents are discussed.

The role of hydrogen bonding in aprotic solvents is discussed at length. Important types of hydrogen-bonded structures include chelate rings; self-associated acids, bases, and salts; hydrogen-bonded ion pairs; and homo- and heteroconjugate cations and anions. Examples are given in which hydrogen bonding of these types affects such properties as the absorption spectrum of a salt, the catalytic effect of an acid, and the accurate location of a titration endpoint.

Monogr. 106. **Nickel and its alloys,** S. J. Rosenberg, Nat. Bur. Stand. (U.S.), Monogr. 106, 160 pages (May 1968).

Key words: Alloys; corrosion-resisting alloys; copper-nickel alloys; electroplating; electrical resistance alloys; heat resisting alloys; magnetic alloys; maraging steels; nickel; stainless steels; steels.

This monograph reviews available information on the production, properties, and uses of high-purity and commercial forms of nickel, and on the properties and applications of its important alloys, both ferrous and nonferrous. It is a revision of National Bureau of Standards Circular 592, issued in 1958. (Supersedes NBS Circ. 592.)

Monogr. 107. **Acceleration due to gravity at the National Bureau of Standards,** D. R. Tate, Nat. Bur. Stand. (U.S.), Monogr. 107, 24 pages (June 1968).

Key words: Absolute gravity; acceleration; free-fall; *g*; gravity; Potsdam.

A determination of the absolute value of the acceleration due to gravity was completed in June 1965 at the National Bureau of Standards near Gaithersburg, Maryland. The determination resulted in a value of 980.1018 centimeters per second squared for a reference point on the first floor of the Engineering Mechanics Building. The result was published in the Journal of Research of the National Bureau of Standards, Vol. **70C,** No. 2, Engineering and Instrumentation, page 149, April-June 1966. The present paper describes in detail the apparatus and the techniques employed and presents the summarized data from which the value was derived.

Monogr. 108. **Oscillator strengths and transition probabilities for 3288 lines of Fe I (2100-9900 Å),** C. H. Corliss and J. L. Tech, Nat. Bur. Stand. (U.S.), Monogr. 108, 68 pages (Mar. 1968).

Key words: Fe I; iron; oscillator strengths; spectrum; spectrum of neutral iron; transition probabilities in Fe I.

A homogeneous set of intensity-related data has been calculated for 3288 spectral lines of Fe I in the region from 2100 to 9900 angstroms. The quantities tabulated in the present monograph include log ($gf\lambda$), log (gf), gf, f, gA, and A. The data are presented on the absolute scale established in a previous work by Corliss and Bozman. In that work and the later extensions of it by Corliss and Warner, the calculation of gf-values included the application of an empirically determined normalization correction to the level populations, the normalization being given as a function of upper energy level for the transition. Since recent investigations do not support these excitations corrections in the case of Fe I and certain other spectra, the present tabulation incorporates a removal of that normalization function. This recalculation affects the values for all lines whose upper energy levels lie above 46000 cm^{-1} and should significantly improve the internal consistency of the present data.

Monogr. 109. **Investigation of the exploding wire process as a source of high temperature studies,** E. C. Cassidy, S. Abramowitz, and C. W. Beckett, Nat. Bur. Stand. (U.S.), Monogr. 109, 53 pages (Nov. 1968).

Key words: Electrical discharges; exploding wire; high current; high speed; high speed photography; high temperature; high voltage; light sources; time-resolved electrical measurements; time-resolved spectroscopy.

Numerous experiments with electrically exploded wires are described. The results include time-resolved measurements of electrical energy, power, voltage, and current during the discharge; periodic still and high-speed photographs of the entire explosion process; integrated and time-resolved measurements of the intensity and spectral distribution of the radiation emitted; and time-resolved absorption spectra from the products of the discharge, with emphasis on observations of the spectrum of the AlO molecule. The apparatus, instrumentation, and fast-measurement techniques developed in order to permit these direct experimental observations and measurements, under the extreme and transient conditions of the explosive discharge, are also described. Results from calculations of the composition, entropy, enthalpy, and density of the explosion mixture are given.

Monogr. 110. **Infrared spectroscopy of carbohydrates. A review of the literature,** R. S. Tipson, Nat. Bur. Stand. (U.S.), Monogr. 110, 24 pages (June 1968).

Key words: Analysis; carbohydrates; conformations; infrared spectra; spectrometry; structure.

A survey has been made of the literature on the infrared spectroscopy of carbohydrates, in order to assemble and systematize information in this field. The Monograph discusses principles and instrumentation, sampling techniques, comparison of samples, and the interpretation of the spectra, particularly as regards functional groups of carbohydrates and their derivatives, correlations for the fingerprint region and beyond, and conformational studies. In addition, examples are discussed of the use of infrared spectra for qualitative and quantitative purposes and in the determination of structure. Special techniques are briefly described, including use of plane-polarized radiation, the technique of attenuated total reflection, and Raman spectra.

Monogr. 111. **Technology of liquid helium,** R. H. Kropschot, B. W. Birmingham, and D. B. Mann, Editors, Nat. Bur. Stand. (U.S.), Monogr. 111, 380 pages (Oct. 1968).

Key words: Conservation; cryoelectronics; cryogenics; cryopumping; helium; liquefaction; magnets; purification; refrigeration; safety; storage; thermodynamic properties; transportation.

The discovery of the element helium was made just 100 years ago in 1868. Today helium is produced in large quantities and used in many technological applications. This treatise is a source document containing information on helium resources, production, conservation, themodynamic properties, liquefaction and refrigeration techniques, transportation and storage of liquid and safety requirements. It also contains a discussion of uses for liquid and cold gas in cryoelectronics, superconductivity, bubble chambers, cryopumping and missile and space systems. The book brings together articles by noted authorities in cryogenic technology in which they discuss their specialized field in great depth.

Monogr. 112. **An introduction to the description and evaluation of microwave systems using terminal invariant parameters,** G. F. Engen, Nat. Bur. Stand. (U.S.), Monogr. 112, 27 pages (Oct. 1969).

Key words: Attenuation; impedance; microwave power; precision connector; terminal invariant.

The description and evaluation of microwave systems is usually by means of microwave circuit analysis, which may be regarded as an extension of the practice at lower frequencies. In order to insure its validity, it is necessary to postulate that the different components, which comprise the microwave system, are interconnected via uniform and lossless waveguide, and which is usually (but not necessarily) restricted to single mode operation. As a consequence, precision (uniform) waveguide and connectors are usually considered necessary elements for an accurate experimental evaluation of a microwave system.

It is possible to avoid this requirement in an alternative formulation where the description is based upon net power, instead of the complex traveling wave amplitudes. In this reformulation the basic parameters include available power, maximum efficiency (or intrinsic attenuation), and several different "mismatch factors." The important feature of these parameters is their "terminal invariant" property, i.e., their invariance to an arbitrary shift in the terminal reference surface (in an assumed lossless region).

In this way the precision waveguide and connector requirement is avoided for an important class of measurement problems. In addition the physical model, upon which the description is based, is a simple one which provides improved insight into mismatch errors and corrections.

Monogr. 113, Volume 1. **Research and development in the computer sciences. 1. Information acquisition, sensing, and input: A selective literature review,** M. E. Stevens, Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 1, 170 pages (Mar. 1970).

Key words: Audio inputs; automatic pattern recognition; character recognition; communication systems; data transmission; graphic inputs; image enhancement; remote sensing; source data automation; speech recognition.

This report, the first of a projected series on research and development efforts and requirements in the computer and information sciences, is concerned with a selective literature review involving the operations of information acquisition, sensing, and input to information processing systems considered in generalized terms. Specific topics include but are not limited to: source data automation and remote sensing techniques, communication systems and data transmission links, audio and graphic inputs, preprocessing operations upon input items such as image enhancement and property filtering, character recognition, speech recognition, and various other aspects of automatic pattern recognition. Supplemental notes and a bibliography of over 640 cited references are included.

Monogr. 113, Volume 2. **Research and development in the computer and information sciences. 2. Processing, storage, and output requirements in information processing systems: A selective literature review,** M. E. Stevens, Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 2, 125 pages (May 1970).

Key words: Computer-assisted-instruction; information display; information recording; machine-aided design; memory allocation; microforms; multiple-access systems; on-line systems; output modes; photocomposition and typesetting; storage hierarchies; time sharing.

Areas of concern with respect to processing, storage, and output requirements of a generalized information processing system are considered. Special emphasis is placed on multiple-access systems. Problems of system management and control are discussed, including hierarchies of storage levels. Facsimile, digital, and mass random access storage media and techniques are considered. A variety of output mode requirements are also considered, including direct recording to microforms; on-line display systems; printing, photocomposition, and automatic character generation; and three-dimensional, color, and other special-purpose display systems. Problems of system use and evaluation are also briefly noted. A bibliography of approximately 480 cited references is included, together with supplemental notes and quotations from the literature.

Monogr. 113, Volume 3. **Research and development in the computer and information sciences. 3. Overall system design considerations: A selective literature review,** M. E. Stevens, Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 3, 147 pages (June 1970).

Key words: Data recording; debugging; holography; information control; input-output; integrated circuits; lasers; memory systems; multiprocessing; networks; on-line systems; programming; simulation; storage.

This report, the third in a series on research and development efforts and requirements in the computer and information sciences, is concerned with a selective literature review involving overall system design considerations in the planning of information processing systems and networks. Specific topics include but are not limited to: requirements and resources analysis, problems of system networking, input/output and remote terminal design, character sets, programming problems and languages, processor design considerations, advanced hardware developments, debugging and on-line diagnosis or instrumentation, and problems of simulation. Supplemental notes and a bibliography of over 570 cited references are included.

Monogr. 114. **Survey of micromanometers,** W. G. Brombacher, Nat. Bur. Stand. (U.S.), Monogr. 114, 62 pages (June 1970).

Key words: Calibration techniques; capacitance pressure gages; gas column manometers; manometers; meteorographs: micromanometers; piston gages; pressure measurement; vane gages; vapor pressure measurement.

This survey is concerned with instrumentation for measuring pressures from about 0.001 to 50 mm of mercury (0.13 to 6650 Nm^{-2}), described in publications during the years 1900-1968. U-tube micromanometers and diaphragm-capacitance gages are treated in considerable detail. Other instrumentation described includes gas column manometers; elastic element micromanometers with optical, inductance, resistance wire, strain gage, and vacuum tube transducers; piston gages; vane gages; and centrifugal micromanometers. The measurement of dynamic pressure, atmospheric pressure oscillations, low vapor pressure, and calibration techniques are discussed. Only technical periodicals, books, and government or university laboratory serials were used as sources of information. Details of electrical measurement circuits, amplifiers, and recorders have been omitted. Schematic diagrams of approximately 70 instruments are included. References to the sources of information and available performance data are given.

Monogr. 115. **The calculation of rotational energy levels and rotational line intensities in diatomic molecules,** J. T. Hougen, Nat. Bur. Stand. (U.S.), Monogr. 115, 52 pages (June 1970).

Key words: Diatomic molecules; Hund's coupling cases; rotational levels; rotational line intensities; theoretical calculations.

Procedures are described, in this pedagogical monograph, for making quantum mechanical calculations of rotational energy levels and rotational line intensities in diatomic molecules. The procedures are illustrated by sample calculations. A familiarity with the material of this report should enable a practicing electronic spectroscopist to carry out, though in a rather mechanical way, his own theoretical calculations for molecules under experimental investigation. The material of this report is aimed at electronic spectroscopists who have had the equivalent of one semester of graduate-level quantum mechanics.

Monogr. 116. **Hydrogen Stark broadening calculations with the unified classical path theory,** C. R. Vidal, J. Cooper, and E. W. Smith, Nat. Bur. Stand. (U.S.), Monogr. 116, 143 pages (May 1970).

Key words: Classical path; hydrogen lines; line wings; one-electron theory; Stark broadening; unified theory.

The unified theory has been generalized for the case of upper and lower state interaction by introducing a more compact tetradic notation. The general result is then applied to the Stark broadening of hydrogen. The thermal average of the time development operator for upper and lower state interaction is presented. Except for the time ordering it contains the effect of finite interaction time between the radiator and perturbers to all orders, thus avoiding a Lewis type cutoff. A simple technique for evaluating the Fourier transform of the thermal average has been developed. The final calculations based on the unified theory and on the one-electron theory are compared with measurements in the high and low electron density regime. The unified theory calculations cover the entire line profile from the line center to the static wing and the simpler one-electron theory calculations provide the line intensities only in the line wings.

Monogr. 117. **Hearing aids,** E. L. R. Corliss, Nat. Bur. Stand. (U.S.), Monogr. 117, 26 pages (Oct. 1970).

Key words: Audition; communications; hearing; hearing aids; selection of hearing aids; speech communication.

This publication contains information, useful to the hard of hearing, on several topics relating to hearing and hearing aids. It is assumed that the individual has already consulted a physician on the diagnosis of his hearing loss, for this is the necessary first step in correcting any faulty hearing condition. The publication may also be of interest to teachers and others wishing to explore this field.

This publication represents an extensive revision of NBS Circular 534, Hearing Aids. It includes new material based upon research conducted at the National Bureau of Standards during the intervening years. (Supersedes Circular 534.)

Monogr. 118. **Photonuclear reactions,** E. Hayward, Nat. Bur. Stand. (U.S.), Monogr. 118, 46 pages (Aug. 1970).

Key words: Nuclear hydrodynamics; particle-hole calculations; photon scattering; photonuclear; sum rules.

This paper reviews photonuclear reactions in the approximate energy range 10 to 30 MeV. Various sum rules are discussed and applied to experimental data. Several different theories are described and their predictions compared with experiment, and as often as possible open questions and discrepancies are pointed out.

Monogr. 119. **A high-dispersion spectral analysis of the Ba II star HD 204075 (ζ Capricorni),** J. L. Tech, Nat. Bur. Stand. (U.S.), Monogr. 119, 174 pages (Mar. 1971).

Key words: Abundances of elements in stars; Ba II stars (ζ Capricorni); curve of growth; equivalent widths; identification of spectral lines; ionization in stars; oscillator strengths; temperature in stars; turbulence in stars.

A double differential curve of growth analysis, using both the sun and ϵ Virginis (G9 II-III) as comparison stars, has been performed for the Ba II star ζ Capricorni. The observational material consists of equivalent widths, central depths, and half-widths for 1100 spectral lines measured on direct-intensity tracings of plates obtained by J. L. Greenstein at the coudé focus of the 200-in telescope. The plates cover the spectral regions 3880-4825 Å and 5100-6720 Å at reciprocal dispersions of 2.3 and 3.4 Å/mm, respectively. Line identifications given in earlier lists for barium stars have been critically re-examined. Three lines have been attributed with reasonable certainty to dysprosium, which has not previously been observed in barium stars.

The atmospheric parameters derived for ζ Cap are:

θ_{exc} :	1.13	$[P_e]_{\zeta-\odot}$:	−1.28
θ_{ion} :	0.99	$[P_e]_{\zeta-\epsilon}$:	+0.13
$\log 2\alpha$:	−2.5	$[k]_{\zeta-\odot}$:	−1.10
v_{micro} :	3.5 km/s	$[k]_{\zeta-\epsilon}$:	−0.03
v_{macro} :	5.5 km/s		

Atmospheric abundances have been derived for 37 elements. The results obtained with respect to the two comparison stars are in good agreement. The barium star exhibits essentially solar abundances for most elements lighter than germanium, but overabundances by factors of about two are indicated for carbon and lithium. With the exception of europium, all observed elements heavier than germanium are found to be overabundant in ζ Cap. Improved NBS *gf*-values, converted to the system of line strengths in ϵ Vir, have yielded exceptionally well-defined curves of growth for several rare earths. Overabundances by factors of about eight or nine have been found for the *s*-processed rare earths, as well as for dysprosium, which is generally considered to be *r*-processed. The abundances derived for the rare earths are greater by about a factor of three than those derived for the same star by Warner (Mon. Not. Roy. Astron. Soc. **129**, 263 (1965)).

Monogr. 120. **Unified theory calculations of Stark broadened hydrogen lines including lower state interactions,** C. R. Vidal, J. Cooper, and E. W. Smith, Nat. Bur. Stand. (U.S.), Monogr. 120, 45 pages (Jan. 1971).

Key words: Classical path; hydrogen lines; line wings; Stark broadening; unified theory.

Recently published calculations of hydrogen Stark broadening on the basis of the unified classical path theory have been extended to include lower state interactions in the final line profile. A detailed comparison with experiments in the density range 10^{13}-10^{17} cm^{-3} is given

Monogr. 121. **The effect of time ordering on the Lyman α profile,** J. T. Godfrey, C. R. Vidal, E. W. Smith, and J. Cooper, Nat. Bur. Stand. (U.S.), Monogr. 121, 14 pages (June 1971).

Key words: Lyman-α; Stark-broadening; time-ordering; unified theory.

Using a unified theory of spectral line broadening previously developed, the effects of time-ordering over the complete line profile are investigated. The behavior of the time-ordered thermal average and un-time-ordered thermal average are compared. The Fourier transform of the thermal average is obtained analytically. Calculations for the line profile of the Lyman-α line of hydrogen are presented and are representative in that the full thermal average is replaced by the thermal average with the electron velocity distribution approximated by $f(v)=\delta v-v_{av})$ where v_{av} is the thermal velocity for the plasma in question.

Monogr. 122. **Mechanics of pneumatic tires,** S. K. Clark, Editor, Nat. Bur. Stand. (U.S.), Monogr. 122, 853 pages (Nov. 1971).

Key words: Friction; rubber; skid; tire contact; tire cord; tires; tire stress; tire structure; vehicles.

The pneumatic tire has been an integral part of automotive transportation almost since its inception, yet it remains a product whose characteristics are not easily predictable or comprehensible by conventional engineering techniques. This treatise is an attempt to provide a rational descriptive and analytical basis for tire mechanics. Chapters of this book are contributed by active research workers in the fields of rubber and textile properties, friction, material properties, tire stress problems, tire design and construction, vehicle skid and handling, and tire mechanical properties.

Monogr. 123. **BOLOVAC systems for measuring electrical quantities from 0.5 MHz through microwaves,** M. C. Selby, Nat. Bur. Stand. (U.S.), Monogr. 123, 24 pages (Jan. 1972).

Key words: BOLOVAC; calibration of current meters through microwaves; calibration of power meters through microwaves; calibration of voltmeters through microwaves; current measurement; disk-type bolometer evaluation; frequency-domain pulse evaluation; measurement of microwave current; measurement of microwave power; measurement of microwave voltage; mismatch error; picosecond rise-time pulse evaluation; power measurement; pulse-rise-time standardization; sampling oscilloscope standardization; spectrum analyzer standardization; termination mismatch error elimination; thin-film bolometers; voltage measurement.

A novel device—the BOLOVAC—is employed in measurement systems that furnish known voltages and currents up to 18 GHz, remove serious difficulties in power measurements, and are applicable in impedance, attenuation and other measurements. Typical of such measurements are the evaluation of rf power sources; calibration of power meters; measurement of net and incident power flow in a system; calibration of signal generators, voltmeters, current meters, picosecond-rise-time pulse-display oscilloscopes, spectrum analyzers; determination of insertion loss of components; and calibration of directional couplers. The Bolovac also serves as an accurately known resistive termination for match or mismatch applications from LF through microwaves.

Monogr. 124. **Reference tables for low-temperature thermocouples,** L. L. Sparks, R. L. Powell, and W. J. Hall, Nat. Bur. Stand. (U.S.), Monogr. 124, 61 pages (June 1972).

Key words: Cryogenics; homogeneity tests; liquid helium; liquid hydrogen; liquid nitrogen; thermocouples.

The experimental program to establish low-temperature reference tables for the commonly used thermocouples has been completed. Details of the experimental system, instrumentation, data analysis, error analysis, and materials tested are given in order to allow the user to better evaluate and apply the results. The results presented here include: (1) Reference tables for thermocouple types E, K, and T, both as $E=f(T)$ and $T=f(E)$. The shorter $f(E)$ tables have a 0 °C (273.15 K) reference temperature while all other tables have a 0 K reference temperature; (2) Reference tables for Pt and *Ag*-28 at% Au vs the materials used in thermocouple types E, K, and T. These data are presented as $E=f(T)$ only; (3) Orthogonal polynomials and the associated coefficients necessary to generate the data with reduced order approximations; and (4) Power series coefficients for full precision reproduction of the reference data.

The data presented in the $E=f(T)$ tables cover the temperature range from 0 to 280 K. The $T=f(E)$ tables cover temperature ranges from 273.15 K down to the lowest temperatures allowed by table resolution.

Monogr. 125. **Thermocouple reference tables based on the IPTS-68,** R. L. Powell, W. J. Hall, C. H. Hyink, Jr., L. L. Sparks, G. W. Burns, M. G. Scroger, and H. H. Plumb, Nat. Bur. Stand. (U.S.), Monogr. 125, 410 pages (Mar. 1974) SD Catalog No. C13.44:125.

Key words: base metal alloys; noble metal alloys; temperature scale; temperature standards; thermocouples; thermometry.

Revision of the International Practical Temperature Scale requires that there be changes for all accurately tabulated thermophysical values. Revised reference data for thermocouples have been generated in a cooperative program between groups of the National Bureau of Standards in Boulder and Gaithersburg. This Monograph contains tables, analytic expressions, various approximations, and explanatory text. Only the standard letter-designated thermocouples are described: noble metal Types S, R, and B and base metal Types E, J, K, and T. Their appropriate "single-leg" or thermoelement versus Pt-67 values are also included. The new reference data reflect not only revisions in the temperature scale, but also slight changes in the materials themselves and improvements in data fitting methods. The temperature ranges vary for different types, from a low of −270 °C for Type E to a high of 1820 °C for Type B. The main functions and tables are given in terms of Celsius degrees and microvolts. Tables in the appendices represent the data with less precision, in millivolts, and in degrees Fahrenheit as well as Celsius. Approximate quadratic, cubic, and quartic analytic expressions are also given for each thermocouple type in various temperature ranges. Supersedes NBS Circular 561.

Monogr. 125, Suppl. 1. **Thermocouple reference tables based on the IPTS-68: Reference tables in degrees Fahrenheit for thermoelements versus platinum (Pt-67),** R. L. Powell and G. W. Burns, Nat. Bur. Stand. (U.S.), Monogr. 125, Suppl. 1, 46 pages (Jan. 1975) SD Catalog No. C13.44:125/Suppl. 1.

Key words: base metals alloys; noble metal alloys; temperature scale; temperature standards; thermoelements; thermometry.

Reference tables for several thermoelements versus platinum (Pt-67) are given with values of the thermoelectric voltage as a function of temperature in degrees Fahrenheit. Only tables for standard letter-designated thermoelements are included: Types BP, BN, JP, JN, KP (same as EP), KN, TP, and TN (same as EN). These tables supplement those given in NBS Monograph 125 and were calculated from the power series expansions presented in that Monograph. They are based upon the absolute electrical units and the International Practical Temperature Scale of 1968 (IPTS-68).

Monogr. 126. **Platinum resistance thermometry,** J. L. Riddle, G. T. Furukawa, and H. H. Plumb, Nat. Bur. Stand. (U.S.), Monogr. 126, 129 pages (Apr. 1973) $2.10, SD Catalog No. C13.44:126.

Key words: Calibration; calibration errors; cryostat; fixed points; freezing point; International Practical Temperature Scale; platinum resistance thermometer; Thermodynamic Temperature Scale; thermometry; triple point.

The monograph describes the methods and equipment employed at the National Bureau of Standards for calibrating standard platinum resistance thermometers (SPRT) on the International Practical Temperature Scale (IPTS-68). The official text of the scale is clarified and characteristics of the scale are described. Several designs of SPRT's are shown and discussed in the light of the requirements and recommendations on the text of the IPTS-68. Possible sources of error such as those due to the internal and external self-heating effects and the immersion characteristics of SPRT's are described in detail. Precautions and limitations for the mechanical and thermal treatment and for the shipment of SPRT's are indicated, and a guide is given for those desiring the thermometer calibration services of NBS. The description of equipment employed at the National Bureau of Standards for maintaining the IPTS-68 includes the triple point of water cell, tin point cell, zinc point cell, oxygen normal boiling point comparison cryostat, the 13 to 90 K comparison cryostat, and the reference SPRT's upon which the NBS- IPTS-68 in the region 13 to 90 K is based. Methods are given for calculating temperatures from the calibration data and observed resistances; the propagation of calibration errors is discussed. Supplemental information given in the Appendixes includes the authorized English version of the text of the IPTS-68, tabular values of the "reference function" used below 0 °C, tabular values of the differences between IPTS-68 and IPTS-48, analysis of the first derivatives at 0 °C of the IPTS-68 formulations, methods for calibrating potentiometers and Mueller bridges, and the derivation of the coefficients used in the analysis of error propagation.

Monogr. 127. **NBS papers on underground corrosion of steel piling 1962-1971. Corrosion of steel pilings in soils, corrosion evaluation of steel test piles exposed to permafrost soils, performance of steel pilings in soils, and polarization measurements as related to corrosion of underground steel piling,** W. J. Schwerdtfeger and M. Romanoff, Nat. Bur. Stand. (U.S.), Monogr. 127, 63 pages (Mar. 1972).

Key words: Active region; aerated soil; corrosion; disturbed soil; excavated; extracted; H-piling; instantaneous corrosion rate; mill scale; permafrost region; pipe piling; pit depth; polarization; sheet piling; undisturbed soil; weight loss.

This monograph is a collection of published papers on underground corrosion of steel piling. The papers are as follows: (1) Romanoff, Melvin, Corrosion of Steel Pilings in Soils, Nat. Bur. Stand. (U.S.), Monogr. 58, (Oct. 1962); (2) Romanoff, Melvin, Corrosion Evaluation of Steel Test Piles Exposed to Permafrost Soils, Proceedings 25th Conference, National Association of Corrosion Engineers, page 6 (Mar. 1969); (3) Romanoff, Melvin, Performance of Steel Pilings in Soils, Proceedings 25th Conference, National Association of Corrosion Engineers, page 14 (Mar. 1969); (4) Schwerdtfeger, W. J., Polarization Measurements as Related to Corrosion of Underground Steel Piling, J. Res. Nat. Bur. Stand. (U.S.), 75C (Eng. and Instr.) No. 2, 107-121 (Apr.-June 1971).

The papers describe corrosion of various types of steel piling exposed underground in the United States under climatic conditions ranging from semi-tropical to frigid. Corrosion is described on driven piling above and below the water table after many years of exposure in soils having resistivities between 78 and 50,000 ohm-cm and ranging in pH from 2.3 to 8.8.

One of the papers demonstrates the value of a polarization technique in measuring corrosion. Polarization data were obtained on weighed steel pipe specimens exposed underground for seven years in backfilled soil trenches in the vicinity of driven sheet piling. The technique was evaluated by comparing calculated cumulative weight losses of specimens with their actual weight losses. The technique was also shown to be applicable to underground pipe piling. Supersedes NBS Monograph 58.

Monogr. 128. **Corrosion rates on underground steel test piles at Turcot Yard, Montreal, Canada—Part 1,** W. J. Schwerdtfeger and M. Romanoff, Nat. Bur. Stand. (U.S.), Monogr. 128, 17 pages (July 1972).

Key words: Average penetration rate; H-piles; instantaneous corrosion rate; linear polarization; pit depth; polarization curve.

In 1966, isolated steel H-piles allocated for underground corrosion tests were installed in three locations at the Turcot Yard Interchange of the Transcanadian Highway at Montreal. The reason for the installation was to furnish answers to some questions concerning the corrosion characteristics of piles, 12 in-74 lb/ft(30.5 cm-110 kg/m), which are identical with the piles supporting the concrete piers under the highway. Polarization measurements have been made once every year since installation.

This paper describes the determination of corrosion rates based on the polarization measurements made up to the time of removal of the first group of piles in 1969. The piles, placed underground at the three locations, differ mainly in that at one site all the piles are bare, at the second site the upper ends of the piles are coated with an epoxy paint and at the third site the upper ends are encased in concrete. Physical measurements made on the cleaned piles after removal are correlated with corrosion rates calculated from the polarization measurements. Also penetration rates on the piling based on the polarization data are compared with average penetration rates (based on actual weight losses) on relatively small pipe specimens. The pipe specimens were removed from 28 underground sites having a range of soil resistivities comparable to those of the three piling sites.

Using one of the polarization techniques applied to the individual test piles, polarization measurements were also carried out on 32 interconnected piles supporting one of the concrete piers. The calculated average corrosion rate of the 32 piles was found to compare favorably with that of the separate test piles in the same area.

Monogr. 129. **The development of Loran-C navigation and timing,** G. Hefley, Nat. Bur. Stand. (U.S.), Monogr. 129, 144 pages (Oct. 1972).

Key words: Cyclan; cytac; Loran; Loran-C; low frequency; navigation; pulse propagation; radio positioning; time dissemination; time transfer system.

The Loran-C timing and navigation concept and its implementation in the form of the Loran-C system has taken on considerable importance in a variety of military and civilian applications such as microsecond clock synchronization, precision tactical or civil navigation, etc. Future applications like tying together continental surveys, aircraft collision avoidance, etc., have yet to be explored in detail. This work traces the development of the Loran-C concept from its inception as a 100 kHz pulse hyperbolic navigation system to more recent times when it found a variety of applications to both timing and navigation. This work is intended to present the story of Loran-C in a readable and understandable way without resorting to the complicated mathematical formulation of the theory or detailed instrumentation aspects. Thus, the history, experimental and theoretical developments, political decisions, and field testing of the early equipment are described and the lessons learned can certainly be a guide for modern development of the system in all its detailed applications.

Monogr. 130. **The divergent beam (Kossel) x-ray method and its uses in measuring strain contours in an individual grain of Fe-3 weight percent Si transformer sheet,** H. Yakowitz, Nat. Bur. Stand. (U.S.), Monogr. 130, 80 pages (Aug. 1973) 95 cents, SD Catalog No. C13.44:130.

Key words: Divergent beam x-ray diffraction; electron probe microanalysis; iron-silicon alloy; Kossel; strain; stress; transformer sheet.

Residual and impressed stresses and strains in Fe-3 wt. pct. Si alloy transformer sheet were studied. Results were obtained by the divergent beam (Kossel) x-ray microdiffraction techniques. The optically opaque Fe-3 wt. pct. Si alloy was mapped for residual and impressed stresses and strains. These maps are roughly analogous to polarized light stress analysis of transparent materials. The results showed that a variable strain distribution existed in the alloy sheet at the time it was ready for insertion into a transformer core. Small applied compressive and tensile loads tended to rearrange this variable strain distribution but not to appreciably alter the total stored elastic energy.

Monogr. 131. **Thermal conductivity of solids at room temperature and below. A review and compilation of the literature,** G. E. Childs, L. J. Ericks, and R. L. Powell, Nat. Bur. Stand. (U.S.), Monogr. 131, 624 pages (Sept. 1973) $7.80, SD Catalog No. C13.44:131.

Key words: Cryogenic thermal conductivity; elements, alloys, commercial metals, semiconductors, semimetals, ionic and valence crystals, minerals, molecular crystals, polymers, glasses, disordered dielectrics, thermal conductivity of; review; thermal conductivity.

An extensive compilation is given of the measured values of thermal conductivity for nearly all solid materials from room temperature down to 0.01 kelvin. The reviewed materials include elements, alloys and commercial metals, semiconductors, semimetals, ionic and valence crystals, minerals, molecular crystals, polymers, glasses, and disordered dielectrics. Excluded are foams, powders, earths, fibers, layers of composites, and similar other heterogeneous solids. Data for temperatures below 1 kelvin are presented separately. The tables and graphs are complete for literature references from 1900 to mid-1971. Experimental methods and physical phenomena are discussed in the text and coded in the tables for references for which curves are shown. Supersedes NBS Circular 556.

Monogr. 132. **A compilation and evaluation of mechanical, thermal, and electrical properties of selected polymers,** R. E. Schramm, A. F. Clark, and R. P. Reed, Nat. Bur. Stand. (U.S.), Monogr. 132, 848 pages (Sept. 1973) $10.25, SD Catalog No. C13.44:132.

Key words: Compilation; electrical properties; mechanical properties; plastics; polymers; thermal properties.

This compilation abstracts original experimental data on the mechanical, thermal, and electrical properties of six commercially available polymers. After an extensive review of the open literature, all available data were collected together in graphical and tabular form along with material characterization, experimental method, and reference to the original publication. The data are also summarized and a brief description of each polymer is included.

Monogr. 133. **Mass and mass values,** P. E. Pontius, Nat. Bur. Stand. (U.S.), Monogr. 133, 39 pages (Jan. 1974) SD Catalog No. C13.44:133.

Key words: apparent mass; buoyancy corrections; mass comparison; mass value; true mass; weighing.

There are several bases for assigning mass values to weights to be used as mass standards. As a consequence a given weight may have several assigned mass values depending on the basis used. In many cases, the differences between these assigned values, although easily detectable with precise weighing equipment, are of no practical concern. However, in some instances these differences may be crucial. The first part of this paper is a historical summary of weighing, standards, and the assignment of value; and the interfacing of mass measurements with civilization. The second part of this paper discusses in detail the methods of assigning mass values. Ways to convert from values on one basis to values on another basis are discussed. Sample problems relating to the buoyant effect of the air are presented in the appendices.

Monogr. 134. **Space groups and lattice complexes,** W. Fisher, H. Burzlaff, E. Hellner, and J. D. H. Donnay, Nat. Bur. Stand. (U.S.), Monogr. 134, 184 pages (May 1973) $4.10, SD Catalog No. C13.44:134.

Key words: Crystallography; crystal point groups; crystal structure; lattice complexes; site sets; space groups.

The lattice complex is to the space group what the site set is to the point group—an assemblage of symmetry-related equivalent points. The symbolism introduced by Carl Hermann has been revised and extended. A total of 402 lattice complexes are derived from 67 Weissenberg complexes. The Tables list site sets and lattice complexes in standard and alternate representations. They answer the following questions: What are the coordinates of the points in a given lattice complex? In which space groups can a given lattice complex occur? What are the lattice complexes that can occur in a given space group? The higher the symmetry of the crystal structures is, the more useful the lattice-complex approach should be on the road to the ultimate goal of their classification.

Monogr. 135. **Properties of glasses in some ternary systems containing BaO and SiO_2,** G. W. Cleek and C. L. Babcock, Nat. Bur. Stand. (U.S.), Monogr. 135, 42 pages (Sept. 1973) 70 cents, SD Catalog No. C13.44:135.

Key words: Barium glasses; barium silicates; glass properties; glass property factors; oxide glasses; silicate substructures; ternary glasses.

The glass forming regions in six ternary oxide systems containing BaO, SiO_2 and a third oxide have been determined. The

properties of the resulting glasses were measured and the results are reported. The data on refractive indices, dispersions and specific volumes were evaluated by computer methods in an attempt to identify "substructures" containing the cations present in the glasses.

Monogr. 136. **Graphical recoupling of angular momenta,** D. R. Lehman and J. S. O'Connell, Nat. Bur. Stand. (U.S.), Monogr. 136, 18 pages (Oct. 1973) 50 cents, SD Catalog No. C13.44:136.

Key words: Angular momentum; diagrams; graphs; quantum theory; recouping; transformation theory.

A diagrammatic method for solving angular momentum recoupling problems is presented. It is shown that a few graphical elements with a set of rules for their use lead to the solution of many types of recoupling problems in an intuitive and systematic way. Several examples are given together with exercise to develop the reader's facility with the method.

Monogr. 137. **Applications of waveguide and circuit theory to the development of accurate microwave measurement methods and standards,** R. W. Beatty, Nat. Bur. Stand. (U.S.), Monogr. 137, 322 pages (Aug. 1973) $5.20, SD Catalog No. C13.44:137.

Key words: Attenuation definitions; attenuation measurement; barretter mount efficiency; coaxial connectors; impedance measurement; microwave network theory; mismatch errors; phase shift-measurement; power measurement; reflectometers; waveguide joints; waveguide theory.

The basic theory and analytical methods used in the development of accurate microwave measurement methods and standards are presented.

Developments at the U.S. National Bureau of Standards during 1948-1968 are described in which the above theory and analytical methods were applied.

These developments were in the fields of power, impedance, attenuation and phase shift, and led to the establishment of National Standards and calibration methods at frequencies from about 300 MHz to 30 GHz.

Monogr. 138. **MeV total neutron cross sections,** R. B. Schwartz, R. A. Schrack, and H. T. Heaton II, Nat. Bur. Stand. (U.S.), Monogr. 138, 160 pages (Jan. 1974) SD Catalog No. C13.44:138.

Key words: MeV neutrons; neutron time-of-flight; neutron total cross sections.

This report is a compilation of the MeV neutron total cross section data measured at the National Bureau of Standards over the past several years. The measurements generally span the energy interval from 0.5 to 15 or 20 MeV; data are presented in graphical form for twelve normally occuring elements, plus the separated isotopes ^{235}U, ^{238}U, and ^{239}Pu. An appendix is included which gives complete details of the experimental technique.

Monogr. 139. **Interactions of high energy particles with nuclei,** W. Czyż, Nat. Bur. Stand. (U.S.), Monogr. 139, 73 pages (Sept. 1975) SD Catalog No. C13.44:139.

Key words: diffractive production; diffractive scattering; Glauber model; hadronic components of photons; high energy scattering; multiple scattering; neutrino-nucleus interactions; shadowing effects.

Elastic scattering and diffractive production processes induced in nuclear targets by high energy projectiles are discussed in this article. Special attention is paid to the interaction of high energy hadrons and photons. Interactions of high energy electrons and neutrinos are briefly mentioned. The common features of all these processes are emphasized throughout the article: The multiple scattering and shadowing processes inside of the target nuclei. An effort is made to develop a unified way of treating nuclear interactions of particles which are either hadrons or exhibit some hadronic components in such interactions.

This article is divided into five sections: 1) Introduction, 2) Description of multiple scattering, 3) Elastic scattering of hadrons from nuclei, 4) Diffractive dissociation and diffractive excitation, 5) Diffractive production of hadrons in hadron-nucleon collisions.

Monogr. 140. **Time and frequency: Theory and fundamentals,** B. E. Blair, Ed., Nat. Bur. Stand. (U.S.), Monogr. 140, 470 pages (May 1974) SD Catalog No. C13.44:140.

Key words: accuracy; Allan variance; atomic frequency standards; atomic time scales; AT(NBS); BIH; buffer gases; CCIR; clock ensembles; clocks; crystal aging; Cs frequency standard; dissemination techniques; figure of merit; flicker noise; frequency stability; frequency standards; frequency/time metrology; hydrogen maser; leap seconds; Loran-C; magnetic resonance; masers; NBS-III; NBS-5; NBS/USNO time coordination; Omega; optical pumping; precision; quartz crystal oscillators; radio T/F dissemination; Rb frequency standards; satellite T/F dissemination; short-term stability; SI Units; TAI; television T/F dissemination; thallium beam standards; time; time dispersion; time domain; time/frequency statistics; time scale algorithm; time scales; "unified standard"; URSI; USA standard time zones; UTC (NBS); UTC (USNO).

This is a tutorial Monograph describing various aspects of time and frequency (T/F). Included are chapters relating to elemental concepts of precise time and frequency; basic principles of quartz oscillators and atomic frequency standards; historical review, recent progress, and current status of atomic frequency standards; promising areas of developing future primary frequency standards; relevance of frequency standards to other areas of metrology including a unified standard concept; statistics of T/F data analysis coupled with the theory and construction of the NBS atomic time scale; an overview of T/F dissemination techniques; and the standards of T/F in the USA. This Monograph addresses both the specialist in the field as well as those desiring basic information about time and frequency. The authors trace the development and scope of T/F technology, its improvement over periods of decades, its status today, and its possible use, applications, and development in days to come.

Monogr. 141. **The measurement of lumped parameter impedance: A metrology guide,** R. N. Jones, Nat. Bur. Stand. (U.S.), Monogr. 141, 211 pages (June 1974) SD Catalog No. C13.44:141.

Key words: adapters; capacitance; capacitors; detectors; generators; impedance instruments; impedance standards; inductance; inductors; measurement methods; reactance; resistance; resistor; standards.

The measurement of two-terminal impedance in the 30 kHz to 300 MHz range involves a variety of different methods including null, resonance, active and comparison. Each method is represented by a number of instruments having specific capabilities, strengths, and weaknesses. This metrology guide is intended to assist the scientist who is not intimately familiar with impedance measurement, in the selection and use of the best instrument for a particular requirement. Information is included on range and accuracy capabilities as well as availability and ease of operation. In addition to providing help in the selection of the appropriate instrument, there are operating tips which enhance accuracy, criteria for choosing standards, means for extending normal measurement range of an instrument, a discussion on generators and detectors, and a section on the evaluation and use

adapters. Finally, an extensive bibliography is included to assist in pursuing a particular problem beyond the depth of the guide.

Monogr. 142. **The measurement of noise performance factors: A metrology guide,** M. G. Arthur, Nat. Bur. Stand. (U.S.), Monogr. 142, 202 pages (June 1974) SD Catalog No. C13.44:142.

Key words: effective input noise temperature; measurement errors; noise factor; noise measurements; noise performance factors; noise temperature; Y-factor measurements.

This metrology guide provides the basis for critical comparisons among seven measurement techniques for average noise factor and effective input noise temperature. The techniques that are described, discussed, and analyzed include the (1) Y-Factor, (2) 3-dB, (3) Automatic, (4) Gain Control, (5) CW, (6) Tangential, and (7) Comparison Techniques. The analyses yield working equations and error equations by which accuracy capabilities are compared. Each technique is also analyzed for (a) frequency range for best measurement results, (b) special instrumentation requirements, (c) speed and convenience, (d) operator skill required, and (e) special measurement problems. General instrumentation requirements and practical measurement problems are discussed for the benefit of the nonexpert metrologist. Worked examples illustrate the principles involved in applying the working and error equations. An extensive bibliography and suggested reading list aid the metrologist to locate additional material on these measurements. Taken altogether, this guide will be helpful in selecting the best measurement technique for any of a wide range of operational requirements and, once the technique is selected, it will be of further benefit in helping the metrologist identify where his efforts should be placed to derive the greatest efficiency and accuracy from his measurement system.

Monogr. 143. **Analysis of optically excited mercury molecules,** R. E. Drullinger, M. M. Hessel, and E. W. Smith, Nat. Bur. Stand. (U.S.), Monogr. 143, 51 pages (Jan. 1975) SD Catalog No. C13.44:143.

Key words: dissociation laser; excimers; excited state kinetics; *f*-values; mercury molecules; new spectroscopic techniques; optical excitation; potential curves.

The Hg_2 molecule is representative of a class of molecules which have dissociative ground states and bound excited states. It can therefore be used as a prototype of this class of molecules which are of interest as potential new laser candidates. Because of the non-bound ground state, standard absorption spectroscopic techniques cannot be used to obtain the necessary information about the excited states. We have therefore developed new measurement techniques to obtain potential curves, *f*-values, and kinetic behavior for Hg_2. These techniques are applicable to this whole class of dissociation molecular systems.

Monogr. 144. **The rotary-vane attenuator as an interlaboratory standard,** W. Larson, Nat. Bur. Stand. (U.S.), Monogr. 144, 70 pages (Nov. 1975) SD Catalog No. C13.44:144.

Key words: attenuation; interlaboratory standard; measurement; rotary-vane attenuator.

This paper presents a comprehensive report on the measurement and the use of the rotary-vane attenuator as an interlaboratory standard.

Methods of attenuation measurement developed at NBS are used to supply data for the evaluation of the deviations from theoretical $\cos^2$ law due to rotor misalignment, gear eccentricity, resettability, resolution, and insufficient maximum attenuation.

A precision rotary-vane attenuator with an optical readout capable of 1 second of arc angular resolution has an effective attenuation resolution of 0.00005 dB at a 3 dB dial setting, and 0.0005 dB at a 30 dB dial setting. This type of precision attenuator is an effective standard for use in the dual detection microwave bridge measurement system.

Monogr. 145, Part I. **Tables of spectral-line intensities. Part I—Arranged by elements,** W. F. Meggers, C. H. Corliss, and B. F. Scribner, Nat. Bur. Stand. (U.S.), Monogr. 145, Part 1, 403 pages (May 1975) SD Catalog No. C13.44:145/I.

Key words: classification of spectral lines; intensities of spectral lines; spectral-line intensities; tables of spectral-line intensities; wavelengths of spectral lines.

The relative intensities, or radiant powers, of 39 000 spectral lines with wavelengths between 2000 and 9000 Ångstroms have been determined on a uniform energy scale for seventy chemical elements. This was done by mixing 0.1 atomic percent of each element in powdered copper, pressing the powder-mixture to form solid electrodes which were burned in a 10 ampere, 220 volt direct-current arc, and photographing the spectra with a stigmatic concave grating while a step sector was rotating in front of the slit. The sectored spectrograms facilitated the estimation of intensities of all element lines relative to copper lines which were then calibrated on an energy scale provided by standardized lamps, and all estimated line intensities were finally adjusted to fit this calibration. Comparisons with other intensity measurements in individual spectra indicate that the National Bureau of Standards spectral-line intensities may have average errors of 20 percent, but first of all they provide uniform quantitative values for the seventy chemical elements commonly determined by spectrochemists. These data are presented by element in part I, and all 39 000 observed lines are given in order of wavelength in part II. Supersedes Monograph 32, Parts I and II and its supplement.

Monogr. 145, Part II. **Tables of spectral-line intensities. Part II—Arranged by wavelengths,** W. F. Meggers, C. H. Corliss, and B. F. Scribner, Nat. Bur. Stand. (U.S.), Monogr. 145, Part II, 228 pages (May 1975) SD Catalog No. C13.44:145/II.

Key words: classification of spectral lines; intensities of spectral lines; spectral-line intensities; tables of spectral-line intensities; wavelengths of spectral lines.

The relative intensities, or radiant powers, of 39 000 spectral lines with wavelengths between 2000 and 9000 Ångstroms have been determined on a uniform energy scale for seventy chemical elements. This was done by mixing 0.1 atomic percent of each element in powdered copper, pressing the powder-mixture to form solid electrodes which were burned in a 10 ampere, 220 volt direct-current arc, and photographing the spectra with a stigmatic concave grating while a step sector was rotating in front of the slit. The sectored spectrograms facilitated the estimation of intensities of all element lines relative to copper lines which were then calibrated on an energy scale provided by standardized lamps, and all estimated line intensities were finally adjusted to fit this calibration. Comparisons with other intensity measurements in individual spectra indicate that the National Bureau of Standards spectral-line intensities may have average errors of 20 percent, but first of all they provide uniform quantitative values for the seventy chemical elements commonly determined by spectrochemists. These data are presented by element in part I, and all 39 000 observed lines are given in order of wavelength in part II. Supersedes NBS Monograph 32, Parts I and II.

Monogr. 146. **The theory of the optical wedge beam splitter,** Y. Beers, Nat. Bur. Stand. (U.S.), Monogr. 146, 31 pages (Oct. 1974) SD Catalog No. C13.44:146.

Key words: optical attenuation; optical beam splitter.

An optical wedge beam splitter consists of a prism of transparent material with a very small apex angle, usually about one degree. If a pencil beam of radiation is incident upon it, a portion enters the material and undergoes a series of reflections at the surfaces. At each reflection a refracted beam emerges from the material. This paper gives the basic theory for computing the ratio of the intensity of the incident beam to the intensity of any selected emerging beam and also for computing the direction of the emerging beam, assuming that the wedge angle, index of refraction, angle of incidence, and number of reflections are known.

The paper also gives the results of numerical calculations based upon this theory for sample situations which are of interest. It is shown that polarization effects can be minimized by the use of a small wedge angle and be the proper selection of the angle of incidence. In particular, it is shown that it is possible by the use of four reflections and a wedge angle of one degree to obtain attenuation factors of about 400,000 (56 db), and that the effect of changes in polarization on the attenuation factor can be held down to about one percent.

Monogr. 147. **Relativistic many-body bound systems,** M. Danos and V. Gillet, Nat. Bur. Stand. (U.S.), Monogr. 147, 149 pages (Apr. 1975) SD Catalog No. C13.44:147.

Key words: composite particles; interacting quantum fields; nuclear structure; particle structure; relativistic bound systems; relativistic nuclear physics.

The principles and the mathematical details of a fully relativistic nuclear theory are given. Since the concept of nuclear forces is a strictly non-relativistic construct, it must be abandoned and the forces must be replaced explicitly by their physical origin, i.e., by the interaction between nucleons and mesons. Thus, in this monograph the description of a nucleus has been formulated as a problem of relativistic quantum field theory which is solved by nuclear physics methods. To wit: The physics is described by specifying a Lagrangian which is a functional of the constituent fields (=of the parton fields). The solutions for the physical systems then are obtained in a time-independent treatment as expansions in the parton fields: both particles and nuclei are composite systems, made up of parton configurations, which define a representation of the Hamiltonian (associated with the specified Lagrangian). The Hamiltonian is truncated by omitting all configurations having a diagonal element exceeding that of the lowest configuration by a pre-determined value, E_{max}, and is diagonalized. All formulae needed to carry out this program are derived and given in full detail for spin 0, 1/2, and 1 parton fields for PS, PV, and φ^4 interactions. Particular attention is devoted to the center-of-mass position coordinate which in relativistic kinematics is a non-separable many-body operator. Finally, the configurations up to $E_{max}=1$ GeV are listed for the nucleon, the deuteron, and the pion.

Monogr. 148. **The role of standard reference materials in measurement systems,** J. P. Cali, T. W. Mears, R. E. Michaelis, W. P. Reed, R. W. Seward, C. L. Stanley, H. T. Yolken, and H. H. Ku, Nat. Bur. Stand. (U.S.), Monogr. 148, 56 pages (Jan. 1975) SD Catalog No. C13.44:148.

Key words: certification; meaningful measurement; measurement; measurement system; precision; reference method; specificity; SRM; standard reference material; systematic error.

This publication is a guide to the use of Standard Reference Materials (SRM's) and should be useful to all users of SRM's, particularly those in countries developing national measurement systems. It is not intended to be an exhaustive description of the NBS-SRM program, but rather a review of the role SRM's play in the measurement system, how SRM's are certified, and what the certification means. To illustrate the use of SRM's several selected industries are described in which SRM's have made significant contributions.

Monogr. 149. **Measurement assurance program—A case study: Length measurements. Part 1. Long gage blocks (5 in to 20 in),** P. E. Pontius, Nat. Bur. Stand. (U.S.), Monogr. 149, 75 pages (Nov. 1975) SD Catalog No. C13.44:149.

Key words: measurement algorithm; measurement assurance; measurement process; measurement unit; process variability; uncertainty.

The differences between the methods of traditional metrology and the measurement assurance programs are briefly discussed. The historical data relative to long gage blocks (5 in to 20 in) are analyzed to provide a basis for comparison with results from new measurement processes formulated in accordance with the philosophies of the measurement assurance programs. The results from the new processes are in agreement with the work of the past. The current length values assigned and associated uncertainties are shown for selected long gage blocks used in the dissemination of length by the National Bureau of Standards. These long gage blocks are a part of a growing collection of similar well characterized artifact standards for use in comparative measurement processes. The methods and techniques used in developing the new measurement process are discussed in some detail. It is the author's intent that, in addition to the technical content, this paper be largely tutorial in the area of measurement process analysis. This paper is, in essence, a report on the extension of the techniques first suggested in NBS Monograph 103 "Realistic Uncertainties and the Mass Measurement Process" to the area of length measurement.

Monogr. 150. **Liquid-in-glass thermometry,** J. A. Wise, *Nat. Bur. Stand. (U.S.), Monogr. 150,* 30 pages (Jan. 1976) SD Catalog No. C13.44:150.

Key words: calibration; emergent stem; liquid-in-glass thermometer; reference point; stirred liquid comparison bath; temperature scale.

This Monograph, which supersedes NBS Monograph 90, contains information of general interest to manufacturers and users of liquid-in-glass thermometers. Instructions explaining how to submit a thermometer to the National Bureau of Standards for calibration are provided, and the techniques and equipment, such as stirred liquid comparison baths, used in the calibration procedures are described. A discussion of important principles of acceptable thermometer design and factors affecting their use is included. Listed are tables of tolerances reflecting good manufacturing practices and reasonably attainable accuracies expected with liquid-in-glass thermometers. The calculation of corrections for the temperature of the emergent stem is given in detail for various types of thermometers and conditions of use.

Monogr. 151. **Automatic measurement of network parameters—A survey,** R. W. Beatty, *Nat. Bur. Stand. (U.S.), Monogr. 151,* 113 pages (June 1976) SD Catalog No. C13.44:151.

Key words: automatic network analyzers; computer-controlled measurement; magic tee; microwave measurement methods; multiple probe devices; reflectometers; rotating probe devices; slotted lines; survey of automatic techniques; swept frequency measurements; Wheatstone Bridge.

A survey is made of principles, methods, and systems developed for semiautomatic and automatic measurement of network parameters, such as the complex scattering coefficients, impedance, VSWR, return loss, attenuation, and group delay time. The period covered is from 1922 to 1975 and develop-

ments range from simple ideas such as a motor driven probe for a slotted line, to computer-controlled transmission and reflection measurement systems.

The essential ideas and features of each development are briefly described and both similarities and differences between various schemes are pointed out. Trends in modern developments are noted and some of the options open for future work are mentioned. A bibliography of 151 references is included.

Monogr. 152. **A gage block measurement process using single wavelength interferometry,** J. S. Beers, Nat. Bur. Stand. (U.S.), Monogr. 152, 34 pages (Dec. 1975) SD Catalog No. C13:44:152.

Key words: calibration; gage blocks; interferometery; laser; length; measurement process; uncertainty.

The interferometric transfer of the length unit from its defined wavelength to NBS reference standard gage blocks is basic to the gage block calibration program at NBS. The interferometric measurement process using a laser light source and a Kosters type gage block interferometer is described here. Continuous evaluation and refinement of the process is aided by statistical treatment and control chart techniques. All error sources, both random and systematic, are evaluated and the process is maintained in a state of statistical control.

Monogr. 153. **The first spectrum of hafnium (Hf I),** W. F. Meggers and C. E. Moore, *Nat. Bur. Stand. (U.S.), Monogr. 153,* 117 pages (July 1976) SD Catalog No. C13.44:153.

Key words: analysis, Hf I spectrum; hafnium, analysis of first spectrum; spectrum, Hf I; Zeeman effect, Hf I.

The present publication terminates the work on the analysis of Hf I which was started by the late W. F. Meggers in 1928 and left unfinished in 1966. His final line list contains some 4700 lines of which about 67 percent have been classified. Observed g-values are known for 198 levels. The reliability of the Zeeman observations is indicated in tables containing sums of Observed and Landé g-values for selected groups of "even" and "odd" terms.

An attempt has been made to continue Meggers' analysis in LS-coupling as far as possible. This coupling is not rigorous in Hf I, and many intervals are irregular. Consequently, the levels are given also in numerical order with the even and odd levels presented in separate tables.

An ionization limit of 54700 ± 600 cm^{-1}, giving an ionization potential of 6.78 ± 0.07 eV has been derived from a two-member series.

The long line lists are given in two Appendices: Appendix A contains the observed Zeeman data for the individual lines, 531 in all; Appendix B consists of the complete line list of observed and classified lines.

By far the greater part of the analysis is that of Meggers. Detailed notes explain changes that have been introduced and additions to this work.

Monogr. 154. **The dynamics of fields of higher spin,** R. W. Hayward, *Nat. Bur. Stand. (U.S.), Monogr. 154,* 99 pages (Aug. 1976) SD Catalog No. C13.44:154.

Key words: causality; high spin fields; inhomogeneous Lorentz group; relativistic fields; wave equations.

There are several difficulties that plague all existing relativistic equations of motion describing elementary fields having an intrinsic spin greater than one. While the free field equations can be shown to be explicitly covariant, the introduction of interactions gives rise to a phenomenon of noncausality. In the presence of interactions, the retarded solutions spread beyond the light cone and the influence travels faster than light. Furthermore, the solutions in certain simple potentials do not have a finite norm, violating the probabilistic requirements of quantum mechanics.

This paper develops a relativistic theory that is free of the aforementioned difficulties. This Lagrangian theory describes fields and particles with arbitrary mass and charge and having any discrete spin, integer or half integer. Apart from gauge conditions there are no subsidiary conditions.

A matrix formulation is used. The generators of the inhomogeneous Lorentz group for a field of any intrinsic spin and mass are defined in terms of Wigner operators of the group SU(2) and a metric operator. A maximal Abelian set of invariants is formed which defines two completely reducible representation bases of the inhomogeneous Lorentz group having distinct structures. A set of γ matrices, obeying a Clifford algebra, is also defined in terms of the Wigner operators and the metric operator. State vectors having different structures and Lorentz transformation properties can be related to one another by operators involving the γ matrices.

The equations of motion can be obtained from the Lagrangian by variational methods, and certain aspects of the canonical formalism can be used to quantize the fields. Invariance of the Lagrangian under infinitesimal displacements and rotations yield conservation laws and constants of the motion for pertinent physical observables. The metric of the Hilbert space of the states is uniquely defined for any spin field, assuring positive definite four momenta and charge.

The Dirac formulation for the spin one-half field and the Maxwell-Lorentz formulation for the electromagnetic field are special cases of this theory.

Monogr. 157. **Computers, health records, and citizen rights,** A. F. Westin, *Nat. Bur. Stand. (U.S.), Monogr. 157,* 401 pages (Dec. 1976) SD Catalog No. C13.44:157.

Key words: citizen rights; computers; confidentiality; data systems; health records; information policy; management principles; medical records; privacy; recordkeeping practices; security.

This report investigates the impact of computers on citizen rights in the health recordkeeping area. Under Dr. Alan F. Westin's direction, from July of 1974 to April of 1976, a small interdisciplinary team did the following: (1) examined published literature from medicine and health, law, computing, and social science; (2) conducted interviews with major computer manufacturers, systems developers, health professionals and civil liberties, public interest, consumer, and minority-rights groups; (3) made on-site visits to six representative health-care organizations using computers to handle personal records; (4) corresponded with 70 organizations in the health field; and (5) subjected an initial draft report to review by a conference of experts in September 1975 and subsequently by about 50 outside reviewers. The findings of this investigation were then combined into this four-part report. Part One describes the world of medical data and citizen rights within the framework of three zones—primary health care (by health professionals), service payers and health care reviewers, and social uses of health data (such as in employment, life insurance, and welfare); Part Two treats patterns of computerization in health-care organizations that were studied in depth; and Part Four analyzes the impact of computerization on personal health records, presents comparisons with six other democratic nations, and states 12 recommended management principles for health care data systems. The report also contains a 28 page bibliography and twelve appendices with support documents and information.

Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

H44. **Specifications, tolerances, and other technical requirements for commercial weighing and measuring devices,** H. F. Wollin, Compiler and Editor, Nat. Bur. Stand. (U.S.), Handb. 44, Fourth Edition, 222 pages (Dec. 1971).

Key words: Commercial weighing and measuring devices; specifications; technical requirements; tolerances.

NBS Handbook 44, Fourth Edition, "Specifications, Tolerances, and Other Technical Requirements for Commercial Weighing and Measuring Devices," is a revision of the Third Edition of Handbook 44. This Fourth Edition adopted by the National Conference on Weights and Measures is given legal status in practically every state in the United States. (Supersedes NBS Handbook 44—3rd Edition.)

H102. **ASTM metric practice guide,** NBS Handb. 102 (March 10, 1967).

Key words: Metric system; international system (SI); conversion factors.

This Handbook, prepared by the ASTM Ad Hoc Committee on Metric Practice, is intended to assist persons confronted with the task of conversion between U. S. customary units and SI (metric) units.

Rules for conversion and rounding are explained in detail, and an extensive list of factors for conversion is included. A brief history of the development of SI is presented.

H103. **Tabulation of data on receiving tubes,** J. K. Moffitt, NBS Handb. 103 (Sept. 29, 1967).

Key words: Basing connections; characteristics; electron tubes; similar types; tabulation.

A tabulation of Receiving-Type Electron Tubes with some characteristics of each type has been prepared in the form of two major listings, a Numerical Listing in which the tubes are arranged by type number, and a Characteristic Listing in which the tubes are arranged by tube type and further ordered on the basis of one or two important parameters. The tabulation is accompanied by a listing of similar tube types and basing connections for the listed tubes. (Supersedes Handbook 83).

H104. **Tabulation of data on microwave tubes,** J. K. Moffitt, NBS Handb. 104 (Sept. 29, 1967).

Key words: Characteristics tabulation; electron tubes; microwave electron tubes; tabulation.

A tabulation of microwave electron tubes with characteristics of each type has been arranged in the form of two major listings, a Numerical Listing in which the tubes are arranged by type number, and a Characteristic Listing in which the tubes are arranged by the kind of tube, and further ordered on the basis of minimum frequency and power output. (Supersedes NBS Handbook 70).

H105-1. (Apr.1969) Superseded by H105-1, Revised 1972.

H105-1 (Revised 1972). **Specifications and tolerances for reference standards and field standard weights and measures. 1. Specifications and tolerances for field standard weights (NBS class F),** T. M. Stabler, Nat. Bur. Stand. (U.S.), Handb. 105-1, 12 pages (July 1972).

Key words: Field standard weights; specifications; test weights; tolerances; weights and measures inspection; weights used by servicemen.

These specifications and tolerances are recommended as minimum requirements for standards used in the field by State and local weights and measures officials in examination of weighing devices. Revision of NBS Handbook 105-1, April 1969.

H105-2. **Specifications and tolerances for reference standards and field standard weights and measures. 2. Specifications and tolerances for field standard measuring flasks,** B. C. Keysar, Nat. Bur. Stand. (U.S.), Handb. 105-2, 6 pages (Jan. 1971).

Key words: Accurate measurements of volume of liquids; field standard measuring flasks; specification; tolerances; weights and measures inspection.

These specifications and tolerances are recommended as ninimum requirements for standards used in the field by State

H105-3. **Specifications and tolerances for reference standards and field standard weights and measures. 3. Specifications and tolerances for metal volumetric field standards,** B. C. Keysar, Nat. Bur. Stand. (U.S.), Handb. 105-3, 8 pages (May 1971).

Key words: Accurate measurements of volumes; field standard; metal volumetric field standards; provers; specifications; test measures; tolerances; weights and measures inspection.

These specifications and tolerances are recommended as minimum requirements for standards used in the field by State and local weights and measures officials in quantity determinations of liquid commodities.

H106. **CODASYL COBOL journal of development 1968,** Nat. Bur. Stand. (U.S.), Handb. 106, 344 pages (July 1969).

Key words: COBOL; CODASYL; journal.

This document is a report to the COBOL community from the Conference on Data Systems Languages (CODASYL) Common Business Oriented Language (COBOL) Programming Language Committee. It is an official report documenting the development activities of CODASYL through July 1968.

H107. **American National Standard. Radiological safety in the design and operation of particle accelerators,** Nat. Bur. Stand. (U.S.), Handb. 107, 22 pages (June 1970).

Key words: Accelerator design; accelerator operation; health physics; particle accelerators; radiation measurements; radiation protection; standard.

This American National Standard provides the basic considerations essential to the safe operation of a particle accelerator. It applies principally to particle accelerators with primary energies less than 100 MeV. It considers the characteristics of and controls for radiations as they affect accelerator design, operating procedures, and exposure evaluation. The section on radiation protection design criteria includes radiation shielding considerations and the use of safety systems. Operational health physics requirements are treated extensively, and radiation measurements are discussed in terms of the types of radiation that may be produced and proper techniques for monitoring. The final section, on dose assessment, includes basic exposure considerations such as maximum permissible dose and dose equivalent.

H108. **Weights and measures labeling handbook,** D. E. Edgerly, Nat. Bur. Stand. (U.S.), Handb. 108, 406 pages (May 1971)

Key words: Consumer package; exemption; fluid measure; labeling; net quantity; principal display panel; regulations; weights and measures.

The Weights and Measures Labeling Handbook has been prepared for use by State weights and measures officials in the enforcement of State laws and regulations pertaining to the packaging and labeling of commodities. The Handbook provides a cross indexed compilation of the requirements of the Model State Packaging and Labeling Regulation, U. S. Department of Agriculture regulations, and regulations of the Food and Drug Administration and Federal Trade Commission issued pursuant to the Fair Packaging and Labeling Act.

H109. **Aluminum wire tables,** C. Peterson, J. L. Thomas, and H. Cook, Editors, Nat. Bur. Stand. (U.S.), Handb. 109, 66 pages (Feb. 1972).

Key words: Aluminum conductor; aluminum wire cables; conversion factors; electrical conductivity; electrical conductor; electrical resistivity; standard values; temperature coefficient.

This handbook of aluminum wire tables is a companion publication to NBS Handbook 100, Copper Wire Tables, a review of which is contained in Part I, Sections 1 and 2. Data are presented on the conductivities and resistivities of both solid and stranded wires of various sizes and composition, together with a variety of other data of interest to the designer of electrical equipment and installations. Values are expressed in both U.S. Customary and International System (SI) Units. Wire sizes involved are based on and restricted to those manufactured and typically used in the United States. American Wire Gage sizes are used for the smaller range of conductors from 56 gage through 4/0. Larger conductors are sized on the basis of circular mil area. The alloy compositions included in these tables are EC-0 (annealed), EC-H19, 5005-H19, and 6201-T81; values are given over a temperature range of 0 to 100 °C.

H110-1. **National Electrical Safety Code. Part 1. Rules for the installation and maintenance of electrical supply stations and equipment,** Nat. Bur. Stand. (U.S.), Handb. 110-1, 43 pages (June 1972).

Key words: Electrical safety; electrical supply station; electrical utility station; high voltage safety; power station equipment; power station safety.

This Handbook contains Part 1 of the National Electrical Safety Code and supersedes NBS Handbook H31 and pages 31 through 75 of the NBS Handbook H30. Part 1 of this Code covers the electric conductors and equipment in electrical supply stations along with the associated structural arrangements employed, for example, by an electrical or railway utility in the exercise of its function as a utility and accessible only to properly qualified personnel. It also covers similar electric conductors and equipment in electrical supply stations when owned by and installed in an industrial establishment, where the electrical supply stations are under the control of and accessible only to properly qualified persons. Examples of such industrial establishments are the paper and steel industries.

H111. **American National Standard. Radiation safety for x-ray diffraction and fluorescence analysis equipment,** Nat. Bur. Stand. (U.S.), Handb. 111, 20 pages (June 1972).

Key words: Radiation safety; x-ray equipment.

This standard reviews the types of injuries resulting from accidental exposure to ionizing radiation resulting from the operation of x-ray diffraction and fluorescence analysis equipment, establishes equipment design criteria, sets up requirements for approved operating procedures and recommends the establishment of health surveillance, and personnel monitoring programs. The circumstances under which operation of equipment must be limited to specially designated areas equipped with radiation barriers and warning signs are set forth. Maximum permissible dose limits established by the National Council on Radiation Protection and Measurement are stated. A list of references to selected articles on various aspects of radiation safety is given and notes on the detection and measurement of radiation from x-ray diffraction and fluorescence analysis equipment are included in an appendix.

H112. **Examination procedure outlines for commercial weighing and measuring devices. A manual for weights and measures officials,** O. K. Warnlof, Nat. Bur. Stand. (U.S.), Handb. 112, 89 pages (June 1973) $1.10, SD Catalog No. C13.11:112.

Key words: Codes; examination procedure; inspection; meters; outlines; scales; tests.

This handbook presents an operational guide for the field examination of commercial weighing and measuring devices. It includes inspection and test procedures, with code references to National Bureau of Standards Handbook 44, Fourth Edition, "Specifications, Tolerances, and Technical Requirements for Commercial Weighing and Measuring Devices."

H113. **CODASYL data description language. Journal of Development, June 1973,** Nat. Bur. Stand. (U.S.), Handb. 113, 155 pages (Jan. 1974) SD Catalog No. C13.6/2:113.

Key words: COBOL; CODASYL; data base administration; data base management; data base task group; data description language.

This Journal of Development reports the work of the CODASYL Data Description Language Committee. The Committee was assigned the tasks of establishing "ways to aid the functions of data administration and systems administration." The Committee's charter included, "the provision of specifications for the declarations required to establish and maintain data base structures." As a step towards this purpose, the Journal contains three sections which treat the Background and History of the Data Description Language Committee, Major Concepts, and the specifications of the Data Description Language. The Committee based its work, in part, on the 1971 report of the Data Base Task Group Report.

The approved Data Description Language specifications contain the syntax and semantic rules that permit the description of the structure and contents of a data base in a language independent of, but common to, many other high level programming languages. The language specifications will have a significant impact on the development of functionally compatible data base management systems and will increase the portability of programs between different computer systems.

Though not part of the approved language specifications, the presentation of the major concepts will help in the understanding of the specifications. Similarly, the background and history information will help explain the evolutionary growth of the Data Description Language.

H114. **General safety standard for installations using non-medical x-ray and sealed gamma-ray sources, energies up to 10 MeV.** *(ANS N543-1974),* E. H. Eisenhower, Nat. Bur. Stand. (U.S.), Handb. 114, 69 pages (Feb. 1975) SD Catalog No. C13.11:114.

Key words: gamma-ray equipment; radiation installations; radiation safety; x-ray equipment.

This standard establishes requirements for the design and operation of common types of installations which use gamma and x radiation for non-medical purposes. Its objective is to protect persons who work with or are near such installations, as well as the general public, against excessive exposure to radiation. Maximum permissible dose limits established by the National Council on Radiation Protection and Measurements are cited. Methods for achieving adequate radiation protection are described, including structural details, surveys and inspections, and operating procedures. Appendixes contain technical information useful for design of radiation shielding barriers. (Revision of ANS Z54.1-1963, published as NBS Handbook 93).

H115. **Energy Conservation Program Guide for Industry and Commerce (EPIC),** R. R. Gatts, R. G. Massey, and J. C. Robertson, Nat. Bur. Stand. (U.S.), Handb. 115, 212 pages (Sept. 1974) SD Catalog No. C13.11:115.

Key words: energy conservation; energy conservation guide; energy conservation opportunities; energy conservation program; industrial energy conservation.

The Energy Conservation Program Guide for Industry and Commerce (EPIC) is a guide to assist business and industry to establish an on-going conservation program. EPIC outlines the steps in an energy conservation program and suggests specific ways to reduce energy use in manufacturing and commercial businesses. EPIC focuses on two aspects of energy conservation: (1) The key steps in an implementation plan for an energy conservation plan; (2) Energy Conservation opportunities which have been identified by industry.

H115. Supplement 1. **Energy conservation program guide for industry and commerce (EPIC),** R. G. Massey, Ed., Nat. Bur. Stand. (U.S.), Handb. 115, Suppl. 1, 212 pages (Dec. 1975) SD Catalog No. C13.11:115/Suppl. 1.

Key words: energy conservation; energy conservation guide; energy conservation opportunities; energy conservation program; industrial energy conservation.

The Energy Conservation Program Guide for Industry and Commerce (EPIC) is a handbook to assist business firms to establish an on-going conservation program. Supplement contains simplified management program, additional conservation opportunities, case studies, and sources of information.

H116. **American National Standard N540; classification of radioactive self-luminous light sources,** *Nat. Bur. Stand. (U.S.), Handb. 116,* 15 pages (Jan. 1976) SD Catalog No. C13.11:116.

Key words: classification; containment; designation; light sources; national standard; radiation source; radioactive; radioluminous products; self-luminous sources; test procedures.

This standard establishes the classification of certain radioactive self-luminous sources according to radionuclide, type of source, activity, and performance requirements. The objectives are to establish minimum prototype testing requirements for radioactive self-luminous light sources, to promote uniformity of marking such sources, and to establish minimum physical performance for such sources. This standard is primarily directed toward assuring adequate containment of the radioactive material. Testing procedures and classification designations are specified for discoloration, temperature, thermal shock, reduced pressure, impact, vibration, and immersion. A range of test requirements is presented according to intended usage and source activity.

H117. **Examination of vapor-measuring devices for liquefied petroleum gas. A manual for weights and measures officials,** S. Hasko, Nat. Bur. Stand. (U.S.), Handb. 117, 25 pages (Dec. 1975) SD Catalog No. C13.11:117.

Key words: bell prover; calibration; inspection; liquefied petroleum gas; pressure; report form; temperature; temperature compensator; test; vapor meter; volume.

A manual for State and local weights and measures officials for the examination and test of liquefied petroleum gas vapor measuring devices. Definitions, test methods, and testing apparatus (including description and calibration procedures) are given. Inspection and test procedures are reviewed. A proposed test report form along with suggestions on reporting the results of a test are included. Provision is made for accommodating a changeover to metric units of registration in the definitions, correction tables, procedures, and in reporting a test. Supersedes NBS Handbook 45.

H118. **MUMPS Language Standard,** J. T. O'Neill, Ed., Nat. Bur. Stand. (U.S.), Handb. 118, 144 pages (Dec. 1975) SD Catalog No. C13.11.118.

Key words: data handling language; interactive computing; interpretive computer programming language and operating system; medical automation; minicomputer-based systems; MUMPS; MUMPS Development Committee; MUMPS Language Standard.

This NBS Handbook contains a three-part description of various aspects of the MUMPS computer programming language. Part I, the MUMPS Language Specification, consists of a stylized English narrative definition of the MUMPS language which was adopted and approved for publication as a Type A release of the MUMPS Development Committee on March 12, 1975. Part II, the MUMPS Transition Diagrams, represents a formal definition of the language described in Part 1, employing a form of line drawings to illustrate syntactic and semantic rules governing each of the language elements; it was adopted and approved for publication as a Type A release of the MUMPS Development Committee on September 17, 1975. Part III, the MUMPS Portability Requirements, identifies constraints on the implementation and use of the language for the benefit of parties interested in achieving MUMPS application code portability; it was adopted and approved for publication as a Type A release of the MUMPS Development Committee on September 17, 1975.

A bibliography of other MUMPS Development Committee documents is included.

H119. **Quieting: A practical guide to noise control,** R. D. Berendt, E. L. R. Corliss, and M. S. Ojalvo, *Nat. Bur. Stand. (U.S.), Handb. 119,* 163 pages (July 1976) SD Catalog No. C13.11:119.

Key words: airborne and structure-borne sounds; aircraft noise intrusion; annoyance; appliance noise; health and hearing hazards; household noise; legal and community action; loudness; noise control and abatement; traffic noise.

This guide offers practical solutions for ordinary noise problems that a person is likely to meet. The discussion describes the ways in which sounds are generated, travel to the listener, and affect his hearing and well-being. Recommendations are given for controlling noise at the source and along its path of travel, and for protecting the listener. The guide instructs the reader by way of "Warning Signs" on how to determine whether he is being subjected in his environment to prolonged noise exposures that may prove hazardous to his hearing. Remedies are given for noise problems that a person is likely to find in his home, at work and at school, while traveling, and in the growth

and development of his community. The remedies include noise prevention techniques and selection of quiet alternatives to existing noise sources. General principles for selecting quiet appliances are given. Ways of searching for the sources of noise and for determining the paths over which they travel to the listener are described. A detailed index is given for individual noise sources describing specific solutions to the problems they present. General ways of looking for inherently quiet homes and travel accomodations are described. In a final chapter, there are suggestions for enlisting community help where large external sources of noise must be quieted, such as those arising from public utilities and public transportation.

H120. **Energy management guide for light industry and commerce,** W. J. Kelnhofer and L. A. Wood, *Nat. Bur. Stand. (U.S.), Handb. 120,* 28 pages (Dec. 1976) SD Catalog No. C13.11:120.

Key words: energy conservation; energy conservation guide; energy conservation opportunities; energy conservation program; industrial energy conservation.

The Energy Management Guide for Light Industry and Commerce is a training tool to assist small industrial and commercial organizations in an energy conservation program. It is part of a planned series, starting with NBS HB-115 (EPIC), of guides and training aids to assist industry in making the most efficient use of the energy supply.

While much of the information in the Light Industry Guide has been published in EPIC, the material has been edited and rewritten in shortened form for use by the large number of small organizations with a limited supply of technical manpower. The energy conservation case studies (Cost Saving Opportunities) have been written with this target audience in mind.

3.8. MISCELLANEOUS PUBLICATIONS

As the name implies, this series includes material which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series.

The name of this series was changed to Special Publications in 1970.

M236, Superseded by Special Publication 432.

M260, All editions superseded by Special Publication 260, 1975-76 Ed.

M260-11. **Standard reference materials: Viscosity of a standard lead-silica glass,** A. Napolitano and E. G. Hawkins, NBS Misc. Publ. 260-11 (Nov. 7, 1966).

Key words: Beam bending; fiber elongation; glass; glass standard; glass viscosity; lead-silica glass; restrained sphere; rotating cylinders; standard; standard reference material; viscosity; viscosity standard.

The viscosity of a lead-silica glass has been measured at the National Bureau of Standards and seven other laboratories. Determinations were made in the range of 10^2 to 10^{15} poises (1350-400 °C). Measurements were made by the rotating cylinder, restrained sphere, fiber-elongation, and beam-bending methods. The results have been critically evaluated and the glass has been issued as Standard Reference Material No. 711.

M260-12. **Standard reference materials: Homogeneity characterization of NBS spectrometric standards III: White cast iron and stainless steel powder compact,** H. Yakowitz, D. L. Vieth, R. E. Michaelis, NBS Misc. Publ. 260-12 (Sept. 19, 1966).

Key words: Microanalytical techniques; solids mass spectrometer; electron probe microanalyzer; NBS white cast iron sample (SRM 1175); stainless steel powder metallurgy compact; optical metallography; macroanalytical techniques; optical emission; x-ray spectrochemical analysis.

This paper describes a continuation of the NBS effort to characterize metal materials as to their suitability for use in calibrating microanalytical techniques such as the solids mass spectrometer and, especially, the electron probe microanalyzer. An NBS white cast iron sample (SRM 1175) and a specially prepared stainless steel powder metallurgy compact have been investigated by means of electron probe microanalysis and optical metallography. Results for six elements in the cast iron and three in the stainless steel are given. It is concluded that neither of these materials is suitable for use for calibration in microanalytical techniques. It is emphasized, however, that this in no way affects the usefulness of the white cast iron material for macroanalytical techniques such as optical emission and x-ray spectrochemical analysis.

M260-13. **Standard reference materials: Mossbauer spectroscopy standard for the chemical shift of iron compounds,** J. J. Spijkerman, D. K. Snediker, F. C. Ruegg, and J. R. DeVoe, NBS Misc. Publ. 260-13 (July 28, 1967).

Key words: Mossbauer; spectroscopy; standard; differential chemical shift; quadrupole splitting; random error; systematic error; sodium nitroprusside; iron compounds; optical Mossbauer spectrometer; tandem Mossbauer spectrometer; velocity calibration.

The preparation, calibration, and use of the Standard Reference Material for chemical shift of iron compounds in Mossbauer Spectroscopy is described. This standard is a properly oriented single crystal of sodium pentacyanonitrosylferrate (II) dihydrate (sodium nitroprusside). Primary standards were calibrated with a high accuracy optical Mossbauer spectrometer and secondary calibrations were made with a tandem Mossbauer spectrometer. The midpoint between the two absorption peaks in the spectrum at 25.0 °C provide a useful velocity scale calibration of the spectrometer. Descriptions of the spectrometers used and the error analysis associated with the data are given. Suggested format for reporting Mossbauer spectra and their parameters is also presented.

M260-14. **Standard reference materials: Determination of oxygen in ferrous materials, SRM 1090, 1091 and 1092,** O. Menis and J. T. Sterling, NBS Misc. Publ. 260-14 (Sept. 23, 1966).

Key words: Vacuum fusion; inert gas fusion; oxygen; ferrous standard reference materials; CO by infrared absorbancy; homogeneity; certified value; eighteen cooperating laboratories.

A description is presented of methods used for the determination of homogeneity and the establishment of the oxygen values certified by NBS for three ferrous standard reference materials. These standards are represented by two low alloy materials, ingot and vacuum melted iron containing 484 and 28 ppm of oxygen respectively, and a high alloy steel containing 131 ppm of oxygen. The analyses of these materials are based on two vacuum fusion procedures. The poor results for the high alloy steel obtained by the first of these methods are explained. The first method is based on manometric measurements and depends on the conversion of CO to CO_2 by copper oxide and on a differential freezing of gases. In the second method a system is used which provides a highly efficient degassing of sample and a direct measurement of CO by infrared absorbancy. Additional data from an analysis by inert gas fusion method also indicate that the homogeneity of a single rod of ingot iron, over a wide range of sample size, has a relative standard deviation of less than two per cent. From control data and homogeneity studies it was ascertained that the uncertainty limits stated in the NBS certificate include the error due to the relative inhomogeneity between rods. Finally, data from eighteen laboratories cooperating in this program are presented.

M260-15, Superseded by Special Publication 260-41.

M262-2. **Legibility of alphanumeric characters and other symbols: II. A reference handbook,** D. Y. Cornog and F. C. Rose, NBS Misc. Publ. 262-2 (Feb. 10, 1967).

Key words: Alphanumeric characters; displays; handbook; human factors; legibility; psychology; readability; standards; symbols; type faces; typography; visibility.

The major psychological findings and data in the field of the legibility of alphanumeric characters and other symbols are provided in this detailed Reference Handbook. Summaries and extracts of information for 203 experimental, developmental, review, and other legibility reports are presented and are multiply indexed in depth by (1) a matrix, cross-reference index (article versus functional variables - environmental typographical), (2) author indexes (alphabetical and chronological), and (3) a character-face-name index. These Handbook entries are further indexed by the permuted title index in NBS Miscellaneous Publication No. 262-1, "Legibility of Alphanumeric Characters and Other Symbols: I. A Permuted Title Index and Bibliography." Selected samples of several important experimental and other faces are presented in an appendix.

M273. **Critical phenomena. Proceedings of a conference, Washington, D.C., April 1965,** Editors, M. S. Green and J. V. Sengers, NBS Misc. Publ. 273 (Dec. 1, 1966).

Key words: Critical phenomena; critical point; second order phase transition; singularities; Pade approximate fluctuations; opalescence; X-transitions.

A conference on Critical Phenomena was held at the National Bureau of Standards, April 5-8, 1965. This volume contains 30 of the papers included in the program, together with the discussions which followed oral presentation. Topics covered include equilibrium critical phenomena in fluids, critical phenomena in ferro- and antiferromagnets, logarithmic singularities in specific heats, elastic, and inelastic scattering, and transport and relaxation phenomena in the critical region.

M277, Superseded by Special Publication 380.

M278 Supplement. **Bibliography on atomic transition probabilities, May 1966 through December 1967,** B. M. Glennon and W. L. Wiese, Nat. Bur. Stand. (U.S.), Misc. Publ. 278, 46 pages (Apr. 1968). Superseded by SP320 & suppls.

Key words: Allowed; atomic; discrete; forbidden; transition probability.

A supplement to NBS Miscellaneous Publication 278, Bibliography on Atomic Transition Probabilities is presented, which covers the most recent literature on this subject from May 1966 through December 1967. The papers are arranged according to elements and stages of ionization, and the method employed and class of transitions are indicated behind each reference. Only articles on discrete transitions, both allowed and forbidden, are listed. Papers containing data for more than 20 individual elements or stages of ionization are collected separately in front of the list in order to keep this bibliography at a reasonable size. Also included is a selected list of papers dealing with the subject of transition probabilities from a general point of view.

M280. **Hydraulic research in the United States, 1966,** Editors, H. K. Middleton and G. Kulin, NBS Misc. Publ. 280 (Sept. 8, 1966).

Key words: Hydraulic; hydrology; naval hydrodynamics.

Research and development projects being conducted in 1966 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work are given. References to publications relating to the projects and an extensive subject index are included.

M281. **Bibliography on flame spectroscopy. Analytical applications, 1800-1966,** R. Mavrodineanu, NBS Misc. Publ. 281 (Feb. 23, 1967).

Key words: Flame; spectroscopy; analytical emission; atomic absorption; electrical discharge; bibliography; indexed.

Flame spectroscopy, especially in its analytical applications, continues to be an active field of study. Its literature is growing steadily, and the use of flame photometry in many specialized applications calls for a comprehensive indexed bibliography. This collection consists of 5,113 references to works on flame spectroscopy, selected with emphasis toward analytical measurements. It covers the period from 1800 to 1966. Subject indexes, keyed by number to the references cited, precede most of the sections.

M282, Superseded by Special Publication 387.

M283. **Technical highlights of the National Bureau of Standards, Annual Report Fiscal Year 1966,** NBS Misc. Publ. 283 (Apr. 1967).

Key words: Annual report; technical highlights.

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1966. It lists major programs as they were carried out by the three NBS institutes: Institute for Basic Standards, Institute for Materials Research, and Institute for Applied Technology. Summaries are given of typical institute projects in applied mathematics, electricity, metrology, mechanics, heat, atomic physics, physical chemistry, laboratory astrophysics, radiation physics, radio standards, analytical chemistry, polymers, metallurgy, inorganic materials, reactor radiations, cryogenics, building research, information technology, instrumentation, radio propagation, engineering standards, and weights and measures. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, measurement services program, and national and international cooperative activities. This report also includes the description of the new laboratory facilities at Gaithersburg, Md., and the history of their construction.

M284. **Technology and world trade. Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., November 16-17, 1966,** Editor, R. L. Stern, NBS Misc. Publ. 284 (1967).

Key words: Developing countries; international standards; role of government; role of private enterprise; technology; world trade.

The publication embodies the proceedings of the Symposium on Technology and World Trade, held on the occasion of the dedication of the new laboratories of the National Bureau of Standards at Gaithersburg, Maryland. Subjects considered by the 29 speakers and discussants from the United States, nine other nations, and the United Nations, include: Technology's Impact on the Character of World Trade and Investment; International Competition and Co-operation in Technology; The Role of International Standards; The Respective Roles of Government, Public and Private Enterprises in Creating, Using and Transferring Technology; and Technology in Relation to the Developing Countries.

M285. **Nuclear science and technology for ceramists. Proceedings of the American Ceramic Society Symposium, Washington, D.C., April 7-12, 1966,** NBS Misc. Publ. 285 (May 26, 1967).

Key words: Ceramics; lattice defects; nuclear fuels; nuclear science and technology; radiation damage; reactor materials.

An introductory survey is given on the subject of Nuclear Ceramics, consisting of six invited papers presented at an American Ceramic Society Symposium held in April, 1966. Authors and their titles are: C. O. Muehlhause (National Bureau of Standards) "Material Radiation Environment"; A. B. Lidiard (UK Atomic Energy Research Establishment, Harwell, England) "Radiation Damage in Ceramics"; P. W. Levy (Brookhaven National Laboratory) "Physical Properties of Irradiated Ceramic Materials"; R. J. Thorn and G. H. Winslow (Argonne National Laboratory) "Chemical Problems Associated with Lattice Defects"; D. W. Readey and J. H. Handwerk (Argonne National Laboratory) "Nuclear Fuel Materials"; and D. R. deHalas, W. D. Freshley, and W. C. Morgan (Pacific Northwest Laboratories, Batelle Memorial

Institute) "Reactor Materials Design." The volume is intended to provide a survey of those properties involved in the choice and use of ceramics for nuclear technology, and as a reference useful in the teaching of ceramic science.

M286, Superseded by Letter Circular 1071.

M287. **Calculation of the properties of vacancies and interstitials. Proceedings of a conference, Shenandoah National Park, Va., May 1-5, 1966,** NBS Misc. Publ. 287 (Nov. 17, 1966).

Key words: Calculations; electronic states, energies of formation; energies of motion; interstitials; point defects; theory; vacancies; vibrational states.

This is the Proceedings of a Conference on the Calculation of the Properties of Vacancies and Interstitials. The Conference dealt with the theory and techniques of calculation of the properties of point defects in metallic and nonmetallic crystals. The contributed and invited papers divided about evenly among three major topics: (1) static-lattice calculations of the energies and configurations of simple vacancies and interstitials in, mainly, metals and ionic crystals; (2) electronic states at and near point defects in metals, rare gas solids, and insulators (*f*-centers, electron traps); and (3) vibrational states at point defects. The report of a panel discussion on each topic is also included. The emphasis is on the theory of the properties of isolated, simple defects rather than on the statistical properties of defect assemblies. The Conference attempted to examine the point defect theory and calculations critically, from the standpoint of general theory, rather than simply compare results with experiment.

M288, Superseded by Special Publication 417.

M289. **Bibliography of low energy electron collision cross section data,** L. J. Kieffer, NBS Misc. Publ. 289 (Mar. 10, 1967).

Key words: Atom; molecule; electron; collision cross section.

A bibliography of low energy electron collision cross section data is presented. Only references which report original measurements or calculations of electron collision cross sections are included. The cross section data for each process are listed by atomic species in order of their atomic number. The data for molecules are listed in arbitrary order.

M290. **Report of the 51st National Conference on Weights and Measures, 1966,** Report Editor, L. J. Chisholm, NBS Misc. Publ. 290 (May 15, 1967).

Key words: Conference, National; weights and measures.

A report of the proceeding of the fifty-first National Conference on Weights and Measures, held in Denver, Colorado, July 11, 12, 13, 14, and 15, 1966, and attended by state, county, and city weights and measures officials.

M291. **Proceedings of the 1966 Standards Laboratory Conference,** held at the National Bureau of Standards, Gaithersburg, Md., May 9-12, 1966, NBS Misc. Publ. 291 (July 13, 1967).

Key words: Accuracy; calibrations; conferences, 1966 Standards Laboratory; foreign standards laboratories; laboratory management; measurements and standards; measurement system; National Conference of Standards Laboratories; proceedings, 1966 Standards Laboratory Conference; traceability; United States measurement system.

The annual report of the NCSL chairman, and the text of 50 presentations on standards laboratory problems are given in this volume. The subjects treated at the third biennial congress of delegates of the National Conference of Standards Laboratories, held at the NBS Gaithersburg facility, May 9-12, 1966, included committee reports and panel discussions on the 1965-66 measurement agreement comparison, statistical control of the measurement process, information needs and sources, calibration procedures, the measurement system of USA, calibration needs of USA, personnel development, traceability and accuracy ratio, world-wide physical standards, equipment performance, organization and management, workload, and recommended practices.

M292. **Bibliography of Liesegang rings (Second Edition),** K. H. Stern, NBS Misc. Publ. 292 (Sept. 1, 1967).

Key words: Diffusion; Liesegang rings; periodic precipitation.

A bibliography of Liesegang rings (periodic precipitation figures produced by diffusion) and other periodic structures for the period 1855-1965 is compiled in chronological and alphabetical order. An author index and an index to applications of Liesegang rings to extra-chemical fields are also given.

M293. **Technical highlights of the National Bureau of Standards, Annual Report 1967,** NBS Misc. Publ. 293 (Nov. 1967).

Key words: Annual report; technical highlights.

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1967. It lists major programs as they were carried out by the three NBS institutes: Institute for Basic Standards, Institute for Materials Research, and Institute for Applied Technology. Summaries are given of typical institute projects in applied mathematics, electricity, metrology, mechanics, heat, atomic physics, physical chemistry, laboratory astrophysics, radiation physics, radio standards, analytical chemistry, polymers, metallurgy, inorganic materials, reactor radiations, cryogenics, building research, information technology, instrumentation, radio propagation, engineering standards, and weights and measures. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, measurement services program, and national and international cooperative activities.

M294. **Operations research. Proceedings of a conference for Washington area government agencies, April 20, 1966,** Editor, J. A. Joseph, NBS Misc. Publ. 294 (Dec. 1967).

Key words: Conference proceedings; government; operations research; systems analysis.

The proceedings of a one-day conference of practitioners and users of Operations Research in Federal Government in the Washington, D.C. area, sponsored by the National Bureau of Standards. The purpose of the conference was to initiate a series of periodic meetings where information on topics of actual concerns might be exchanged. Invited papers were presented by Prof. Merill M. Flood on "Operations Research in the Civilian Sector of the Government," Dr. John Haldi on "The Planning-Programming-Budgeting System," and Dr. Alan J. Hoffman on "Operations Research and Government O.R." Reports of two panel meetings on "Special Problems of Operations Research in Civil Agencies of Government" and "Broadening the O.R. Competence of Mid-Careerist" are included on the proceedings.

3.9 SPECIAL PUBLICATIONS

Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

SP-236, All previous editions superseded by Special Publication 432

SP-250, All previous editions superseded by Special Publication 250, 1978 Edition.

SP-260, All previous editions superseded by Special Publication 260, 1975-76 Edition.

SP260, 1975-76 Edition. **Catalog of NBS Standard Reference Materials 1975-76 Edition,** R. W. Seward, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-1975-76 catalog, 92 pages (June 1975) SD Catalog No. C13.10:260-1975-76 cat.

Key words: analysis; characterization; composition; General Materials; properties; Research Materials; Standard Reference Materials.

This Catalog lists and describes the Standard Reference Materials (SRM's), Research Materials (RM's), and General Materials (GM's) currently distributed by the National Bureau of Standards, as well as many of the materials currently in preparation. SRM's are used to calibrate measurement systems and to provide a central basis for uniformity and accuracy of measurement. The unit and quantity, the type, and the certified characterization are listed for each SRM, as well as directions for ordering. The RM's are not certified, but are issued to meet the needs of scientists engaged in materials research. RM's are issued with a "Report of Investigation," the sole authority of which is the author of the report. The GM's are standardized by some agency other than NBS. NBS acts only as a distribution point and does not participate in the standardization of these materials. Announcements of new and renewal SRM's, RM's, and GM's are made in the semi-annual supplements of this Catalog, SRM Price List, and in scientific and trade journals.

SP260-16. **Standard reference materials: homogeneity characterization of NBS spectrometric standards IV: preparation and microprobe characterization of W-20% Mo alloy fabricated by powder metallurgical methods,** H. Yakowitz, R. E. Michaelis, and D. L. Vieth, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-16, 30 pages (Jan. 1969).

Key words: Electron probe analysis; metallography; powder metallurgy; spectrometric standards; Standard Reference Materials; W-Mo alloys.

A significant problem of the National Bureau of Standards Standard Reference Materials program is the provision of standards suitable in homogeneity for use with microanalytical techniques such as the spark source mass spectrograph and the electron probe microanalyzer. An interim approach to the problem has been the extended homogeneity characterization of selected existing standards. This paper describes the preparation and evaluation of the first NBS standard tested specifically from the beginning for application to electron probe microanalyzers. The standard designated SRM 480 is a tungsten-20 weight percent molybdenum alloy prepared by a powder metallurgy process. Based on the results of about 1500 determinations for both tungsten and molybdenum electron probe microanalysis, the material was found to be of high homogeneity at about the micrometer level of spatial resolution. The coefficient of variation for molybdenum was 2.5% and that for tungsten 1.5%. Correction of relative intensity ratios to obtain concentrations is discussed in terms of input parameter uncertainties such as mass absorption coefficients, and electron backscatter factors. The result of studies for atomic number correction and effects on operating voltage on the microprobe absorption correction, will be given. It is concluded that SRM 480 should be a valuable addition to any microprobe laboratory doing quantitative analyses.

SP260-17. **Standard reference materials: Boric acid; isotopic and assay; standard reference materials,** E. J. Catanzaro, C. E. Champion, E. L. Garner, G. Marinenko, K. M. Sappenfield, and W. R. Shields, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-17, 70 pages (Feb. 1970).

Key words: Absolute ratios; assay standards; boron; coulometry; isotopic standards; mass spectrometry.

A precise coulometric titration method has been developed for the assay of boric acid. The method is capable of providing boric acid assays precise to within 0.0025 percent (1 sigma) which is an order of magnitude better than existing techniques. Using this method, a lot of high purity boric acid has been assayed and found to be virtually stoichiometric H_3BO_3. Its acidimetric assay value of 100.00 ± 0.01 percent characterizes this material as a primary chemical standard for boron determinations.

Multiple samples of boric acid were studied and characterized with respect to homogeneity and the effect of relative humidity on stoichiometry. Procedures for precise preparation, aliquoting and storage of boric acid solutions were devised.

A mass spectrometric technique for the precise measurement of boron isotope ratios was developed. Single-filament tantalum-ribbon sources are used, and $^{11}B/^{10}B$ ratios are determined by measuring the relative abundances of $Na_2{}^{11}BO_2{}^+$ and $Na_2{}^{10}BO_2{}^+$ ions, at masses 89 and 88, respectively. The effects of various parameters such as sample mounting procedure, filament material, sample size, total sample composition and sodium concentration were studied and alternative procedures were evaluated.

Absolute values were obtained for the isotopic abundance ratios of two boron isotopic standards, using surface emission mass spectrometry. Samples of known isotopic composition, prepared from nearly pure separated boron isotopes, were used to calibrate the mass spectrometers. The resulting absolute values are: SRM 951, Boric Acid, $^{11}B/^{10}B = 4.04362 \pm 0.00137$; and SRM 952, Boric Acid, $^{11}B/^{10}B = 0.053199 \pm 0.000032$. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the means and allowances for effects of known sources of possible systematic error.

SP260-18. **Calibration of NBS secondary standard magnetic tape (computer amplitude reference) reference tape amplitude measurement "process A,"** S. B. Geller, P. A. Mantek, and N. G. Cleveland, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-18, 41 pages (Nov. 1969).

Key words: Average peak signal level, computer amplitude reference; magnetic tape; master standard; saturation curves; secondary standard; signal level calibration; standard reference materials; unrecorded reference.

This publication describes the design and operation of the NBS signal amplitude measuring system (Process A) that is used for calibrating unrecorded Secondary Standard Magnetic Tapes (Computer Amplitude Reference). The signal level calibration is made with respect to a reference signal level derived from the NBS Master Standard Magnetic Tape (Computer Amplitude Reference) that is kept in repository at NBS. The techniques for measuring and recording the data that accompany each Secondary Standard Magnetic Tape in the form of strip chart recordings and saturated curves are described.

SP260-19. **Analysis of interlaboratory measurements on the vapor pressure of gold (Certification of Standard Reference Material 745),** R. C. Paule and J. Mandel, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-19, 21 pages (Jan. 1970).

Key words: Components of error (within- and between-laboratories); gold; heats of sublimation (second and third law); interlaboratory measurements; standard errors; standard reference materials; vapor pressure.

A detailed statistical analysis has been made of results obtained from a series of interlaboratory measurements on the vapor pressure of gold. The gold Standard Reference Material 745 which was used for the measurements has been certified over the pressure range 10^{-8} to 10^{-3} atm. The temperature range corresponding to these pressures is 1300-2100 K. The gold heat of sublimation at 298 K and the associated standard error were found to be 87,720 ± 210 cal/mol (367,040 ± 900 J/mol). Estimates of uncertainty have been calculated for the certified temperature-pressure values as well as for the uncertainties expected from a typical single laboratory's measurements. The statistical analysis has also been made for both the second and third law methods, and for the within- and between-laboratory components of error. Several notable differences in second and third law errors are observed.

SP260-21. **Analysis of interlaboratory measurements on the vapor pressures of cadmium and silver. (Certification of Standard Reference Materials 746 and 748),** R. C. Paule and J. Mandel, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-21, 30 pages (Jan. 1971).

Key words: Cadmium; components of error (within- and between-laboratory); heats of sublimation (second and third law); interlaboratory measurements; silver; standard errors; standard reference materials; vapor pressure.

Detailed statistical analyses have been made of results obtained from a series of interlaboratory measurements on the vapor pressures of cadmium and silver. Standard Reference Materials 746 (cadmium) and 748 (silver) which were used for the measurements have been certified over the respective pressure ranges $10^{-11}-10^{-4}$ atm and $10^{-12}-10^{-3}$ atm. The temperature ranges corresponding to these pressures are 350-594 K for cadmium and 800-1600 K for silver. The heats of sublimation at 298 K and the associated two standard error limits for cadmium and silver are 26660 ± 150 cal/mol and 68010 ± 300 cal/mol, respectively. Estimates of uncertainty have been calculated for the certified temperature-pressure values as well as for the uncertainties expected from a typical single laboratory's measurements. The statistical analysis has also been made for both the second and third law methods, and for the within- and between-laboratory components of error. The uncertainty limits are observed as functions of both the heat of sublimation and the temperature.

SP260-22. **Homogeneity characterization of Fe-3Si Alloy,** H. Yakowitz, C. E. Fiori, and R. E. Michaelis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-22, 30 pages (Feb. 1971).

Key words: Fe-3Si alloy; homogeneity testing; metallography; microprobe analysis; spectrometric analysis; Standard Reference Materials.

An alloy of iron-3.22 wt. pct. silicon (Fe-3Si) was characterized with regard to chemical homogeneity of iron and silicon at the micrometer level of spatial resolution. This alloy is satisfactory for use as a homogeneous standard for electron probe microanalysis. The samples were cut from coarse-grained sheet stock to a final size of about 3 mm × 3 mm × 0.28 mm thick. Homogeneity was checked by means of quantitative raster scanning in which a square matrix (1.1 mm × 1.1 mm) of individual points is analyzed by the microprobe. Each matrix represents 400 separate analyses. Usually, the same matrix was rerun so that each point was sampled twice. The coefficient of variation for both the iron and silicon is less than one percent. Quantitative microprobe analysis was also carried out on this alloy giving a silicon content of 3.14% and an iron content of 96.9%.

SP260-23. **Viscosity of a standard borosilicate glass,** A. Napolitano and E. G. Hawkins, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-23, 10 pages (Dec. 1970).

Key words: Beam-bending; borosilicate glass; glass viscosity; parallel-plate; rotating cylinder; standard reference material; viscosity; viscosity standard.

The viscosity of a borosilicate glass has been measured at the National Bureau of Standards and four other laboratories. Determinations were made in the range 10^2 to 10^{15} poises (1525 to 470 °C). Measurements were made by the rotating cylinder, fiber elongation, beam bending, and parallel-plate methods. The results have been evaluated and the glass has been issued as Standard Reference Material No. 717.

SP260-24. **Standard reference materials: comparison of redox standards,** K. M. Sappenfield, G. Marinenko, J. L. Hague, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-24, 97 pages (Jan. 1972).

Key words: Analytical procedures; arsenic-iodine method; comparison; effective purity; oxidimetric standards.

The methods described in this publication are those that have been used at the National Bureau of Standards for the comparison of the current oxidimetric standard reference materials with each other and for the determination of the effective purity of these standard reference materials. The methods, which are modifications of well-established and previously published methods, were selected or designed for their accuracy and dependability. An accurate method was devised for the determination of the effective purity of the arsenic trioxide standard SRM 83c by adding solid iodine and determining the excess iodine photometrically.

SP260-25. **A standard reference material containing nominally four percent austenite,** G. E. Hicho, H. Yakowitz, S. D. Rasberry, and R. E. Michaelis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-25, 22 pages (Feb. 1971).

Key words: Austenite in ferrite; electron microprobe; powder metallurgy; quantitative microscopy; SRM; x-ray fluorescence analysis.

This standard was produced by powder metallurgical techniques using known amounts of austenite. Using these techniques, 134 specimens were prepared. Because these standards are expected to be used primarily for the calibration of x-ray diffraction equipment, only one surface of each standard is certified, and these surfaces range from 3.1 percent to 5.2 per

cent in austenite content. To make the specimens, 310 stainless steel powder (austenitic) was blended with 430 stainless steel powder (ferritic) to make a mixture of 5 percent austenite in ferrite. The material was compacted, sintered, polished and etched so the austenite appears white and the ferrite, a deep brown. Then quantitative microscopy methods were used to determine the percentage of austenite near the surface. Furthermore, the 310 powder contains 20 percent of nickel while the 430 powder contains virtually no nickel. Therefore, after establishing a meaningful calibration curve, x-ray fluorescence analysis for the nickel content was also used as a direct measurement of the amount of austenite on the surface of the compact. Both procedures were carried out on fifteen specimens statistically selected from the total number of compacts produced. Agreement, within experimental error limits, was obtained between the x-ray fluorescence results and quantitative microscopy results. The x-ray fluorescence method was used to characterize all additional compacts. X-ray diffraction determinations of austenite content are in good agreement with the x-ray fluorescence and quantitative microscopy results. The compacts may be used as x-ray diffraction standards for austenite or in special cases as x-ray fluorescence standards for nickel content.

SP260-26. **Standard reference materials: National Bureau of Standards—U.S. Steel Corporation joint program for determining oxygen and nitrogen in steel,** J. F. Martin, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-26, 40 pages (Feb. 1971).

Key words: Inert gas fusion; one ppm of oxygen and nitrogen in steel; Research Associate Program; simultaneous determination of oxygen and nitrogen; Standard Reference Material for oxygen.

Because of a need for a method for the rapid, simultaneous determination of small concentrations of oxygen and nitrogen in steel, a joint project under the Industrial Fellowship Program of U.S. Steel and the Research Associate Program of the National Bureau of Standards (NBS) was established. After investigation of various techniques, an analytical apparatus was constructed with excellent sensitivity for both elements. This apparatus consists of an inert gas fusion system coupled to a gas chromatograph. Recommended modifications have been completed on this equipment, and simultaneous determinations of oxygen and nitrogen in steel are presently being made. The detection limit is < 1 ppm for both oxygen and nitrogen, and the analysis time is about 5 minutes.

A direct result of this program has been the issuance by NBS of a new Standard Reference Material (SRM), a maraging steel, for oxygen. This SRM has the lowest oxygen concentration (4.5 ppm) of any steel standard yet issued by NBS.

SP260-27. **Uranium isotopic standard reference materials,** E. L. Garner, L. A. Machlan, and W. R. Shields, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-27, 162 pages (Apr. 1971).

Key words: Absolute isotopic abundance; ignition procedure; isotopic standards, mass spectrometry; stoichiometry; uranium.

An ignition procedure has been developed that will yield reproducible stoichiometry for U_3O_8. The effects of temperature, length of ignition, rate of cooling, pressure and type of atmosphere were investigated. This ignition procedure has been used for the blending of high purity ^{235}U and ^{238}U separated isotopes to prepare calibration standards for the determination of bias effects in the thermal emission mass spectrometry of uranium. Weight aliquoting was used to prepare calibration mixes with $^{235}U/^{238}U$ ratios of more than 10 and less than 0.1 and to add a ^{233}U spike for the determination of minor isotope abundances in the uranium isotopic standards by the isotope dilution technique.

A description of the unique features of the mass spectrometer instrumentation including the source, NBS collector and expanded scale recorder are given. Two specific analytical procedures were used for the isotopic analysis of uranium and are adaptable, within a general framework, to fit the particular ion current intensity requirements of a wide range of isotopic distributions. Mass discrimination due to evaporation and ionization on the filaments, and other parameters such as temperature, time, sample size, sample mounting, total sample composition, acidity, filament material, pressure, non-ohmic response, R-C response and source memory were studied as part of the development effort to establish sound analytical procedures.

The absolute isotopic abundances of 18 uranium SRMs were determined by thermal emission mass spectrometry. The general approach was to determine absolute $^{235}U/^{238}U$ ratios by using calibration mixes to correct for filament bias. Then the absolute ^{234}U and ^{236}U were determined by ^{233}U isotope dilution. For SRM U-0002, isotope dilution was the only practical means of determining the low abundance of ^{235}U as well as the ^{234}U. The limits given for the isotopic composition of the uranium SRMs are at least as large as the 95 percent confidence limits for a single determination and include terms for inhomogeneities of the material as well as analytical error.

SP260-28. **Standard reference materials: Preparation and evaluation of SRM's 481 and 482 gold-silver and gold-copper alloys for microanalysis,** K. F. J. Heinrich, R. L. Myklebust, S. D. Rasberry, and R. E. Michaelis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-28, 100 pages (Aug. 1971).

Key words: Alloys; corrections; electron probe; homogeneity; matrix scanner; microanalysis; quantitative analysis; standard reference materials; x-ray emission.

The reasoning behind the choice of the systems Au-Ag and Au-Cu for SRM's, and their suggested uses are described. We also report on the preparations of the materials, their chemical analysis, the tests performed to ascertain macroscopic and microscopic homogeneity, and on relative x-ray intensity measurements at various x-ray lines and voltages. A description of the instrumentation (matrix scanner), techniques, and programs employed in the homogeneity studies, as well as tables and graphs of the x-ray intensity measurements, are appended.

SP260-29. **Calibration of NBS secondary standard magnetic tape (computer amplitude reference) SRM 3200 using the reference tape amplitude measurement "Process A" Model II,** S. B. Geller, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-29, 57 pages (June 1971).

Key words: Average signal peak level; computer amplitude reference; magnetic tape; master standard; saturation curves; secondary standard; signal level calibration; standard reference materials; unrecorded reference.

This publication describes the design, operation and calibration of the NBS signal amplitude measuring system (Process A—Model II) that is used for calibrating unrecorded Secondary Standard Magnetic Tapes (Computer Amplitude Reference) SRM 3200. This system supersedes the measurement system that was described in the NBS Special Publication 260-18 (November 1969). The signal level calibration is made with respect to a reference signal level derived from the NBS Master Standard Magnetic Tape (Computer Amplitude Reference) that is kept in repository at NBS. The techniques for measuring and recording the data that accompany each Secondary Standard Magnetic Tape in the form of strip chart recordings and saturation curves are described.

SP260-30. **Standard reference materials: standard samples issued in the USSR,** R. S. Gorozhanina, A. Y. Freedman, and A. B. Shaievitch, All-Union Scientific Research Institute of Metrology Sverdlovsk Branch, All-Union Scientific Research

Center of the State Service for Standard Samples, translated from the Russian by M. C. Selby, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-30, 86 pages (June 1971).

Key words: Standard reference materials; standard samples; standards in Russia; USSR standards.

This reference handbook contains information on standard samples of properties and composition of substances and materials including areas of their application, nomenclature, certified characteristics, and values of the certified quantities.

The handbook was prepared for personnel of metrological establishments, for laboratories of ferrous and non-ferrous metallurgy, for all branches of industry employing metals and alloys, for the mining industry, geological research service, oil refining industry, scientific research organizations, and institutes of higher education.

SP260-31. **Thermal conductivity of electrolytic iron, SRM 734, from 4 to 300 K,** J. G. Hust and L. L. Sparks, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-31, 19 pages (Nov. 1971).

Key words: Cryogenics; electrical resistivity; electrolytic iron; Lorenz ratio; Seebeck effect; thermal conductivity; transport properties.

Thermal conductivity data are reported for a specimen of electrolytic iron, SRM 734, for temperatures from 4 to 300 K. Variability of this iron was studied by means of electrical residual resistivity ratio measurements on 63 specimens. This study showed that with a two-hour anneal at 1000 °C one can obtain a thermal conductivity Standard Reference Material that has variability of less than 1 percent in thermal conductivity.

SP260-32. **Standard reference materials: Standard quartz cuvettes for high accuracy spectrophotometry,** R. Mavrodineanu and J. W. Lazar, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-32, 27 pages (Dec. 1973) 55 cents, SD Catalog No. C13.10:260-32.

Key words: Cuvette, spectrophotometry; lightpath; pathlength; quartz, cuvette; radiation pathlength.

Accurate knowledge of lightpath and parallelism of cuvettes used in spectrophotometry is one of the indispensable parameters which must be determined when accurate transmittance measurements of liquid materials is considered. A description is given of the design and techniques developed at NBS for the production of quartz cuvettes having a nominal radiation pathlength of 10 mm $\pm$ 0.03 mm and a parallelism certified both with an uncertainty of $\pm$ 0.0005 mm. The method and instrumentation used to determine these parameters is also described in the paper.

SP260-33. **Standard reference materials: comparison of original and supplemental SRM 705, narrow molecular weight distribution polystyrene,** H. L. Wagner, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-33, 30 pages (May 1972).

Key words: Characterized polymers; narrow molecular weight polystyrene; polystyrene standard; Standard Reference Material 705.

Because the supply of the original batch of narrow molecular weight distribution polystyrene, SRM 705, is almost exhausted, another supply of polystyrene, reported to be from the same batch as the original has been characterized to determine whether it is the same as the original as far as the properties listed on the certificate are concerned. No difference in molecular weight as measured by light scattering, osmometry, or gel-permeation chromatography could be found. The limiting viscosity numbers were also the same. It was also shown from solution viscosity measurements that pellet to pellet variation in molecular weight is negligible.

SP260-34. **Standard reference materials: thermoelectric voltage of silver-28 atomic percent gold thermocouple wire, SRM 733, versus common thermocouple materials (between liquid helium and ice fixed points),** L. L. Sparks and J. G. Hust, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-34, 34 pages (Apr. 1972).

Key words: Cryogenics; Seebeck voltage; silver-gold alloy; Standard Reference Material; thermocouple.

Industry wide standardization of thermocouple wire depends, in part, on the ability to thermoelectrically compare commercial wires with a Standard Reference Material (SRM). The alloy *Ag*-28 at% Au, SRM 733, meets the requirements of a thermoelectric reference material, particularly in the temperature range of liquid helium and liquid hydrogen where Pt-67 is not adequate. Thermoelectric voltage comparisons are reported for SRM 733 versus common thermocouple materials between liquid helium and ice fixed points. Detailed standard reference data based on these common materials are given in NBS Monograph 124. The comparisons were made in a thermocouple comparator which was designed to be a permanent holder of three SRM 733 wires; the comparator allows tests to be made without handling the standard wires. Details of the construction, testing, and analysis of the comparators are given.

SP260-35. **Standard reference materials: thermal conductivity of austenitic stainless steel, SRM 735, from 5 to 280 K,** J. G. Hust and L. L. Sparks, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-35, 22 pages (Apr. 1972).

Key words: Cryogenics; electrical resistivity; stainless steel; Standard Reference Material; thermal conductivity.

Thermal conductivity data are presented for a well-characterized austenitic stainless steel. Thermal conductivity and electrical resistivity measurements were conducted on two lots of this steel. Electrical resistivity measurements were performed on the second lot both before and after the material was hot-swaged and reannealed to a size 1/10 the original diameter. These measurements indicate that this steel can be swaged and reannealed without an appreciable change in thermal conductivity. Electrical resistivity measurements as well as direct thermal conductivity measurements on several specimens from both lots indicate a material variability in these lots of less than 1% in thermal conductivity.

SP260-36. **Standard reference materials: a referee method for the determination of calcium in serum,** J. P. Cali, J. Mandel, and L. Moore, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-36, 136 pages (May 1972).

Key words: Accuracy; atomic absorption spectrometry; calcium in serum; clinical chemistry; referee method for calcium.

The first referee method of analysis (a method of known accuracy) in clinical chemistry has been developed by a team of experts from clinical chemistry, 8 cooperating clinical chemistry laboratories, and scientists from the National Bureau of Standards. Subject to the limitations and provisos stated, calcium in serum can be determined by the referee method to within $\pm$ 2% of the "true or absolute" value. Also discussed are: (1) What Constitutes a Meaningful Measurement System; (2) Theory of Operation and Practice Required to Develop a Referee Method; (3) History of the Actual Work; the Referee Method Protocol; (4) Results; (5) The Isotope-Dilution Mass Spectrometry Work; (6) Discussion, Conclusions, and Recommendations for Future Referee Method Developments.

SP260-37. **Standard reference materials: methods of analysis of NBS clay standards,** J. I. Shultz, R. K. Bell, T. C. Rains, and O. Menis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-37, 86 pages (June 1972).

Key words: Atomic absorption; ceramics; classical procedures; clay materials; flame emission; refractories; Standard Reference Materials.

This publication brings together a compilation of methods used at NBS for the analysis of two complex standard reference clay materials. The methods were selected to give the best obtainable results for those elements normally found in clays. In some instances, more than one procedure was employed for an element as a cross-check on the precision and accuracy of the results. The procedures are presented in two parts. Part I is concerned with the determination of the major constituents by the classical analytical procedures. Part II covers the minor elements which are determined instrumentally by flame emission and atomic absorption spectrometry. These clay materials serve as analytical composition standards to provide quality control of the basic raw materials which are used in the ceramics and refractories industries.

SP260-38. **Standard reference materials: preparation and calibration of standards of spectral specular reflectance,** J. C. Richmond and J. J. Hsia, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-38, 57 pages (May 1972).

Key words: Aluminum; gold; infrared reflectance; interferometer; mirrors; reflectance; reflectance standards; spectral reflectance; spectral specular reflectance; specular reflectance; standards; ultraviolet reflectance.

This report describes in detail the preparation and calibration of Standard Reference Materials 2001 through 2008. These standards of spectral specular reflectance were prepared commercially by vacuum depositing opaque coatings of gold and aluminum, respectively, onto polished substrates of fine-annealed borosilicate glass. The near-normal (9° from normal) spectral specular reflectance was measured by the multiple-reflection technique. Four different combinations of source, spectrometer, and detector were used to cover the wavelength range from about 0.25 μm to 30 μm and beyond.

SP260-39. **Standard reference materials: the eddy current decay method for resistivity characterization of high purity metals,** A. F. Clark, V. A. Deason, J. G. Hust, and R. L. Powell, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-39, 53 pages (May 1972).

Key words: Apparatus; characterization; eddy current decay; electrical resistivity; high purity metals; homogeneity; low temperature.

Characterization of high purity metals by resistivity measurements at low temperatures is discussed. In particular, the eddy current decay method of resistivity measurement is described in detail. The advantages and limitations are presented along with the theoretical basis of the method. Detailed instructions are given for constructing and operating the apparatus.

SP260-40. **Standard reference materials: selection of differential thermal analysis temperature standards through a cooperative study (SRM 758, 759, 760),** H. G. McAdie, P. D. Garn, and O. Menis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-40, 71 pages (Aug. 1972).

Key words: DTA; International Confederation on Thermal Analysis; international cooperative testing; Standard Reference Materials NBS 758, 759, 760; temperature scale; thermal analysis.

The testing and evaluation program leading to the certification of 10 materials as Standard Reference Materials NBS 758, 759 and 760, for calibrating the temperature scale for thermal analysis is described. The international cooperative testing program was set up on the basis of a preliminary program initiated in 1966. Thirty-four laboratories reported to the Standards Committee of the International Confederation on Thermal Analysis. The results were obtained on a variety of apparatus under their conditions of experimentation, except that the heating rate was prescribed in the range of 4 to 10 °C per minute. The data were processed to obtain means and measures of scatter, not only in total, but separated in terms of a number of sample number of sample holder parameters. The sample holder geometry was the only parameter having a clear effect on the extrapolated onset and peak temperatures. The effects of the thermocouple position and calibration were tested, but no significant effect was found. The heating rate has only a small effect, tending to increase the spread of onset and peak temperature values from the DTA are somewhat higher than the thermodynamic equilibrium values reported in the literature. Based on the mean values from all the laboratories the standard deviation was 5 to 8 °C, which includes the bias between laboratories as well as measurement errors.

SP260-41. **Standard reference materials: use of standard light-sensitive paper for calibrating carbon arcs used in testing textiles for colorfastness to light,** L. A. Wood and P. J. Shouse, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-41, 24 pages (Aug. 1972).

Key words: Carbon-arcs, standardization of; color-fastness, testing of; fading tests, standardization; light-sensitive paper; paper, light-sensitive; textiles, fading of.

The use of NBS Light-Sensitive Paper and NBS Booklets of Standard Faded Strips in the standardization of carbon arcs is described. These lamps are used to determine the fading characteristics and degradation of textiles and other materials when subjected to visible and ultraviolet radiation. The light-sensitive paper is useful in calibrating the arcs in terms of NBS Standard Fading Hours (SFH) or equivalent exposure in the NBS Master Carbon-Arc Lamp.

SP260-42. **Standard reference materials: the characterization of linear polyethylene SRM 1475,** H. L. Wagner and P. H. Verdier, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-42, 39 pages (Sept. 1972).

Key words: Density; differential refractive index; gel permeation chromatography (GPC); light scattering; linear polyethylene; melt flow rate; molecular weight distribution; number average molecular weight; osmometry; refractive index; standard reference material; viscosity; weight average molecular weight; Z average molecular weight.

The National Bureau of Standards has issued a linear polyethylene standard reference material, SRM 1475. This material is certified for weight average molecular weight (M_w), number average molecular weight (M_n), Z average molecular weight (M_z), molecular weight distribution, limiting viscosity numbers in several solvents, melt flow rate, and density. The experimental details of the determination and certification of these properties are given in these collected papers previously published in the Journal of Research of the National Bureau of Standards.

SP260-43. **Standard reference materials: preparation and homogeneity characterization of an austenitic iron-chromium-nickel alloy,** H. Yakowitz, A. W. Ruff, and R. E. Michaelis, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-43, 19 pages (Nov. 1972).

Key words: Austenitic stainless steel; electron probe microanalysis; Fe-Cr-Ni alloy; homogeneity testing; metallography; stacking fault energy; Standard Reference Material.

An alloy of weight fraction 0.710 iron, 0.183 chromium and 0.107 nickel was characterized at the micrometer level of spatial resolution by means of electron probe microanalysis. This alloy,

designated SRM 479, is of suitable homogeneity for use as a standard in microanalytical techniques. The coefficient of variation for each of the three elements is not more than 1.5% based on about 800 analyses involving five different specimens. There is no statistically significant variation in composition within specimens or from specimen to specimen. Electron probe microanalysis was carried out using different instrumental conditions and operators. SRM 479 is supplied as a disc about 4.6mm diameter by 1mm thick.

SP260-44. **Standard reference materials: preparation and use of superconductive fixed point devices, SRM 767,** J. F. Schooley, R. J. Soulen, Jr., and G. A. Evans, Jr., Nat. Bur. Stand. (U.S.), Spec. Publ. 260-44, 35 pages (Dec. 1972).

Key words: Aluminum; cadmium; cryogenics; indium; lead; magnetic susceptibility; superconductive transition temperature; superconductivity; thermometric fixed points; zinc.

The preparation, testing, and use of SRM 767 devices are described. These devices incorporate samples of lead, indium, aluminum, zinc, and cadmium within a mutual inductance coil pair. These elements become superconductive at temperatures near 7.2, 3.4, 1.2, 0.85 and 0.5 K, respectively, and the transition midpoints, when attained by observing the sample magnetic susceptibilities in negligible small magnetic fields, provide thermometric reference points which are reproducible to ± 1 mK.

SP260-45. **Standard reference materials: Development of NBS Standard Reference Material No. 1579 Powdered Lead-Based Paint,** B. Greifer, E. J. Maienthal, T. C. Rains, and S. D. Rasberry, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-45, 31 pages (Mar. 1973) 50 cents, SD Catalog No. C13.10:260-45.

Key words: Analytical standard; atomic absorption spectrometry; differential cathode ray polarography; electrodeposition; lead-based paint; neutron activation analysis; x-ray fluorescence spectrometry; Standard Reference Material.

The development of NBS Standard Reference Material No. 1579, Powdered Lead-Based Paint is described. This SRM is intended for use in the calibration of apparatus and methods used in determining lead in paint removed from old housing.

Paints scraped from the interior surfaces of old housing were collected, blended, homogenized, and characterized for lead content. The average lead content was found to be 11.87 ± 0.04 percent lead by weight determined by atomic absorption spectrometry and by differential cathode ray polarography.

The analytical procedures involved sample dissolution by dry ashing in a furnace at 450-550 °C followed by exhaustive extractions of the insoluble residue with acids and with ammonium acetate solution.

SP260-46. **Standard reference materials: Thermal conductivity and electrical resistivity. Standard reference materials: Austenitic stainless steel, SRM's 735 and 798, from 4 to 1200 K,** J. G. Hust and P. J. Giarratano, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-46, 42 pages (Mar. 1975) SD Catalog No. C13.10:260-46.

Key words: austenitic stainless steel; electrical resistivity; high temperature; low temperature; standard reference materials; thermal conductivity.

A historical review of the development of selected thermophysical standard reference materials, SRM's, is given and selection criteria for those SRM's are listed. Thermal conductivity and electrical resistivity data for austenitic stainless steel, SRM's 735 and 798, are critically evaluated. Recommended values are presented for the temperature range 4 to 1200 K. Material variability studies, including the effects of heat treatment, have been performed at low temperatures. No irreversible transformations are observed up to temperatures of 1200 K. Based on the results of several types of characterization measurements, effects of material variability are believed to be less than 1 percent in electrical resistivity and not significantly more in thermal conductivity. The uncertainty of the recommended electrical resistivity data is estimated at 1 percent at low temperatures and 2 percent at higher temperatures. The corresponding uncertainty for thermal conductivity is 2 percent below 100 K, increasing to 3 percent at 300 K, and 5 percent at higher temperatures.

SP260-47. **Standard reference materials: Electrical resistivity of electrolytic iron, SRM 797, and austenitic stainless steel, SRM 798, from 5 to 280 K,** J. G. Hust, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-47, 20 pages (Feb. 1974) SD Catalog No. C13.10:260-47.

Key words: austenitic stainless steel; cryogenics; electrical resistivity; electrolytic iron; Lorenz ratio; standard reference material.

Electrical resistivity data are presented for characterized electrolytic iron, SRM 797, and austenitic stainless steel, SRM 798, at temperatures from 5 to 280 K. Resistivities at ice and liquid helium temperatures were determined for 22 randomly selected iron specimens and the same number of steel specimens. These data indicate that the effect of material variability is about 1 percent for each of these SRM's.

SP260-48. **Standard Reference Materials: Description and use of precision thermometers for the clinical laboratory, SRM 933 and SRM 934,** B. W. Mangum and J. A. Wise, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-48, 23 pages (May 1974) SD Catalog No. C13.10:260-48.

Key words: clinical laboratory; enzymology; health care; liquid-in-glass thermometers; standard reference material; SRM 933; SRM 934; thermometers.

Because of the high sensitivity to temperature of many facets of the clinical laboratory, e.g., in enzyme reactions and in pH and blood gas analysis, there is a need for accurate temperature measurements and its control. In order to help satisfy these needs and to aid in getting a usable and accurate temperature scale into the clinical laboratory, the National Bureau of Standards has developed SRM 933 and SRM 934. These are precision thermometers, which are calibrated at 0, 25, 30, and 37 °C and their description, their calibration, and the procedures for their proper usage are discussed.

SP260-49. **Standard reference materials: Calibrated glass standards for fission track use,** B. S. Carpenter and G. M. Reimer. Nat. Bur. Stand. (U.S.), Spec. Publ. 260-49, 25 pages (Nov. 1974) SD Catalog No. C13.10:260-49.

Key words: fission tracks; flux monitors; glass standards; standard reference material; thermal neutron irradiation; uranium.

Four glasses of different uranium concentrations were prepared and certified by the National Bureau of Standards as standards for use as neutron monitors to aid fission track studies. These Standard Reference Materials (SRM) and their uranium concentrations are: SRM 941 (461 ppm), SRM 962 (37.4 ppm), SRM 963 (0.823 ppm), and SRM 964 (0.0721 ppm). These glass wafers were irradiated in the National Bureau of Standards Reactor and the neutron flux was monitored using copper and gold foils.

SP260-50. **Standard reference materials: Thermal conductivity and electrical resistivity standard reference materials: Electrolytic iron SRM's 734 and 797 from 4 to 1000 K,** J. G. Hust

and P. J. Giarratano, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-50, 41 pages (June 1975) SD Catalog No. C13.10:260-50.

Key words: electrical resistivity; electrolytic iron; high temperature; iron; Lorenz ratio; low temperature; standard reference material; thermal conductivity; thermopower.

A historical review of the development of Standard Reference Materials, SRM's, is given and selection criteria of SRM's are listed. Thermal conductivity and electrical resistivity data for electrolytic iron and similar irons are compiled, analyzed, and correlated. Recommended values of thermal conductivity and electrical resistivity for electrolytic iron, SRM's 734 and 797, are presented for the range 4 to 1000 K. These values are based on NBS measurements up to 280 K and on measurements by Oak Ridge National Laboratory on a similar iron above 280 K. The average uncertainty of the thermal conductivity values below ambient is 1.5 percent and 3 percent above ambient. The corresponding uncertainties in electrical resistivity are 1 percent and 2 percent.

SP260-51. **Standard reference materials: Glass filters as a Standard Reference Material for spectrophotometry—selection, preparation, certification, use, SRM 930,** R. Mavrodineanu and J. R. Baldwin, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-51, 118 pages (Nov. 1975) SD Catalog No. C13.10:260-51.

Key words: accuracy in spectrophotometry; glass filters; spectral bandpass; spectrophotometry; standard reference materials; stray radiation; testing of spectrophotometers; transmittance (absorbance) accuracy; wavelength accuracy.

This publication describes various factors which can affect the proper functioning of a spectrophotometer and suggests means and procedures to assess and control these factors. Particular consideration is given to the long and short term stability of a spectrophotometer, to the wavelength accuracy, the spectral bandpass, the stray radiation, and the accuracy of the transmittance or absorbance scale. A description is given of the means and Standard Reference Materials (SRM's) which can be used to control these factors, together with the methods for the preparation, certification, and use of such materials (SRM 930). The results obtained in actual use of SRM 930 are examined in some detail. An appendix contains the reproduction of several publications relevant to the subject discussed in this work.

SP260-52. **Standard reference materials: Thermal conductivity and electrical resistivity standard reference materials: Tungsten SRM's 730 and 799, from 4 to 3000 K,** J. G. Hust and P. J. Giarratano, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-52, 47 pages (Sept. 1975) SD Catalog No. C13.10:260-52.

Key words: electrical resistivity; high temperature; Lorenz ratio; low temperature; standard reference materials; thermal conductivity; thermopower; tungsten.

A historical review of the development of thermophysical Standard Reference Materials, SRM's, is given and selection criteria of SRM's are listed. Thermal conductivity and electrical resistivity data for arc cast and sintered tungsten are compiled, analyzed, and correlated. Recommended values of thermal conductivity (SRM 730) and electrical resistivity (SRM 799) for these lots of tungsten are presented for the range 4 to 3000 K. These values are based on low temperature NBS measurements and higher temperature measurements by participants of the AFML-AGARD project. The uncertainty of the thermal conductivity values below ambient is 2 percent and rises to 5 percent between ambient and 2000 K. Above 2000 K the uncertainty rises to a maximum of about 8 percent. The uncertainty of the electrical resistivity values is 2 percent over the entire temperature range.

SP260-53. **Standard Reference Materials: Standardization of pH measurements,** R. A. Durst, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-53, 48 pages (Dec. 1975) SD Catalog No. C13.10:260-53.

Key words: buffers; buffer solutions; glass electrode; pH; pH buffers; pH electrode; pH measurement; pH standards.

One of the most widely performed analytical measurements in chemical laboratories is that of pH using the glass electrode. In order to insure the consistency of these measurements, the National Bureau of Standards has adopted an operational scale of pH defined in terms of the pH(S) of a series of standard buffer solutions. Certified samples of buffer materials, from which the standard reference solutions of reproducible pH can be prepared, are issued by the NBS. At present, the operational scale is defined by the pH of seven primary and three secondary standard solutions.

This report is concerned primarily with a discussion of the method used at the NBS for the assignment of pH values to the standard buffer solutions, a description of the NBS measurement facilities, and a summary of the characteristics of these standards. A brief discussion of the types of electrodes used and the calibration of pH instrumentation is also presented.

SP295. **Electronic composition in printing.** Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., June 15-16, 1967, R. W. Lee and R. W. Worral, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 295, 133 pages (Feb. 1968).*

Key words: Character generation; composition language; computer technology; computerized text processing; electronic composition; electronic computer; electronic printing; GRACE; Linotron; MACRO coding; MEDLARS; microfilm; photocomposition; Photon; programming; text editing.

A Symposium on Electronic Composition in Printing was held at the Gaithersburg, Md. Laboratories of the National Bureau of Standards June 15 and 16, 1967. Sponsored by the NBS Center for Computer Sciences and Technology, the symposium was a state-of-the-art review of a rapidly advancing field of computer application with great potentialities for increased efficiency and savings in the Federal Government.

Twenty-nine papers were presented and are published in this Proceedings. They include a diverse group by industry representatives reporting recent technological advancements in the field. Several papers define government policy and describe the new Linotron system of photocomposition at the Government Printing Office; another series is devoted to nongovernment applications and research; and a final group details specific applications within several Government agencies.

Technology of Electronic Composition: an Overview, L. H. Hattery.
The Linotron System, D. H. Rollert.
Computer Image Drawing from Digital Data, M. V. Mathews.
High-Speed 901 Zip, A. G. Bernardo.
The Videograph Text Editor, G. T. Gerlach.
The PhotoTextSetters, A. J. Smith.
A Videocomp Systems Approach, A. H. Coleman.
Micromation—Its Impact on the Photocomposing Industry, J. J. Kalagher.
IBM's Position in Electronic Composition and Text Editing, H. E. Weiss.
An Introduction, P. A. Ziemer.
Transition on the Tiber—A New Look at the G.P.O., The Hon. J. L. Harrison.
Present and Projected Policies of the J.C.P., J. F. Haley.
Introductory Remarks, G. E. Roudabush.

Chemical Information—A Computer, and Photocomposition, B. G. Lazorchák.
The Impact of Electronic Composition on Commercial Printing and Publishing, W. C. Lamparter.
Computerized Typesetting Projections, K. B. Ludwig.
Classification in Computerized Text Processing, R. P. Wishner.
System 70, J. W. Seybold.
A Brief Overview, S. N. Alexander.
Comments, M. E. Stevens.
Electronic Composition within the Department of Health, Education and Welfare, E. R. Lannon.
Electronic Composing System Applications, J. J. Boyle.
Use of GRACE at N.L.M., R. E. Bogart.
Computer Typesetting Program at NBS, W. R. Bozman.
Typewriter-to-Computer Roster Publication and Maintenance, A. North.
Implications of the Electronic Composition System for DSA Publications, W. J. Beran.
Conversion to Linotron, V. G. Kehler.

SP296. **Mass transport in oxides.** Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., October 22-25, 1967, J. B. Wachtman, Jr. and A. D. Franklin, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 296, 224 pages (Aug. 1968).*

Key words: Crystal defects; diffusion; ionic conductivity; mass transport; oxides; stoichiometry.

This Special Publication presents the Proceedings of the Conference on Mass Transport in Oxides, held at the National Bureau of Standards in Gaithersburg, Md., from October 22 to October 25, 1967, under the joint sponsorship of the Bureau and the Advanced Research Projects Agency. Invited papers reviewed mass transport in alkali and silver halides as background, and topics relating to oxides including point defects, (both experiment and theory), lattice dynamics and ionic interactions, atomistic mechanisms of diffusion and ionic conduction, chemical diffusion, defect complexes, assessments of the experimental situation for diffusion and ionic conduction, and the availability of good research materials. In contributed papers, attention was focused on color centers in alkaline earth oxides, cation diffusion in MgO, transport of both cations and anions in transition metal oxides, and coulometric and emf techniques for obtaining transport data. A panel discussion summarized the work of the conference.

Mass Transport in the Face-Centered Cubic Alkali and Silver Halides, L. M. Slifkin.
Diffusion of Sodium in Sodium Chloride in an Applied Electric Field, R. J. Friauf and V. C. Nelson.
Characterization of Point Defects in Oxides, J. E. Wertz.
Theory of the Energetics of Simple Defects in Oxides, I. M. Boswarva and A. D. Franklin.
Lattice Dynamics and Ionic Interactions, J. Slater.
On Electron-Lattice Interaction in the CaO *F* Center, J. C. Kemp and W. M. Ziniker.
Electronic States of Defects in Irradiated Oxides, B. Henderson.
Covalency in Metal Oxides, B. E. F. Fender and B. C. Tofield.
Diffusion and Ionic Conductivity: Kinetic Theory, J. R. Manning.
Chemical Diffusion Coefficients for Some Non-Stoichiometric Metal Oxides, J. B. Wagner, Jr.
The Use and Limitations of the Concept of an Effective Binary Diffusion Coefficient for Multi-Component Diffusion, A. R. Cooper.
Divalent Cation Impurity Diffusion in MgO, A. J. Mortlock.
Diffusion of Iron and Nickel in Magnesium Oxide Single Crystals, S. L. Blank and J. A. Pask.
Impurity Cation Diffusion in Magnesium Oxide, B. J. Wuensch and T. Vasilos.
Cavity Formation in Magnesium Oxide, A. Briggs and D. H. Bowen.
Defect Complexes and Microdomains in Non-Stoichiometric Oxides, an Analysis of Wüstite, $Fe_{1-\delta}O$, G. G. Libowitz.
Diffusion in Oxides: Assessment of Existing Data and Experimental Problems, C. E. Birchenall.
The Determination of Thermodynamic Properties in Single Phase Wüstite by Coulometric Titration in a High Temperature Galvanic Cell, H. F. Rizzo, R. S. Gordon, and I. B. Cutler.
The Mechanism of Oxygen Self-Diffusion in Nickel and Cobalt Oxides, M. Hoch and R. Szwarc.
Experimental Evidence for Highly Mobile Electrons in MnO and NiO at High Temperature, D. S. Tannhauser, N. M. Tallan, and M. Gvishi.
High Temperature Defect Structure and Electrical Properties of NiO, I. Bransky and N. M. Tallan.
Ionic Conductivity in Oxides: Experimental Problems; Survey of Existing Data, L. Heyne.
Measurement of High-Temperature Thermodynamic Properties of Non-Stoichiometric Oxides Using Solid State EMF and Coulometric Techniques, B. C. H. Steele.
Interdiffusion Coefficients From Electronic Conductivity Measurements—Application to Cu_2O, R. H. Campbell, W. J. Kass, and M. O'Keeffe.
A Chemla Experiment in BeO, C. F. Cline, H. W. Newkirk, R. H. Condit, and Y. Hashimoto.
Self-Diffusion of Oxygen in Neodymium and Samarium Sesquioxide, G. D. Stone, G. R. Weber, and L. Eyring.
Oxygen Transport During Oxidization, J. B. Lightstone and J. P. Pemsler.
Mechanical and Dielectric Relaxation of Hopping Electrons and the Ionic Defects in Reduced Rutile (TiO_{2-x}), W. W. Scott and R. K. MacCrone.
Purity and Perfection of Research Specimens of Oxides, J. W. Cleland.
The Growth of Oxide Single Crystals by Chemical Transport, Robert Kershaw and Aaron Wold.

SP297. **Report of the 52d National Conference on Weights and Measures, 1967,** R. L. Koeser, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 297, 226 pages (May 1968).*

Key words: Conference; weights and measures—history; weights and measures—laws; weights and measures—regulations; weights and measures—technical requirements; weights and measures.

This is a report of the proceedings (edited) of the Fifty-second National Conference on Weights and Measures, sponsored by the National Bureau of Standards, held in Washington, D.C., June 26-30, 1967 and attended by State, county, and city weights and measures officials and representatives of the Federal Government, business, industry, railroads, and associations.

A Role for Automatic Data Processing in Weights and Measures, W. J. Whitty.
Implementation of the Fair Packaging and Labeling Act—Cooperation or Vexation?, F. E. McLaughlin.
The Fair Packaging and Labeling Act, A. J. Farrar.
Us Procrusteans Make Strange Bedfellows, C. F. Roberts, Jr.
Truth-in-Packaging—A Coming Reality or a Mirage?, W. Sandbach.
Ladder Measurement and Labeling, B. M. Getzoff.
What's New in Aerosol Packaging?, E. D. Giggard.
The Preval Cartridge, R. A. Coever, Jr.
Measurements on the Saturn Space Vehicle, C. T. N. Paludan.
Weights and Measures and Scale Manufacturers Problems and Opportunities, G. D. Reynolds, Jr.
The American Petroleum Institute, R. Southers.

The Petroleum Industry and Its Weights and Measures Subcommittee, J. W. Hale.

A Study to Determine Meter Accuracy Capability, R. P. West.

Activities of the Office of Weights and Measures, National Bureau of Standards, M. W. Jensen.

Hawaii—Weights and Measures Program and Progress, G. E. Mattimoe.

SP298. **Quantitative electron probe microanalysis.** Proceedings of a Seminar held at the National Bureau of Standards, Gaithersburg, Md., June 12-13, 1967, K. F. J. Heinrich, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 298, 305 pages (Oct. 1968).

Key words: Atomic number effect; biological specimens; electron probe microanalysis; electron scattering; fluorescence by the continuum; quantitative analysis; stereometric analysis; x-ray absorption; x-ray emission.

A seminar was held at the National Bureau of Standards in June 1967 to examine critically the factors involved in quantitative electron probe microanalysis. Major consideration was given to proposed methods for data evaluation, and to requirements for further work in theory, in measurement, and in the preparation of standards. This volume contains a series of invited papers which formed the basis of discussion at the seminar. Topics covered include corrections for the atomic number effect, for x-ray absorption, and for fluorescence by characteristic lines and the continuum. The various ways to derive a simplified model of the complex electron-target interaction are critically analyzed by several authors, and the accuracy of several proposed methods is compared by error histograms constructed on the basis of hundreds of analyses of materials of known composition. Applications to the analysis of biological specimens and to problems of stereometric analysis are also discussed.

Quantitative Electron Probe Microanalysis: A Progress Report, K. F. J. Heinrich.

Some Problems With Quantitative Electron Probe Microanalysis, J. Philibert and R. Tixier.

The Theory of Quantitative Electron Probe Microanalysis, I. B. Borovskii and V. I. Rydnik.

On the Structure of Formulas for Quantitative Analysis, J. Criss.

Computational Methods for X-Ray Emission from Targets Excited by Electrons, D. B. Brown.

The Choice of Models for Electron Scattering and Deceleration for Electron Probe Microanalysis, T. Mulvey.

Progress in the Correction for the Atomic Number Effect, D. M. Poole.

The Calculation of Stopping Power and Backscatter Effects in Electron Probe Microanalysis, P. Duncumb and S. J. B. Reed.

Scattering of Electrons in Metallic Targets, K. Murata, R. Shimizu, and G. Shinoda.

Absorption Edge Effects in Electron Probe Analysis, D. Nagel and J. Criss.

Fluorescence Excited by the Continuum, J. Hénoc.

Quantitative Evaluation Methods for Alloy Microstructures by Microprobe Analysis, G. Dörfler.

Some Aspects of the Microprobe Analysis of Biological Specimens, T. Hall.

SP299, Volumes 1 and 2. **Neutron cross sections and technology.** Proceedings of a conference held in Washington, D.C., March 4-7, 1968, D. T. Goldman, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 299, Vol. 1, 660 pages and Spec. Publ. 299, Vol. 2, 718 pages (Sept. 1968).*

Key words: Cross sections; neutrons; nuclear data; nuclear technology; reactors.

* The Second Conference on Neutron Cross Sections and Technology was held in Washington, D.C. on March 4-7, 1968.

Papers from this Conference have been published in two volumes as follows: Volume I, Sessions A-D, pages 1-640; Volume II, Sessions E-H, pages 641-1337. These volumes contain the texts of the invited and contributed papers of the Conference. Topics covered include: The need for neutron data in fields of science and technology; standard data and flux measurements; the determination of neutron cross sections by theoretical and experimental techniques; a presentation of recently measured data and their utilization in a variety of applications. These two volumes are sold as a set.

Volume 1:

The Role of Neutrons in Astrophysical Phenomena, W. A. Fowler.

Cosmic Abundances and the Extrapolation of Nuclear Systematics, P. A. Seeger.

The Field of Shielding Technology, H. Goldstein.

Sensitivity of Gamma-Ray Dose Calculations to the Energy Dependence of Gamma-Ray Production Cross Sections, K. J. Yost and M. Solomito.

Temperature Dependence of the Average Transmission of Tungsten Between 2 keV and 2 MeV Neutron Energy, F. H. Fröhner, J. L. Russell, Jr., and J. C. Young.

Neutron Cross Sections: The Field of Radiation Damage, M. S. Wechsler.

Production of s-Nuclei from e- and r-Seed Nuclei by a Fixed Neutron Flux, J. P. Amiet and H. D. Zeh.

Neutron Flux Measurements, R. Batchelor.

Developments in Standard Neutron Cross Sections, J. H. Gibbons.

Helium Production Cross Section Measurements, J. Weitman and N. Dåverhög.

Measurement of Gamma-Ray Production Cross Sections Using a LINAC, V. J. Orphan, A. D. Carlson, and C. G. Hoot.

Neutron Cross Sections of ^{6}Li in the Kilovolt Region, J. A. Farrell and W. F. E. Pineo.

Total Neutron Cross Sections of ^{6}Li, ^{7}Li, and Lithium from 10 to 1236 keV, C. T. Hibdon and F. P. Mooring.

The Non-Elastic Cross-Section of Beryllium for Neutrons from 2.3 to 5.2 MeV, J. R. P. Eaton and J. Walker.

Fast Neutron Energy Measurements, J. C. Davis and F. T. Noda.

Experimental Techniques in Absolute Measurements of the Fission Neutron Yield, A. De Volpi.

Review of Some Fast Neutron Cross Section Data, Y. Kanda and R. Nakasima.

Characteristics of Various Isotopes for Sandwich Foil Measurements of Neutron Spectra, T. J. Connolly and F. De Kruijf.

Advances in Accurate Fast Neutron Detection, A. De Volpi and K. G. Porges.

Nonelastic and Some Inelastic Cross Sections in C^{12} and N^{14} at 15.3 MeV, L. F. Hansen, J. D. Anderson, M. L. Stelts, and C. Wong.

Neutron Differential Cross Section Evaluation by a Multiple Foil Activation Iterative Method, W. N. McElroy, J. A. Ulseth, S. Berg, G. Gigas, and T. B. Crockett.

Spatially Continuous Neutron Flux Plotting with Spark Chambers, K. G. Porges, W. W. Managan, and W. C. Kaiser.

The Manganese-55 Resonance Activation Integral, R. Sher.

Use of Neutron Data in Thermal Reactor Power Plant Design, R. J. French.

Sensitivity of Reactivity Characteristics to Cross Section Uncertainties for Plutonium-Fueled Thermal Systems, U. P. Jenquin, V. O. Uotinen, and C. B. Heeb.

Significance of Neutron Data to Fast Reactor Power Plant Design, P. Greebler, B. A. Hutchins, and B. Wolfe.

Fission Product Cross-Section and Poisoning in Fast Reactors, V. Benzi.

The (n,γn') and Fission Reactions as Possible Sources of Low Energy Neutrons in Fast Critical Assemblies, K. Parker, E. D. Pendlebury, J. P. Shepherd, and P. Stanley.

Fissile Doppler Effect Measurement Data and Techniques, C. E. Till and R. A. Lewis.

An Examination of Methods for Calculating the Doppler Coefficient in Fast Breeder Reactors, M. W. Dyos, C. R. Adkins, and T. E. Murley.

Influence of Neutron Data in the Design of Other Types of Power Reactors, A. M. Perry.

Effects of Cross-Section Uncertainties in Compact Space Power Reactors, P. S. Brown, J. L. Watts, and R. J. Doyas.

New Cross Section Needs for Zirconium Hydride SNAP Reactors, E. H. Ottewitte.

FISSPROD, A Fission Product Program for Thermal Reactor Calculations, F. E. Lane and W. H. Walker.

Effects of Uncertainties in Nuclear Data on Experimental and Calculated Reactor Burnup, D. E. Christensen, R. C. Liikala, R. P. Matsen, and D. L. Prezbindowski.

Ratio of Photon to Neutron Fission Rates in Fast Reactors, E. J. Dowdy, W. H. Kohler, R. T. Perry, and N. B. Poulsen.

Criticality and Central Reactivity Calculations Using ENDF/B Data, R. J. LaBauve and M. E. Battat.

Transuranium Cross Sections Which Influence FBR Economics, E. H. Ottewitte.

Measurements on Fissile Nuclei: Experimental Results and Interpretation, A. Michaudon.

Normalization of Relative ^{235}U Fission Cross-Section in the Resonance Region, A. J. Deruytter and C. Wagemans.

Fission Cross-Section Measurement on U^{235}, M. G. Cao, E. Migneco, J. P. Theobald, J. A. Wartena, and J. Winter.

Precise 2200 m/s Fission Cross-Section of U^{235}, A. J. Deruytter, J. Spaepen, and P. Pelfer.

Measurement of the U^{235} Fission Cross-Section in the keV Energy Range, W. P. Poenitz.

Scattering Cross-Section of Pu^{240}, M. G. Cao, E. Migneco, J. P. Theobald, and J. A. Wartena.

Final Results on the Neutron Total Cross Section of Pu^{240}, W. Kolar and K. H. Böckhoff.

Resonance Grouping Structure in the Neutron Induced Subthreshold Fission of Pu^{240}, E. Migneco and J. P. Theobald.

Neutron Capture Measurements in the Resonance Region: Cu and Pu^{240}, H. Weigmann, J. Winter, and H. Schmid.

Neutron Scattering Cross-Section of U^{233}, U^{235}, and Pu^{241} from 1 to 30 eV, G. D. Sauter and C. D. Bowman.

Fission Cross Section Measurements: Present and Potential Capabilities, J. A. Farrell.

Neutron Induced Fission Cross-Section Measurements in ^{244}Cm, R. R. Fullwood, J. H. McNally, and E. R. Shunk.

U^{238} Neutron Capture Results from Bomb Source Neutrons, N. W. Glass, A. D. Schelberg, L. D. Tatro, and J. H. Warren.

Measurement of the Absolute Value of Eta for Pu^{241} by the Manganese Bath Method, J. R. Smith and S. D. Reeder.

Techniques for Fission Cross-Section Measurements for Elements with High α and Spontaneous Fission Activity, P. G. Koontz and D. M. Barton.

Fragment Angular Distributions for Monoenergetic Neutron-Induced Fission of Pu^{239}, J. R. Huizenga, A. N. Behkami, J. W. Meadows, Jr., and E. D. Klema.

Fission Cross-Section of ^{232}Th for Thermal Neutrons, M. N. De Mevergnies and P. Del Marmol.

A Single Level Analysis of U^{233} Cross Sections, M. J. Schneider.

Relative Fission Cross Sections of U^{236}, U^{238}, Np^{237}, and U^{235}, W. E. Stein, R. K. Smith, and H. L. Smith.

Low Energy U-235 ν Measurements, S. Weinstein and R. C. Block.

Volume 2:

Neutron Cross Section Measurements in the Resonance Region, M. C. Moxon.

A Study of Partial Radiative Widths at and Between Neutron Resonances, C. Samour, R. Alves, H. E. Jackson, J. Julien, and J. Morgenstern.

Gamma Rays Following Neutron Capture in Iron, Sodium, and Thorium, O. A. Wasson, J. B. Garg, R. E. Chrien, and M. R. Bhat.

Total Neutron Cross Section and Resonance Parameters for Pm^{147}, G. J. Kirouac, H. M. Eiland, R. E. Slovacek, C. A. Conrad, and K. W. Seemann.

Radiation Width of the 2.85-keV Resonance in Na^{23}, S. J. Friesenhahn, W. M. Lopez, F. H. Fröhner, A. D. Carlson, and D. G. Costello.

Fast Neutron Cross Sections: keV to MeV, S. A. Cox.

Neutron Radiative Capture in the keV Region, R. W. Hockenbury, Z. M. Bartolome, W. R. Moyer, J. R. Tatarczuk, and R. C. Block.

Neutron Scattering Measurements in Low Energy Cd and Rh Resonances, T. J. King and R. C. Block.

High Resolution Total Fast Neutron Cross Sections on Some Non-Fissible Nuclei in the Energy Range $0.5 \leq E_n \leq 30$ MeV, S. Cierjacks, P. Forti, D. Kopsch, L. Kropp, and J. Nebe.

Elastic Scattering of Fast Neutrons by Praseodymium and Lanthanum, D. L. Bernard, G. H. Lenz, and J. D. Reber.

Gamma Rays from Inelastic Neutron Scattering in Nitrogen, H. Condé, I. Bergqvist, and G. Nystrom.

Total Neutron Cross-Sections of Carbon, Iron, and Lead in the MeV Region, R. B. Schwartz, R. A. Schrack, and H. T. Heaton, II.

Nuclear Level Schemes from Resonance Neutron Capture (^{196}Pt, ^{184}W, ^{200}Hg, ^{64}Cu, ^{68}Cu, ^{36}Cl, ^{198}Au, ^{60}Co), R. N. Alves, C. Samour, J. M. Kuchly, J. Julien, and J. Morgenstern.

Neutron-Resonance Parameters of Cadmium and Antimony, A. Asami, M. Okubo, Y. Nakajima, and T. Fuketa.

Neutron Capture Resonances of Tungsten in the Range 150 eV to 100 keV, Z. M. Bartolome, W. R. Moyer, R. W. Hockenbury, J. R. Tatarczuk, and R. C. Block.

The Neutron Inelastic Cross-Section for the Production of ^{103m}Rh, J. P. Butler and D. C. Santry.

The ^{14}N (n,n'γ) Reaction for $5.8 \leq E_n \leq 8.6$ MeV, J. K. Dickens, E. Eichler, F. G. Perey, P. H. Stelson, J. Ashe, and D. O. Nellis.

Measurements of Absorption Resonance Integrals for ^{176}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf, and ^{180}Hf, R. H. Fulmer, L. J. Esch, F. Feiner, and T. F. Ruane.

Measurements of Neutron Scattering from ^{7}Li, H. H. Knitter and M. Coppola.

Capture Cross-Section Measurements for Lu, ^{151}Eu, and ^{153}Eu and the Total Cross-Section of Eu, M. V. Harlow, A. D. Schelberg, L. D. Tatro, J. H. Warren, and N. W. Glass.

A Systematic Investigation of Fast Neutron Elastic Scattering, B. Holmqvist and T. Wielding.

Total Neutron Cross-Sections of ^{9}Be, ^{14}N, and ^{16}O, C. H. Johnson, F. X. Haas, J. L. Fowler, F. D. Martin, R. L. Kernell, and H. O. Cohn.

Cross-Section Measurements of Zirconium, W. M. Lopez, F. H. Fröhner, S. J. Friesenhahn, and A. D. Carlson.

The Strength Functions S_0 and S_1, The Total Radiative Width Γ_γ and the Mean Level Spacing D as a Function of Mass Number and Spin Value, J. Morgenstern, R. Alves, S. de Barros, J. Julien, and C. Samour.

The Thermal Cross-Sections and Paramagnetic Scattering Cross-Sections of the Yb Isotopes, S. F. Mughabghab and R. E. Chrien.

Cross-Section Measurements for the Reaction ^{152}Eu (n,γ) ^{152m}Eu Between 0.02 eV and 0.5 eV, F. Poortmans, A. Fabry, and I. Girlea.

Precision Measurements of Excitation Functions of (n,p), (n,α), and (n,2n) Reactions Induced by 13.5-14.7 MeV Neutrons, H. K. Vonach, W. G. Vonach, H. Munzer, and P. Schramel.

Total Neutron Cross-Section of ^{204}Tl from 0.2 eV to 1000 eV, T. Watanabe, G. E. Stokes, and R. P. Schuman.

Detection of a Spin Dependent Effect in the Gamma Spectrum Following Neutron Capture, C. Coceva, F. Corvi, D. Giacobbe, and G. Carraro.

Nuclear Theory and Neutron Cross-Sections, E. W. Vogt.

Correlations in Positions of Single-Particle Levels on Complex Nuclei, S. I. Sukchoruchkin.

Calculations of Elastic Scattering and Inelastic Direct Processes of Fast Neutrons by U-238, F. Bühler.

Determination of the Optical Potential Depth from a Many Body Approach, N. Azziz.

Thermal Neutron Cross-Sections and Resonance Integrals for Transuranium Isotopes, A. Prince.

Interpretation of the Correlated Analysis of Fission, Total and Capture Cross-Section Data, F. T. Adler and D. B. Adler.

Gerade-Ungerade Symmetry and the Nuclear Mass Division in Fission, J. J. Griffin.

Calculation of Photon Production Cross-Sections and Spectra from 4 to 15 MeV Neutron Induced Reactions, R. J. Howerton.

Theory of Doppler Broadening of Neutron Resonances, S. N. Purohit, T. Shea, and S. Kang.

The Neutron Cross-Section and Resonance Integrals of Holmium, T. E. Stephenson.

Recent Developments in the Automated Compilation and Publication of Neutron Data, S. Pearlstein.

Automated Evaluation of Experimental Data, H. A. Alter.

Principles of Cross-Section Evaluation, J. J. Schmidt.

Neutron Data Compilation at the International Atomic Energy Agency, H. D. Lemmel, P. M. Attree, T. A. Byer, W. M. Good, L. Hjaerne, V. A. Konshin, and A. Lorenz.

The ENEA Neutron Data Compilation Centre, V. I. Bell.

An Integrated System for Producing Calculational Constants for Neutronics and Photonics Codes, R. J. Howerton.

A Computer File of Resonance Data, T. Fuketa, Y. Nakajima, and K. Okamoto.

Storage and Retrieval of Photon Production and Interaction Data in the ENDF/B System, D. J. Dudziak and R. J. LaBauve.

A Mathematical Scheme for Evaluating Cross-Section Data on the Fissile Isotopes U^{233}, U^{235}, and Pu^{239} in the Energy Range 10 keV-10 MeV, P. C. Young and K. B. Cady.

On Line Computer System for Cross-Section Evaluation, L. E. Beghian and J. Tardelli.

Data Reduction with a Small Remote Computer Linked to a CDC-6600, W. R. Moyer, R. P. Bianchini, and E. Franceschini.

Evaluation of Uranium 238 Neutron Data in the Energy Range .0001 eV to 15 MeV, M. Vaste and J. Ravier.

Neutronic Measurements in Non-Critical Media, C. A. Stevens.

The Use of Integral Spectrum Measurements to Improve Neutron Cross-Section Data, E. D. Pendlebury.

Fast Neutron Spectra in Multiplying and Non-Multiplying Media, J. M. Neill, J. L. Russell, Jr., R. A. Moore, and C. A. Preskitt.

Studies of the Angular Distribution of Fast Neutrons in Depleted Uranium, E. Greenspan, B. K. Malaviya, N. N. Kaushal, E. R. Gaerttner, and A. Mallen.

Adequacy of Fast and Intermediate Cross-Section Data From Neutron Spectrum Measurements in Bulk Media, B. K. Malaviya, E. Greenspan, E. R. Gaerttner, and A. Mallen.

Differential Data and the Interpretation of Large, Fast Reactor, Critical Experiments, W. G. Davey.

Calculations of Fast Critical Experiments Using ENDF/B Data and a Modified ENDF/B Data File, T. A. Pitterle, E. M. Page, and M. Yamamoto.

A Comparison of Pu-240 Cross-Section Evaluations by Calculations of ZPR-III Assemblies 48 and 48B, T. A. Pitterle and M. Yamamoto.

Integral Test of Capture Cross-Sections in the Energy Range 0.1-2 MeV, A. Fabry and M. De Coster.

^{238}Pu Production Predictions from Available Neutron Cross-Sections, E. J. Hennelly, W. R. Cornman, N. P. Baumann.

Foil Measurements of Integral Cross-Sections of Higher Mass Actinides, R. L. Folger, J. A. Smith, L. C. Brown, R. F. Overman, and H. P. Holcomb.

Reactor Cross-Sections for ^{242}Pu-^{252}Cf, J. A. Smith, C. J. Banick, R. L. Folger, H. P. Holcomb, and I. B. Richter.

Thermal Reactor Absorption Cross-Sections of Radioactive Nuclides, R. S. Mowatt and W. H. Walker.

The Decay of a Neutron Pulse in a Fast Nonmultiplying System as an Integral Check on the High Energy Inelastic Scattering, T. Gozani and P. d'Oultremont.

SP300, Volume 1. **Precision measurement and calibration. Selected papers on statistical concepts and procedures,** H. H. Ku, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 1, 436 pages (Feb. 1969).

Key words: Accuracy; analysis of measurement data; design of experiments; functional relationships; interlaboratory tests; measurement process; precision; statistical concepts in measurements; systematic error.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 1 deals with methodology in the generation, analysis, and interpretation of precision measurement data. It contains 40 reprints assembled in 6 sections: (1) The Measurement Process; (2) Design of Experiments in Calibration; (3) Interlaboratory Tests; (4) Functional Relationships; (5) Statistical Treatment of Measurement Data; (6) Miscellaneous. Each section is introduced by an interpretive foreword, and the whole is supplemented by abstracts and selected references.

SP300, Volume 2. **Precision measurement and calibration temperature. Selected NBS papers on temperature,** J. F. Swindells, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 2, 520 pages (Aug. 1968).

Key words: Acoustical thermometry; cerous magnesium nitrate thermometer; error analysis; liquid-in-glass thermometry; reprints; resistance thermometry; spectroscopic thermometry; standards; temperature scales; thermoelectric thermometry.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 2 contains reprints through June 1967 covering the general topics: Uncertainties, Temperature Scales, Resistance Thermometry, Thermoelectic Thermometry, Liquid-in-Glass

Thermometry, Optical Pyrometry, and Spectroscopic Thermometry. A selected bibliography covering the period from January 1953 through December 1965 is included. (Supersedes in part NBS Handb. 77, Vol. II.)

SP300, Volume 3. **Precision measurement and calibration. Selected NBS papers on electricity—low frequency,** F. L. Hermach and R. F. Dziuba, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 3, 498 pages (Dec. 1968).

Key words: Ac-dc transfer standards; capacitors; current transformers; dielectric measurements; electrical calibrations; electrical measurements; electrical standards; electrical units; high voltage measurements; inductive voltage dividers; inductors; magnetic measurements; resistance apparatus; resistors; standard cells; voltage transformers; zener diodes.

This volume is one of an extended series which brings together some of the previously published papers, monographs, abstracts and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 3 contains reprints through 1967 on d-c and low-frequency electrical measurements covering the following topics: Electrical Units, Electrical Standards, Standard Cells, Zener Diodes, Resistors, Resistance Apparatus, Capacitors, Inductors, Instruments, AC-DC Transfer Standards, Transformers, Inductive Voltage Dividers, High Voltage Measurements, Dielectric Measurements, and Magnetic Measurements. A selected list of NBS publications on electrical measurements is also included.

SP300. Volume 4. **Precision measurement and calibration. Electricity—radio frequency,** A. J. Estin, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 4, 456 pages (June 1970).

Key words: Admittance; antenna; attenuator; bolometer; calorimetry; horn; impedance; interferometry; measuring system; phase; power; radiometry; resonant cavity; voltage; waveform; waveguide junction.

This volume is one of an extended series which brings together some of the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 4 contains reprints through June 1967 on radio-frequency electrical measurements covering the following topics: Power, Sinusoidal Voltage and Current, Electromagnetic Fields and Antennas, Radar and Baseband Pulses, Noise, Attenuation and Phase, Impedance, Radio Frequency Materials, Quasi-optics and Millimeter Waves, and Applications to Measurement Systems.

SP300. Volume 5. **Precision measurement and calibration. Selected NBS papers on frequency and time,** B. E. Blair and A. H. Morgan, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 5, 565 pages (June 1972).

Key words: Atomic beams; atomic clocks; atomic standards; atomic time; clock synchronization; coordinated U.T. dissemination of frequency and time; flicker noise; frequency and time standards; frequency measurement; frequency stability; international comparison of atomic standards; lasers; masers; radio frequency measurements; satellite timing; spectral density; standard frequency and time broadcasts; statistics of frequency and time measurements; time scales; time synchronizations; TV timing; VLF timing.

This is one of a series of volumes consisting of a group of selected papers and monographs by NBS authors, and abstracts of papers by non-NBS and NBS authors, dealing with the precision measurement of specific physical quantities and related topics. The contents should be useful to those in the scientific community who are engaged in frequency and time measurements or are otherwise interested in these physical quantities.

This volume contains selected reprints, and abstracts of very general papers, printed in chronological order in most cases from January 1960 through June 1969, covering the following general topics: Frequency and Time Standards, Time Scales, Distribution of Frequency and Time Signals, Statistics of Frequency and Time Standards, and Selected Frequency and Time References.

SP300. Volume 6. **Precision measurement and calibration. Selected NBS papers on heat,** D. C. Ginnings, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 6, 387 pages (Feb. 1970).

Key words: Bomb calorimetry; calorimetric design principles; calorimetric methods; calorimetric theory; cryoscopic studies; differential thermal analysis; heat measurements; heat transfer; high temperature calorimetry; low temperature calorimetry; reaction calorimetry.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 6 contains reprints through 1968 covering the following topics: General Calorimetry and Techniques, Low Temperature Calorimetry, High Temperature Calorimetry, Reaction Calorimetry, and Heat Transfer.

SP300. Volume 7. **Precision measurement and calibration. Radiometry and photometry,** H. K. Hammond, III, and H. L. Mason, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 7, 685 pages (Nov. 1971).

Key words: Emissivity; flashing light; flux measurement; irradiance; material properties; photometry; projectors; radiance; radiometry; reflectometry.

This volume is one of an extended series which brings together some of the previously published papers, monographs, abstracts and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 7 contains reprints of more than 60 items on radiometry and photometry published between 1957 and 1970. The material has been placed in groups according to the following subjects: general radiometry, emissivity standards, emissivity measurements and techniques, material properties, irradiance standards, radiometric measurement techniques, radiance standards, flux measurement, reflectometry, general photometry, projectors, flashing lights, and chronological bibliography of publications by NBS staff.

SP300. Volume 8. **Precision measurement and calibration. Selected NBS papers on mechanics,** R. L. Bloss and M. J. Orloski, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 8, 590 pages (Jan. 1972).

Key words: Acoustics; fluid mechanics; force; gravity; humidity; pressure; strain; vacuum; vibration; viscosity.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 8 consists primarily of published works of the staff of the Mechanics Division of NBS. It includes papers in the fields of acoustics, fluid mechanics, force, gravity, humidity, pressure, strain, vacuum, vibration, and viscosity. Although most of the papers had been previously published, original papers in the fields of "gravity" and "viscosity" are included.

SP300. Volume 9. **Precision measurement and calibration. Selected NBS papers on colorimetry,** I. Nimeroff, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 9, 460 pages (June 1972).

Key words: Appearance evaluation; colorimetry; color spacing; color vision; gloss; metamerism; spectrophotometry; standards; uncertainty; variability.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with the precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to the NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 9 treats the field of Colorimetry. It contains 37 reprints on Colorimetry and Spectrophotometry assembled in 8 sections: (1) Spectrophotometry, (2) Color Vision, (3) Color Specification, (4) Sources and Instrumentation, (5) Color Spacing and Metamerism, (6) Variabilities and Uncertainties, (7) Appearance and Gloss, (8) List of Publications, LP39 (in part), Colorimetry and Spectrophotometry Publications by the Staff of the National Bureau of Standards, January 1957 through August 1969.

SP300. Volume 10. **Precision measurement and calibration. Selected NBS papers on image optics,** C. S. McCamy, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 10, 953 pages (Nov. 1972) $11.10, SD Catalog No. C13.10:300, Vol. 10.

Key words: Camera calibration; image evaluation; image optics; image stability; interferometry; lens testing; light filters; light sources; photography.

This volume is one of an extended series which brings together the previously published papers, monographs, abstracts, and bibliographies by NBS authors dealing with precision measurement of specific physical quantities and the calibration of the related metrology equipment. The contents have been selected as being useful to the standards laboratories of the United States in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation.

Volume 10 deals with image optics, including photography. It contains 57 reprints assembled in 4 sections: (1) Refractometry and Optical Homogeneity: (2) Interferometry in Image Optics; (3) Optical Image Evaluation; (4) Photography. Each section is introduced by an interpretive foreword, including in some instances, pertinent references.

SP301. **Molecular dynamics and structure of solids.** Proceedings of the Second Materials Research Symposium held at the National Bureau of Standards, Gaithersburg, Md., October 16-19, 1967, R. S. Carter and J. J. Rush, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 301, 580 pages (June 1969).*

Key words: Crystal; crystal structure; diffraction; lattice dynamics; molecular dynamics; molecular solid; rotation; spectroscopy; vibration.

This volume is based on material presented at the Second Materials Research Symposium of the National Bureau of Standards, held October 16-19, 1967. It provides a review of the application of spectroscopic and diffraction techniques to the study of the structure and dynamics of molecular solids. Invited papers on the theory and practice of the major experimental methods, including neutron and x-ray diffraction, neutron inelastic scattering, infrared and Raman spectroscopy and nuclear magnetic resonance, serve as a background for the more detailed presentation and discussion of results which follows. The topics covered in a series of invited and contributed papers include the lattice dynamics of molecular crystals, the spectroscopy and crystal structure of organic and inorganic solids and the dynamics of polymers.

Theoretical Basis of Techniques for the Investigation of Molecular Dynamics and Structure of Solids, Elliott Montroll.
The Contributions of Neutron and X-Ray Diffraction Techniques, G. E. Bacon.
Infrared and Raman Studies on Molecular Structure and Motion in Condensed Phases, G. R. Wilkinson.
Neutron Inelastic Scattering Studies of Molecular Solids and Liquids, P. A. Egelstaff.
The Principles Involved in the Study of Molecular Motion in Solids by Nuclear Magnetic Resonance, R. E. Richards.
Spectroscopic and Diffraction Studies of Simple Hydrogen Bonds in Solids, James A. Ibers.
Structure and Dynamics in Molecular Crystals: Some Comparisons, Walter C. Hamilton.
Dynamical Effects of Deuteron Intrabond Jumping in KD_2PO_4, V. Hugo Schmidt.
The Detection of Atom Tunnelling in Solids, I. Pelah and Y. Imry.
Proton Delocalization in Inorganic Solids, J. J. Fripiat, P. G. Rouxhet, H. Jacobs, and A. Jelli.
Structure Refinements, Thermal Motion and Madelung Constants of CdI_2- and $Cd(OH)_2$-Type Layer Structures, Y. M. de Haan.
The Aquated Hydrogen Ion: Single Crystal Diffraction Investigations of Compounds Containing the $(H_2O{\cdot}H{\cdot}OH_2)^+$ Ion, Jack M. Williams.
Infrared Investigation of Ordering and Structural Changes in Ammonium Halides, C. W. Garland and N. E. Schumaker.
Nuclear Magnetic Resonance and Neutron-Scattering Studies of Hindered Rotation in Phosphonium Iodide, T. C. Farrar and J. J. Rush.
A Neutron Diffraction Study of Lithium Perchlorate Trihydrate, A. Sequeira and Ivan Bernal.
The Structure of Several Uranyl Nitrate Compounds as Determined by Neutron Diffraction, M. H. Mueller and N. Kent Dalley.
Infrared Spectral Studies as a Tool for Sensing the Environment About Water Molecules in Hydrates, J. Schiffer and D. F. Hornig.
Nuclear Magnetic Resonance Studies of Molecular Motion in

Clathrate-Hydrates, C. A. McDowell and P. Raghunathan.
Calculation and Analysis of Pulsed-NMR Line Shapes of Crystals, Marcel Kopp.
The Vapor Pressure of CO/N_2 Solid Solutions, J. A. Morrison, D. M. T. Newsham, and R. D. Weir.
Structural Study of Ti_5O_9, L. K. Keys.
Significance of Weighting Schemes in an Anisotropic Least Squares Refinement of Ruby, J. W. McCauley and G. V. Gibbs.
The Crystal Structure of $C_8Al_{2.1}B_{51}(AlB_{10})$, A. J. Perrotta, W. D. Townes, and J. A. Potenza.
Lattice Dynamics of Molecular Solids, Gerald Dolling.
Epithermal Neutron Inelastic Scattering from Metal Hydrides, S. S. Pan, M. L. Yeater, and W. E. Moore.
Vibration Spectra of Hydrides Possessing the Cubic Perovskite Structure by the Inelastic Scattering of Cold Neutrons, Arnulf J. Maeland.
Absorption of Light by the Sound Waves of Orientationally Disordered Crystals, E. Whalley.
Lattice Vibrations in Some Simple Molecular Crystals, J. C. Laufer, J. E. Cahill, and G. E. Leroi.
The Optical and Anharmonic Thermal Properties of a Diatomic Molecular Solid, George E. Jelinek.
Neutron Scattering Studies of Molecular Vibrations in Ice, H. Prask and H. Boutin.
Infrared Absorption Studies of Intermolecular Vibrations in the Low Frequency Region, Neil T. McDevitt, R. E. Witkowski, and W. G. Fateley.
Optical Phonons in Mixed Sodium Potassium Tantalates, T. G. Davis, N. E. Tornberg, C. H. Perry, and N. Knable.
On the Second Order Elastic Constants of Molecular Solids, M. L. Klein.
Diffraction Studies of Molecular Dynamics in Organic Crystals, K. N. Trueblood.
Information on Molecular Motion Derived From Anisotropic Temperature Factor Coefficients, Carroll K. Johnson.
Influence of Bonding Effects on Thermal Parameters as Determined by X-Ray Diffraction, Philip Coppens.
High Pressure Crystal Structure of Metal Free Phthalocyanine, R. S. Kirk.
X-Ray Diffraction and Radiofrequency Spectroscopic Investigation of Dimethyltin Dichloride, Jack D. Graybeal and Domnic A. Berta.
The Crystal and Molecular Structure of Tetraethylammonium Bis-(3)-1,2-Dicarbollylcuprate (II), Richard M. Wing.
Nuclear Magnetic Resonance Studies of Single Crystals of Trichloroacetic Acid, David C. Haddix and Paul C. Lauterbur.
Thermal and Composition Expansion of Clathrates in the Ethylene Oxide-Water System, J. A. McIntyre and D. R. Petersen.
Nuclear Magnetic Resonance and Molecular Motion in Organic Crystals, E. R. Andrew.
Far Infrared Spectra and Space Group of Crystalline Hydrazine and Hydrazine-d_4, F. G. Baglin, S. F. Bush, and J. R. Durig.
Molecular Rotation in Condensed Phases of Simple Molecules, M. Blumenfeld.
Correlation of Infrared and Inelastic Neutron Scattering Spectra of Solid Methane, Ashok K. Agrawal and Sidney Yip.
Theory of Phase Transitions in Solid Methanes, Tsunenobu Yamamoto, Yosuke Kataoka, and Hideo Yasuda.
NMR Relaxation in Adamantane and Hexamethylenetetramine: Molecular Rotation and Diffusion, H. A. Resing.
Thermodynamic Approach to Molecular Freedom, Especially in Plastically Crystalline Substances, Edgar F. Westrum, Jr.
Spectral Assignment in Inelastic Neutron Scattering Spectroscopy by Atomic Substitution Techniques, J. W. White.
Anisotropic Lattice Dynamic Studies of Organo-Tin Compounds by Mössbauer Spectroscopy, Hans A. Stöckler and Hirotoshi Sano.
Relaxation in Solid Polymers, David W. McCall.
Low Frequency Vibrations in Polyethylene, W. R. Meyers and P. H. Randolph.
Neutron Scattering in Deuterated Polyethylene, L. A. Feldkamp and J. S. King.
Epithermal Neutron Inelastic Scattering by Polyethylene, W. E. Moore, G. J. Kirouac, L. J. Esch, K. W. Seemann, and M. L. Yeater.
The Vibrational Properties of Polyoxymethylene, S. F. Trevino and V. E. LaGarde.
Vibration Spectra of Polyglycine, V. D. Gupta, S. Trevino, and H. Boutin.
Thermal Conductivity and Specific Heat of Amorphous Polymers Between 0.4 and 4 °K, C. L. Choy, G. L. Salinger, and Y. C. Chiang.

SP302. **Thermal conductivity.** Proceedings of the seventh conference held at the National Bureau of Standards, Gaithersburg, Md., November 13-16, 1967, D. R. Flynn and B. A. Peavy, Jr., Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 302, 820 pages (Sept. 1968).*

Key words: Conductance; conductivity; contact conductance; contact resistance; electrical conductivity; electrical resistivity; heat transfer; Lorenz function; resistivity; temperature; thermal conductivity; thermal diffusivity; thermal resistivity; thermophysical properties.

The Seventh Conference on Thermal Conductivity was held at the National Bureau of Standards on November 13-16, 1967. This volume contains the texts of the papers presented. Topics covered include surveys of the present state of knowledge regarding the thermal conductivity of different materials, descriptions of different apparatuses for measuring thermal conductivity, new experimental data on the thermal conductivity or diffusivity of a variety of materials, and correlations between experimental results and theoretical predictions.

The State of Knowledge Regarding the Thermal Conductivity of the Metallic Elements, R. W. Powell and C. Y. Ho.
The State of Knowledge Regarding the Thermal Conductivity of the Non-Metallic Elements—Those Solid at Normal Temperature, C. Y. Ho and R. W. Powell.
Some Aspects Concerning Thermal Conductivity Data of Liquids and Proposals for New Standard Reference Materials, H. Poltz.
The Thermal Conductivity of Non-Metallic Elements (in Liquid or Gaseous State at NTP) in Solid, Saturated and Atmospheric Pressure States, P. E. Liley.
Thermal Conductivity of Vitreous Silica: Selected Values, Lois C. K. Carwile and Harold J. Hoge.
Development of High Temperature Thermal Conductivity Standards, Alfred E. Wechsler and Merrill L. Minges.
Glass Beads—A Standard for the Low Thermal Conductivity Range?, Alfred E. Wechsler.
Lattice Thermal Conductivities of Semiconductor Alloys, I. Kudman.
Thermal Conductivity of N-type Germanium from 0.3 to 4.2 °K, Bruce L. Bird and Norman Pearlman.
The Lattice Thermal Conductivity of Bismuth Telluride and Some Bismuth Telluride-Bismuth Selenide Alloys, D. H. Damon, R. W. Ure, Jr., and J. Gersi.
Thermal Conductivity of Cadmium Arsenide from 60 to 400 °K, D. P. Spitzer.
Measurement of Dislocation Phonon Scattering in Alloys, P. Charsley, A. D. W. Leaver, and J. A. M. Salter.
The Thermal Resistivity Resulting From the Combined Scattering of Phonons by Edge Dislocation Dipoles and by Normal

Processes, P. P. Gruner.

Thermal Diffusivity Measurements With Stationary Waves Method, A. Sacchi, V. Ferro, and C. Codegone.

Rotating Thermal Field, C. Codegone, V. Ferro, and A. Sacchi.

Thermal Attenuation through Homogeneous and Multilayer Slabs in Steady Periodic Conditions—Theory and Experiments, V. Ferro, A. Sacchi, and C. Codegone.

Heat Losses in a Cut-Bar Apparatus: Experimental-Analytical Comparisons, Merrill L. Minges.

Application of Neutron Diffusion Theory Techniques to Solution of the Conduction Equation, I. Catton and J. R. Lilley.

Conduction from a Finite-Size Moving Heat Source Applied to Radioisotope Capsule Self-Burial, C. R. Easton.

Evaluation of Steady-Periodic Heat Flow Method for Measuring the Thermal Diffusivity of Materials with Temperature-Dependent Properties, C. J. Shirtliffe and D. G. Stephenson.

Comparison of Modes of Operation for Guarded Hot Plate Apparatus with Emphasis on Transient Characteristics, C. J. Shirtliffe and H. W. Orr.

Method for Measuring Total Hemispheric Emissivity of Plane Surfaces with Conventional Thermal Conductivity Apparatus, Nathaniel E. Hager, Jr.

Heat Pulse Experiments and the Study of Thermal Transport at Low Temperatures, R. J. von Gutfeld.

Deviations from Matthiessen's Rule in the Low Temperature Thermal and Electrical Resistivities of Very Pure Copper, J. T. Schriempf.

Thermal Conduction in Bismuth at Liquid Helium Temperatures-Effects at Intermediate Fields, S. M. Bhagat and B. Winer.

Thermal Conductivity of Pure and Impure Tin in the Normal and Superconducting States, C. A. Reynolds, J. E. Gueths, F. V. Burckbuchler, N. N. Clark, D. Markowitz, G. J. Pearson, R. H. Bartram, and C. W. Ulbrich.

Temperature Dependence of the Lattice Thermal Conductivity of Copper-Nickel Alloys at Low Temperatures, J. C. Erdmann and J. A. Jahoda.

Thermal Conductivity of Aerospace Alloys at Cryogenic Temperatures, J. G. Hust, D. H. Weitzel, and Robert L. Powell.

Physical Properties of Indium from 77 to 350 °K, M. Barisoni, R. K. Williams, and D. L. McElroy.

Thermal Conductivity of Aluminum Between About 78 and 373 °K, K. E. Wilkes and R. W. Powell.

Physical Properties of Chromium from 77 to 400 °K, J. P. Moore, R. K. Williams, and D. L. McElroy.

The Thermal Conductivity of Chromium Above and Below the Néel Temperature—An Analysis, J. F. Goff.

Thermal Conductivity of a Round-Robin Armco Iron Sample, D. C. Larsen and R. W. Powell.

High Temperature Transport Properties of Some Platinel Alloys, M. J. Laubitz and M. P. van der Meer.

The Thermal Diffusivity of Gold, H. R. Shanks, M. M. Burns, and G. C. Danielson.

Experimental Determination of the Thermal Conductivity of Solids Between 90 and 200 °K, J. G. Androulakis and R. L. Kosson.

The Thermal Conductivities of Several Metals: An Evaluation of a Method Employed by the National Bureau of Standards, David R. Williams and Harold A. Blum.

A Longitudinal Symmetrical Heat Flow Apparatus for the Determination of the Thermal Conductivity of Metals and their Alloys, H. Chang and M. G. Blair.

The Intrinsic Electronic Thermal Resistivity of Iron, M. S. R. Chari.

The Thermal Conductivity and Electrical Resistivity of Tungsten-26 Weight Percent Rhenium, A. D. Feith.

Thermal Conductivity of Magnesium Stannide, J. J. Martin, H. R. Shanks, and G. C. Danielson.

Thermal Properties of SNAP Fuels, C. C. Weeks, M. M. Nakata, and C. A. Smith.

Thermal Conductivity, Diffusivity, and Specific Heat of Calcium Tungstate from 77 to 300 °K, Phillipp H. Klein.

Measurement of the Thermal Conductivity of Self-Supporting Thin Films of Aluminum Oxide 325 to 2000 Angstroms Thick, G. A. Shirfin and Robert W. Gammon.

Impulse Thermal Breakdown in Silicon Oxide Films, N. Klein and E. Burstein.

High Temperature Radial Heat Flow Measurements, J. P. Brazel and K. H. Styhr.

An Investigation of the Mechanisms of Heat Transfer in Low-Density Phenolic-Nylon Chars, E. D. Smyly and C. M. Pyron, Jr.

Biological Specimen Holder for Thermal Diffusivity Determinations, Floyd V. Matthews, Jr., and Carl W. Hall.

Thermal Diffusivity of Actinide Compounds, J. B. Moser and O. L. Kruger.

The Thermal Diffusivity and Thermal Conductivity of Sintered Uranium Dioxide, J. B. Ainscough and M. J. Wheeler.

Suitability of the Flash Method for Measurements of the Thermal Diffusivity of Uranium Dioxide Specimens Containing Cracks, D. Shaw, L. A. Goldsmith, and A. J. Little.

Thermal Conductivity of Uranium Oxycarbides, J. Lambert Bates.

The Effect of Irradiation on the Thermal Conductivity of Some Fissile Ceramics in the Range 150-1600 °C up to a Dose of 10^{21} Fissions cm^{-3}, D. J. Clough.

Phase Studies on Fueled Zirconium Hydride, M. M. Nakata, C. A. Smith, and C. C. Weeks.

On the Development of Methods for Measuring Heat Leakage of Insulated Walls with Internal Convection, G. Lorentzen, E. Brendeng, and P. Frivik.

Thermal Diffusivity Measurements from a Step Function Change in Flux Into a Double Layer Infinite Slab, E. K. Halteman and R. W. Gerrish, Jr.

A Guarded Hot Plate Apparatus for Measuring Thermal Conductivity from -80 +100 °C, J. C. Rousselle.

A Study of the Effects of Edge Insulation and Ambient Temperatures On Errors in Guarded Hot-Plate Measurements, H. W. Orr.

Ring Heat Source Probes for Rapid Determination of Thermal Conductivity of Rocks, Wilbur H. Somerton and Mohammad Mossahebi.

Thermal Conductivity and Thermal Diffusivity of Green River Oil Shale, S. S. Tihen, H. C. Carpenter, and H. W. Sohns.

Experimental Study Relating Thermal Conductivity to Thermal Piercing of Rocks, V. V. Mirkovich.

Measurement of Thermal Conductivity of Gases, S. C. Saxena.

Thermal Conductivity of Gases: Hydrocarbons at Normal Pressures, Dipak Roy and George Thodos.

The Thermal Conductivity of 46 Gases at Atmospheric Pressure, P. E. Liley.

Calculation of Total Thermal Conductivity of Ionized Gases, Warren F. Ahtye.

Thermal Conductivity of the Alkali Metal Vapors and Argon, Chai-sung Lee and Charles F. Bonilla.

Recent Developments at Bellevue on Thermal Conductivity Measurements of Compressed Gases, B. Le Neindre, P. Bury, R. Tufeu, P. Johannin, and B. Vodar.

Theoretical Developments on the Density Dependence of the Thermal Conductivity of Compressed Gases, J. V. Sengers.

Discrepancies Between Viscosity Data For Simple Gases, H. J. M. Hanley and G. E. Childs.

Thermal Conductivity of Binary, Ternary and Quaternary Mixtures of Polyatomic Gases, S. C. Saxena and G. P. Gupta.

Thermal Conductivities of Gaseous Mixtures of Diethyl Ether with Inert Gases, P. Gray, S. Holland, and A. O. S. Maczek.

Determination of the Eucken Factor for Parahydrogen at 77 °K, Lee B. Harris.

Prediction of Minor Heat Losses in a Thermal Conductivity Cell and Other Calorimeter Type Cells, D. R. Tree and W. Leidenfrost.

The Thermal Conductivity of Pure Organic Liquids, J. E. S. Venart and C. Krishnamurthy.

Pressures and Temperature Dependence of the Thermal Conductivity of Liquids, E. McLaughlin.

Thermal Conductivity of Several Dielectric Liquids of Low Boiling Point, R. C. Chu, O. Gupta, and J. H. Seely.

Thermal Conductivity of Two-Phase Systems, Alfred L. Baxley, Nicholas C. Nahas, and James R. Couper.

Measurements of the Thermal Conductivity of Granular Carbon and the Thermal Contact Resistance at the Container Walls, C. A. Fritsch and P. E. Prettyman.

The Thermal Conductivity of Thoria Powder From 400 to 1200 °C in Various Gases at Atmospheric Pressure, A. D. Feith.

Thermal Conductivity of a 58% Dense MgO Powder in Nitrogen, J. P. Moore, D. L. McElroy, and R. S. Graves.

Measurements of the Thermal Conductivity of Glass Beads in a Vacuum at Temperatures from 100 to 500 °K, R. B. Merrill.

The Measurement of the Effective Thermal Conductivities of Well-Mixed Porous Beds of Dissimilar Solid Particles by use of the Thermal Conductivity Probe, C. S. Beroes and H. D. Hatters.

Thermal Conductivity Measurements on a Fibrous Insulation Material, R. R. Pettyjohn.

The Effect of Thickness and Temperature on Heat Transfer Through Foamed Polymers, T. T. Jones.

Measurements of In-Vivo Thermal Diffusivity of Cat Brain, G J. Trezek, D. L. Jewett, and T. E. Cooper.

A Correlation for Thermal Contact Conductance of Nominally-Flat Surfaces in a Vacuum, C. L. Tien.

Thermal Conductance of Imperfect Contacts, Evan Charles Brown, Jr., and Vernon Emerson Holt.

Ultrasonic Measurement of the Thermal Conductance of Joints in Vacuum, Ludwig Wolf, Jr., and Constantine Kostenko.

Thermal Resistance of Sapphire-Sapphire Contact, Y. Baer.

Heat Transfer Across Surfaces In Contact: Effects of Thermal Transients on One-Dimensional Composite Slabs, C. J. Moore, Jr., and H. A. Blum.

SP303. **Mechanical and thermal properties of ceramics.** Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., April 1-2, 1968, J. B. Wachtman, Jr., Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 303, 275 pages (May 1969).*

Key words: Ceramics; elasticity; fracture; inelastic deformation; melting point; standards; thermal conductivity; thermal expansion; thermal radiation; viscoelasticity.

The proceedings of the Symposium on Mechanical and Thermal Properties of Ceramics, held at the National Bureau of Standards in Gaithersburg, Md., on April 1-2, 1968 are presented. The symposium was cosponsored by the American Ceramic Society, the American Society for Testing and Materials, and the National Bureau of Standards. Attention was concentrated upon properties primarily of structural and/or high temperature use including melting points, thermal expansion, thermal conductivity, thermal radiation properties, elasticity, viscoelasticity, inelastic deformation, and fracture. The dependence of these properties upon composition and microstructure was surveyed and the importance of controlling these features of character to insure reliability of ceramics was emphasized. The procedures by which American ceramists formulate standards and specifications to assist in insuring reliability were summarized.

The American Ceramic Society and Ceramic Materials Technology, J. S. Owens.

ASTM: Its Function and Philosophy, F. J. Mardulier.

ASTM Activities in Ceramics, J. C. Richmond.

Properites of Ceramics for Structural and/or High Temperature Use: Need for Control, Measurement, and Compilation, C. S. Bersch.

Melting Points of Ceramics, S. J. Schneider.

Thermal Expansion of Ceramics, R. K. Kirby.

Thermal Conductivity of Ceramics, D. R. Flynn.

Thermal Radiation Properties of Ceramic Materials, J. C. Richmond.

Elastic Deformation of Ceramics and Other Refractory Materials, J. B. Wachtman, Jr.

Viscoelasticity of Glasses, P. B. de Macedo.

Inelastic Deformation of Oxide Ceramics, R. M. Spriggs.

Plastic Deformation of Carbides, G. E. Hollox.

Fracture of Ceramics, S. M. Wiederhorn.

Strength Testing of Ceramics—A Survey, L. Mordfin and M. J. Kerper.

SP-304, All previous editions superseded by Special Publication 304, Revised October 1972.

SP-304A, All previous editions superseded by Special Publication 304A, Revised August 1976.

SP305. **Publications of the National Bureau of Standards 1966-1967,** B. L. Oberholtzer, Nat. Bur. Stand. (U.S.), Spec. Publ. 305, 221 pages (Apr. 1969).

Key words: Articles; publications.

All published work by National Bureau of Standards authors from the middle of 1966 to the end of 1967, both in the extensive publications issued by NBS itself and in outside publications, is covered in this latest supplement to the NBS catalog. Each title is accompanied by complete bibliographic information, plus a list of key words and an abstract, both prepared by the authors. In addition, there is information on the NBS publishing program, purchase procedures, publication announcement services, and price lists.

Information in the catalog is accessible through two indexes: an author index and a key word index. In the latter, the group of key words for each catalog entry is permuted so that each key word appears once as the first in the group, and therefore determines the alphabetical order in which the group appears in the index. The user can thus locate papers of interest to him through the subject-related key words.

SP305. Supplement 1. **Publications of the National Bureau of Standards 1968-1969. A compilation of abstracts and key word and author indexes,** B. L. Oberholtzer, Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 1, 497 pages (Dec. 1970).

Key words: Articles; publications.

This Supplement lists the publications of the NBS from January 1968 to December 1969. A brief abstract for each publication is given. It also includes abstracts of those papers by Bureau authors that have appeared in non-NBS media. Subject and author indexes are included and general publication information is furnished. This catalog and previous lists give reference to the publications printed by the Bureau during the period 1901 to December 1969. To accompany NBS Circular 460, its Supplement, Miscellaneous Publication 240, its Supplement, and Special Publication 305.

SP305. Supplement 2. **Publications of the National Bureau of Standards 1970. A compilation of abstracts and key word and author indexes,** B. L. Oberholtzer, Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 2, 378 pages (July 1971).

Key words: Abstracts, NBS publications; key words; publications.

This Supplement to Special Publication 305 Supplement 1 of the National Bureau of Standards lists the publications of the Bureau issued between January 1, 1970 and December 31, 1970. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 1), key word and author indexes, and general information and instructions about NBS publications. Previous catalogs of NBS publications referenced in Special Publication 305, Supplement 1 remain in effect. To accompany National Bureau of Standards Circular 460, its Supplement, Miscellaneous Publication 240, its Supplement, Special Publication 305 and its Supplement 1.

SP305. Supplement 3. **Publications of the National Bureau of Standards 1971 catalog. A compilation of abstracts and key word and author indexes,** B. L. Oberholtzer, Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 3, 342 pages (July 1972).

Key words: Abstracts, NBS publications; key words; publications.

This supplement to Special Publication 305 Supplements 1 and 2 the National Bureau of Standards lists the publications of the Bureau issued between 1 January 1971 and 31 December 1971. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 2), key-word and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) and its supplement (covering the period July 1, 1960 through June 30, 1966), Special Publication 305 (covering the period July 1966 through December 1967) and Special Publication 305 Supplement 1 (covering the period 1968-1969), and Special Publication 305 Supplement 2 (covering the period 1970), remain in effect. Two earlier lists, Circular 460 (Publications of the National Bureau of Standards, 1901 to June 1947) and its supplement (Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957) are also still in effect. To accompany National Bureau of Standards Circular 460; its Supplement, Miscellaneous Publication 240; its Supplement, Special Publication 305; and its Supplements 1 and 2.

SP305. Supplement 4. **Publications of the National Bureau of Standards 1972 catalog. A compilation of abstracts and key word and author indexes,** B. L. Oberholtzer, Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 4, 449 pages (July 1973) $3.75, SD Catalog No. C13.10:305 Suppl. 4.

Key words: Abstracts, NBS publications; key words; publications.

This supplement to Special Publication 305 Supplements 1, 2, and 3 of the National Bureau of Standards lists the publications of the Bureau issued between January 1, 1972 and December 31, 1972. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 3), key-word and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) and its supplement (covering the period July 1, 1960 through June 30, 1966), Special Publication 305 (covering the period July 1966 through December 1967) and Special Publication 305 Supplement 1 (covering the period 1968-1969), Special Publication 305 Supplement 2 (covering the period 1970), and Special Publication 305 Supplement 3 (covering the period 1971) remain in effect. Two earlier lists, Circular 460 (Publications of the National Bureau of Standards, 1901 to June 1947) and its supplement (Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957) are also still in effect.

SP305. Supplement 5. **Publications of the National Bureau of Standards 1973 catalog. A compilation of abstracts and key word and author indexes,** B. L. Oberholtzer, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 5, 349 pages (July 1974) SD Catalog No. C13.10:305.

Key words: abstracts, NBS publications; key words; publications.

This supplement to Special Publication 305 Supplements 1, 2, 3, and 4 of the National Bureau of Standards lists the publications of the Bureau issued between January 1, 1973 and December 31, 1973. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 3), key-word and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) and its supplement (covering the period July 1, 1960 through June 30, 1966), Special Publication 305 (covering the period July 1966 through December 1967) and Special Publication 305 Supplement 1 (covering the period 1968-1969), Special Publication 305 Supplement 2 (covering the period 1970), Special Publication 305 Supplement 3 (covering the period 1971), and Special Publication 305 Supplement 4 (covering the period 1972) remain in effect. Two earlier lists, Circular 460 (Publications of the National Bureau of Standards, 1901 to June 1947) and its supplement (Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957) are also still in effect. To accompany National Bureau of Standards Special Publication 305; and its Supplements 1, 2, 3, and 4.

SP305. Supplement 6. **Publications of the National Bureau of Standards 1974 catalog. A compilation of abstracts and key word and author indexes,** B. L. Hurdle, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 6, 523 pages (June 1975) SD Catalog No. C13.10:305 Suppl. 6.

Key words: abstracts, NBS publications; key words; publications.

This supplement to Special Publication 305 Supplements 1 through 5 of the National Bureau of Standards lists the publications of the Bureau issued between January 1, 1974 and December 31, 1974. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 4), key-word and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) and its supplement (covering the period July 1, 1960 through June 30, 1966), Special Publication 305 (covering the period July 1966 through December 1967) and Special Publication 305 Supplement 1 (covering the period 1968-1969), Special Publication 305 Supplement 2 (covering the period 1970), Special Publication 305 Supplement 3 (covering the period 1971), Special Publication 305 Supplement 4 (covering the period 1972), Special Publication 305 Supplement 5 (covering the period 1973) remain in effect. Two earlier lists, Circular 460 (Publications of the National Bureau of Standards, 1901 to June 1947) and its supplement (Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957) are also still in effect.

SP305. Supplement 7. Publications of the National Bureau of Standards 1975 catalog. **A compilation of abstracts and key word and author indexes,** B. L. Hurdle, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 305 Suppl. 7,* 595 pages (June 1976) SD Catalog No. C13.10:305 Suppl. 7.

Key words: abstracts; NBS publications; key words; publications.

This supplement to Special Publication 305 Supplements 1 through 6 of the National Bureau of Standards lists the publications of the Bureau issued between January 1, 1975 and December 31, 1975. It includes an abstract of each publication (plus some earlier papers omitted from Special Publication 305 Supplement 6), key-word and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) and its supplement (covering the period July 1, 1960 through June 30, 1966), Special Publication 305 (covering the period July 1966 through December 1967), and Special Publication 305 Supplement 1 (covering the period 1968-1969), Special Publication 305 Supplement 2 (covering the period 1970), Special Publication 305 Supplement 3 (covering the period 1971), Special Publication 305 Supplement 4 (covering the period 1972), Special Publication 305 Supplement 5 (covering the period 1973), Special Publication 305 Supplement 6 (covering the period 1974), remain in effect. Two earlier lists, Circular 460 (Publications of the National Bureau of Standards, 1901 to June 1947) and its supplement (Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957) are also still in effect.

SP306-1. **Bibliography on the analyses of optical atomic spectra. Section 1. ^{1}H-^{23}V,** C. E. Moore, Nat. Bur. Stand. (U.S.), Spec. Publ. 306-1, Sec. 1, 89 pages (Sept. 1968).

Key words: Analyses of atomic spectra; atomic spectra, H thru V; bibliography, atomic spectra; elements, spectra of H thru V; references to atomic spectra; spectra, atomic.

The three published volumes on "Atomic Energy Levels," NBS Circ. 467, contain for each spectrum the bibliography that was used in compiling the data. The present work is a continuation of these bibliographies arranged in the same form. The time interval is the span from the respective dates of the earlier publications to the present. The selection of references is restricted to those needed for the preparation of revised tables of atomic energy levels and multiplets.

The bibliography is being published in three sections each of which covers the same elements as the respective volumes of AEL. The present section contains reference lists for the elements 1 H through 23 V, corresponding to Volume I. The spectra of a given element are listed in order of increasing stage of ionization. Listings are included for spectra of the 23 elements.

The original papers have been examined for nearly all of the quoted references. A selected list of general literature references is also included.

SP306-2. **Bibliography on the analyses of optical atomic spectra. Section 2. ^{24}Cr-^{41}Nb,** C. E. Moore, Nat. Bur. Stand. (U.S.), Spec. Publ. 306-2, Sec. 2, 63 pages (Feb. 1969).

Key words: Analyses of atomic spectra; atomic spectra, Cr through Nb; bibliography, atomic spectra; elements, spectra of Cr through Nb; references to atomic spectra; spectra, atomic.

The three published volumes on "Atomic Energy Levels," NBS Circ. 467, contain for each spectrum the bibliography that was used in compiling the data. The present work is a continuation of these bibliographies arranged in the same form. The time interval is the span from the respective dates of the earlier publications to the present. The selection of references is restricted to those needed for the preparation of revised tables of atomic energy levels and multiplets.

The bibliography is being published by sections, each of which covers the same elements as the respective volumes of AEL. Section 1 was issued in September 1968; it contains references for the elements ^{1}H through ^{23}V, corresponding to AEL Volume I.

The present section is similarly arranged, giving references to the spectra of the elements ^{24}Cr through ^{41}Nb, corresponding to AEL Volume II. For a given element the spectra are listed in order of increasing stage of ionization.

The original papers have been examined for nearly all of the quoted references.

SP306-3. **Bibliography on the analyses of optical atomic spectra. Section 3. ^{42}Mo-^{57}La and ^{72}Hf-^{89}Ac,** C. E. Moore, Nat. Bur. Stand. (U.S.), Spec. Publ. 306-3, Sec. 3, 37 pages (May 1969).

Key words: Analyses of atomic spectra; atomic spectra; bibliography, atomic spectra, Mo through La, Hf through Ac; elements, spectra of Mo through La, Hf through Ac; references to atomic spectra; spectra, atomic.

The three published volumes on "Atomic Energy Levels," NBS Circ. 467, contain for each spectrum the bibliography that was used in compiling the data. The present work is a continuation of these bibliographies arranged in the same form. The time interval is the span from the respective dates of the earlier publications to the present. The selection of references is restricted to those needed for the preparation of revised tables of atomic energy levels and multiplets.

The bibliography is being published by sections, each of which covers the same elements as the respective volumes of AEL. Section 1 was issued in September 1968; it contains references for the elements ^{1}H through ^{23}V, corresponding to AEL Volume I. Section 2 appeared in February 1969; as in AEL Volume II, the references cover the elements ^{24}Cr through ^{41}Nb.

The present section is similarly arranged, giving references to the spectra of the elements, ^{42}Mo through ^{57}La and ^{72}Hf through ^{89}Ac, similar to AEL Volume III. For a given element the spectra are listed in order of increasing stage of ionization.

The original papers have been examined for nearly all of the quoted references.

SP306-4. **Bibliography on the analyses of optical atomic spectra. Section 4. ^{57}La-^{71}Lu and ^{89}Ac-^{99}Es,** C. E. Moore, Nat. Bur. Stand. (U.S.), Spec. Publ. 306-4, Sec. 4, 55 pages (Aug. 1969).

Key words: Analyses of rare-earth spectra; atomic spectra; La through Lu, Ac through Es; rare-earth spectra; references to atomic spectra; spectra, atomic: elements, spectra of rare-earths.

There is a steady demand for information on rare-earth spectra. In an attempt to satisfy this need the present bibliography has been prepared. It comprises Section 4, concludes this publication, and completes the coverage of the Periodic Table. The references listed have been selected on a general basis as those needed for the preparation of Volume 4 of "Atomic Energy Levels."

Since rare-earth structure is revealed in the neighboring spectra, ^{57}La and ^{89}Ac, the references for these elements are repeated in the present Section, which contains the two groups of ele-

ments: ^{57}La to ^{71}Lu and ^{89}Ac to ^{99}Es. A selected list of general literature references is also included.

Nearly all of the quoted references have been checked from the original papers.

SP307. **Wolf-Rayet stars.** Proceedings of a symposium held at the Joint Institute for Laboratory Astrophysics, National Bureau of Standards, Boulder, Colo., June 10-14, 1968, K. M. Grebbe and R. N. Thomas, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 307, 286 pages (Dec. 1968).*

Key words: Atomic cross sections; atmospheric aerodynamics; diagnostic spectroscopy; non-equilibrium gases; stellar instability; Wolf-Rayet stars.

A symposium on Wolf-Rayet stars was held at the Joint Institute for Laboratory Astrophysics on the campus of the University of Colorado, Boulder, Colorado, June 10-14, 1968. The Wolf-Rayet stars represent the most extreme example studied on an interaction between aerodynamic motions and a radiation field to produce a high temperature, large-scale plasma in a steady but non-equilibrium state. As such these stars provide a perfect example of the kind of gaseous ensemble that JILA was created to study. In order to understand them, we require a knowledge of gases with temperatures between 10^4 and 10^7 °K and differential velocities between 0 and 10^3 km/sec. In particular we need information on radiative and collisional atomic cross sections for a wide range of ions, on collective interactions of ions and photons, on methods of diagnostic spectroscopy, and on velocity fields generated by convective, gravitational, nuclear, radiative, rotational, thermal, and other instabilities. The material of the symposium was divided into four broad topics: the distribution, physical properties and evolutionary status of Wolf-Rayet stars; the detailed features of their spectra; the interpretations of these features and the models on which they are based; and finally a survey of the material and ideas arising out of the symposium itself. This volume contains the introductory summaries of each of these broad topics, together with an edited version of the discussions which followed.

Part A.—The Features of the System of Wolf-Rayet Stars.
Part B.—A Survey of Spectroscopic Features of Wolf-Rayet Stars.
Part C.—Spectroscopic Diagnostics, Interpretation, and Atmospheric Models.
Part D.—Summary of Problems, Ideas, and Conclusions on the Physical Structure of the Wolf-Rayet Stars.

SP308. **Technical highlights of the National Bureau of Standards, Annual Report Fiscal Year 1968,** Nat. Bur. Stand. (U.S.), Spec. Publ. 308, 216 pages (Nov. 1968).

Key words: Annual report; technical highlights.

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1968. It lists major programs as they were carried out by the three NBS institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology and by the Bureau's Center for Radiation Research. Summaries are given of typical projects in measurement engineering, applied mathematics, electricity, metrology, mechanics, heat, atomic physics, radio standards, laboratory astrophysics, cryogenics, analytical chemistry, polymers, metallurgy, inorganic materials, physical chemistry, engineering standards, weights and measures, invention and innovation, vehicle systems research, product evaluation, building research, electonic technology, technical analysis, computer sciences, and radiation research. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, and national and international cooperative activities.

SP309, Volume 2. **Computer literature bibliography 1964-1967,** W. W. Youden, Nat. Bur. Stand. (U.S.), Spec. Publ. 309, Vol. 2, 385 pages (Dec. 1968).

Key words: Author index; coden; computer bibliography; information retrieval; permuted index; title word index.

This bibliography is a continuation of NBS Miscellaneous Publication 266, *Computer Literature Bibliography, 1946 to 1963,* and is intended as a further service to the computer community. It contains approximately 5,200 references to computer literature published during the years 1964 through 1967. The Bibliography Section includes the full title and the names of all of the authors of each item published in 17 journals, 20 books composed of chapters by individual authors, and 43 conference proceedings. In addition, references to all items that were reviewed in the IEEE Transactions on Electronic Computers have been included.

The Title Word Index Section provides the means for locating an item if any part of its title is known. Likewise, it can be used to identify all items whose titles include a particular word or phrase. The Author Index Section lists all authors of each item, but does not indicate whether an individual is its sole author.

SP310. **Nuclear standards for chemistry and technology.** Proceedings of a Symposium on Standards in Nuclear Chemistry and Technology held at the 156th National Meeting of the American Chemical Society, Atlantic City, N.J., September 8-9, 1968, H. F. Beeghly, J. P. Cali, and W. W. Meinke, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 310, 261 pages (Dec. 1968).*

Key words: Activation analysis standards; isotope reference standards; nuclear fuel burn-up standards; radiation effect standards; radioactivity standards; standards for nuclear chemistry; standards for nuclear technology.

Many diverse organizations are engaged in developing the nuclear standards needed by science, industry, and government for the rapidly growing field of nuclear technology. Often there has been inadequate communication between these groups and insufficient opportunity to get an overall picture of the needs of the country for the many different kinds of standards necessary for this new industry. The Symposium sponsored by the American Chemical Society Division of Nuclear Chemistry and Technology in cooperation with the Committee on Standardization Relations brought together most of the groups with interests in standards for nuclear chemistry and technology to identify the problems, to discuss present programs, and to outline future needs for standards in this broad field. Standards for purposes of the symposium were defined very broadly to include standard materials, standard procedures, standard specifications, standard data, and engineering standards. The mechanisms available for standardization, the "state of the art" in standardization in many areas of the nuclear field, some indications of unmet needs, and estimates of future needs were discussed in a series of papers and panel discussions which are presented here in either complete or summary form.

The Nuclear Standards Board of the U.S.A. Standards Institute (USASI)—An Overview, J. W. Landis.
The International Standards Organization (ISO) Activities of TC85 Committees, D. C. Fleckenstein.
The International Commission on Radiological Units and Measurements (ICRU): An Overview with Special Emphasis on Radioactivity Measurements, W. B. Mann.
Activities of the Subcommittee on Use of Radioactivity Standards, NAS-NRC, B. Kahn.
Standards Program of the American Nuclear Society, R. G. Chalker.
The Position of ASTM in Nuclear Technology, J. W. Caum.

ASTM C-21, Subcommittee V, Nuclear Applications, H. J. Anderson.

A Review of the Work of ASTM Subcommittee II, D9/D20, Effects of High Energy Radiation on Plastics and Electrical Insulation, O. Sisman.

ASTM Committee D19, Methods for Radiochemical Analysis of Water, D. L. Reid.

ASTM Committee E-10 on Radioisotopes and Radiation Effects, D. N. Sunderman.

Activities of ASTM: E-10; Subcommittee I on Nuclear Fuel Burnup, R. C. Shank.

Government Assistance in Developing Voluntary Standards, D. R. Mackay.

The Standard Reference Material Program of the National Bureau of Standards, J. P. Cali.

Programs and Services of the Radioactivity Standards Group at the National Bureau of Standards, S. B. Garfinkel.

Present and Future Needs of the AEC for Standards for Reactor Development and Technology, J. W. Crawford.

Standards for Nuclear Safeguards National and International, S. C. T. McDowell, R. J. Jones, and L. R. Norderhaug.

Standards in Radioisotope Development, W. E. Mott, W. K. Eister.

Standards Needs for the Division of Biology and Medicine Programs, W. F. Marlow.

Radioactivity Source Standards for Public Health Service Needs, H. E. Kolde and P. A. Cliggett.

Standards for Nuclear Instruments, L. E. Packard.

Standards Needs for Activation Analysis, V. P. Guinn.

Standards Needs of the Nuclear Power Industry, J. C. R. Kelly.

Nuclear Industry Responsibility in the Standards Area, E. A. Wiggin.

The National Standard Reference Data System, E. L. Brady and M. B. Wallenstein.

Standards Needs of a Major National AEC Laboratory, A. F. Rupp.

Nuclear Standards and the AEC New Brunswick Laboratory, C. J. Rodden.

The Need for Standards in Environmental Analysis, J. H. Harley.

SP311. **Report of the 53d National Conference on Weights and Measures, 1968,** R. L. Koeser, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 311, 182 pages (Mar. 1969).*

Key words: Conference; weights and measures—history; weights and measures—laws; weights and measures—regulations; weights and measures—technical requirements; weights and measures.

This is a report of the proceedings (edited) of the Fifty-third National Conference on Weights and Measures, sponsored by the National Bureau of Standards, held in Washington, D.C., June 17-21, 1968 and attended by State, county, and city weights and measures officials and representatives of the Federal Government, business, industry, railroads, and associations.

Maximum Effectiveness with Limited Resources, M. H. Becker.

Activities of the Office of Weights and Measures, National Bureau of Standards, M. W. Jensen.

Weights and Measures in Ceylon, H. Goonetilleke.

Two-Way Dividends from Industry-Government Collaboration, D. S. Ring.

Packaging Standards for Fluid Milk Products, G. W. Spotts.

The Production of Package Labels under the Fair Packaging and Labeling Act, F. R. Cawley.

Progress Through Cooperation, H. J. Sheerin.

The Emphasis is on "With," F. McLaughlin.

"The Metric System and You," J. T. Myers.

Meeting the Challenge, R. C. Primley.

Little Omissions Can Lead to Serious Errors, A. Sanders.

The Development of a State Measurement Center, M. Jennings.

SP312, Volumes I and II. **Modern trends in activation analysis.** Proceedings of the 1968 International Conference held at the National Bureau of Standards, Gaithersburg, Md., October 7-11, 1968, J. R. DeVoe, Editor and P. D. LaFleur, Assistant Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 312, Vol. I, 691 pages and Vol. II, 676 pages (June 1969).*

Key words: Activation analysis; applications; archaeology; biology; charged particles; computation; conference; criminology; data handling; geochemistry; industry; neutron; nuclear reactions; photons; radiation detectors; radiochemical separation.

A conference on Modern Trends in Activation Analysis was held at the National Bureau of Standards, October 7-11, 1968. Volume I contains texts of two invited plenary lectures, one on the applications of activation analysis and one on radiochemical separations, contributed papers, remarks by honored guests, and synopses of discussion sessions by each chairman. Topics covered include applications of activation analysis in the environmental sciences, biology, medicine, archaeology, criminology, geochemistry, geology, and industry. Also included are studies on radiochemical separations. Volume II contains texts of three plenary lectures, one on nuclear reactions, one on radiation detectors and data processing, and one on computation methods in activation analysis. Contributed papers, remarks by honored guests, and synopses of discussion sessions by chairmen are included. Topics covered include nuclear reactions in activation analysis, radiation detectors, data handling and processing, computation methods, error analysis, and information retrieval. These two volumes are sold as a set.

Volume I:

The Halogen Composition of Aerosol Particles Over Lake Michigan, R. H. Loucks, J. W. Winchester, W. R. Matson, and M. A. Tiffany.

Thermal Neutron Activation Analysis of Airborne Particulate Matter in Chicago Metropolitan Area, S. S. Brar, D. M. Nelson, E. L. Kanabrocki, C. E. Moore, C. D. Burnham, and D. M. Hattori.

Application of Activation Analysis and Ge(Li) Detection Techniques for the Determination of Stable Elements in Marine Aerosols, N. D. Dudey, L. E. Ross, and V. E. Noshkin.

Activation Analysis Applied to Sediments From Various River Deltas, A. J. de Groot, K. H. Zschuppe, M. de Bruin, J. P. W. Houtman, and P. A. Singgih.

Measurements of Movements of Solid Substances in Water by Means of Stable Tracers and Activation Analysis, C. Cappadona.

Specific Activation Analysis Techniques and Methods for the Assay of Trace Substances in Aquatic and Terrestrial Environments, G. W. Leddicotte.

Post-Sampling Activation Analysis of Stable Nuclides for Estuary Water Tracing, J. K. Channell and P. Kruger.

Neutron Activation Analysis of Vanadium in Natural Waters, K. D. Linstedt and P. Kruger.

Neutron Activation Analysis Identification of the Source of Oil Pollution of Waterways, V. P. Guinn and S. C. Bellanca.

The Multielement Analysis of Biological Material by Neutron Activation and Direct Instrumental Techniques, L. A. Rancitelli, J. A. Cooper, and R. W. Perkins.

Multielement Analysis of Pathological Tissue, D. M. Linekin, J. F. Balcius, R. D. Cooper, and G. L. Brownell.

The Use of Neutron Capture Gamma Radiations for the Analysis of Biological Samples, D. Comar, C. Crouzel, M. Chastel and, R. Riviere, and C. Kellershohn.

Element Imbalances of Atherosclerotic Aortas, W. H. Strain, G. G. Rob, W. J. Pories, R. C. Childers, M. F. Thompson, Jr., A. A. Hennessen, and F. M. Graber.

A Useful Neutron Activation Analysis Method for the Determination of Tellurium in Human Tissues, A. Abu-Samra and G. W. Leddicotte.

Neutron Activation Analysis of Brain for Copper and Manganese, E. D. Bird, J. F. Emery, S. B. Lupica, and W. S. Lyon.

Neutron Activation Analysis of Barnacle Shells, C. M. Gordon and R. E. Larson.

Sampling Methodology Development in a Large Scale Cystic Fibrosis Screening Program Based on Automated Neutron Activation Analysis, L. E. Fite, R. E. Wainerdi, H. P. Yule, G. M. Harrison, G. Bickers, and R. Doggett.

Clinical Experience With the Use of Neutron Activation Analysis in the Diagnosis of Cystic Fibrosis, G. L. Woodruff, W. E. Wilson, Jr., Y. Yamamoto, A. L. Babb, and S. J. Stamm.

Activation Analysis in Plant Biology. Radioecological Applications Using Simple or Automated Radiochemical Separation Techniques, A. Fourcy, M. Neuburger, C. Garrec, A. Fer, and J. P. Garrec.

Determination of Vanadium by Neutron Activation Analysis at Nanogram Levels in Diets for Experimental Animals, J. P. F. Lambert and R. E. Simpson.

The Instrumental Determination of Fifteen Elements in Plant Tissue by Neutron Activation Analysis, W. A. Haller, R. Filby, L. A. Rancitelli, and J. A. Cooper.

Simultaneous Determination of Arsenic, Antimony and Mercury in Biological Materials by Neutron Activation Analysis, I. Hadzistelios and A. P. Grimanis.

Instrumental Neutron Activation Analysis of Tobacco Products, R. A. Nadkarni and W. D. Ehmann.

Simultaneous Determination of Arsenic and Copper in Wines and Biological Materials by Neutron Activation Analysis, A. P. Grimanis

Aspects of Low Temperature Irradiation in Neutron Activation Analysis, D. Brune.

Determination of the Specific Activity of Commercial Iodine-125 Preparations by Neutron Activation Analysis, K. Heydorn.

Investigations on the Age and Place of Origin of Paintings by Neutron Activation Analysis, F. Lux, L. Braunstein, and R. Strauss.

An Investigation of the Silver Content of Roman Coinage by Neutron Activation Analysis, D. Gibbons and D. Lawson.

Nondestructive Activation Analysis of Ancient Coins Using Charged Particles and Fast Neutrons, P. Meijers.

The Analysis of English and American Pottery of the American Colonial Period, J. S. Olin and E. V. Sayre.

Comparison of Forensic Soil Specimens by Neutron Activation Analysis, C. M. Hoffman, R. L. Brunelle, K. B. Snow, and M. J. Pro.

Recent Forensic Applications of Instrumental Activation Analysis, A. K. Perkons and R. E. Jervis.

The Examination of Actual Case Evidence Samples by Neutron Activation Analysis, H. L. Schlesinger, H. R. Lukens, and D. M. Settle.

Arsenic Content of Human Hair After Washing as Determined by Activation Analysis, A. J. van den Berg, J. J. M. de Goeij, J. P. W. Houtman, and C. Zegers.

Comparison of Activation Analysis and Spark Source Mass Spectrometry for Forensic Applications, T. G. Williamson and W. W. Harrison.

Routine Determinations of Al, K, Cr, and Sn in Geochemistry by Neutron Activation Analysis, H. A. Das, J. G. van Raaphorst, and H. J. L. M. Umans.

Determination of Trace Elements in Meteorites by Neutron Activation Analysis, W. Kiesl.

The Nondestructive Determination of Iridium in Meteorites Using Gamma-Gamma Coincidence Spectrometry, W. D. Ehmann and D. M. McKown.

Determination of Some Rare Earths in Rocks and Minerals by Neutron Activation and Gamma-Gamma Coincidence Spectrometry, O. B. Michelsen and E. Steinnes.

Neutron Activation Method for the Isotopic Analysis of Lead, P. P. Parekh, M. S. Das, and V. T. Athavale.

Determination of Protactinium by Neutron Activation and Alpha Spectrometry, J. N. Rosholt and B. J. Szabo.

Use of a Ge(Li) Detector After Simple Chemical Group Separation in the Activation Analysis of Rock Samples. IV. Simultaneous Determination of Strontium and Barium, H. Higuchi, K. Tomura, H. Takahashi, N. Onuma, and H. Hamaguchi.

Activation Analysis of Geochemical Materials Using Ge(Li) Detectors, R. H. Filby and W. A. Haller.

Ge(Li) Detectors in the Activation Analysis of Geological Samples, K. Randle and G. G. Goles.

An Investigation of Trace Elements in Marine and Lacustrine Deposits by Means of a Neutron Activation Method, O. Landstrom, K. Samsahl, and C. G. Wenner.

Geochemical Surveying by Means of Neutron Activation Analysis with Possible Application to Continental Drift Studies, E. A. Uken, G. G. Santos, and R. E. Wainerdi.

Volcanological Studies Using Activation Analysis Techniques, G. Santos and R. E. Wainerdi.

Aluminum and Silicon Abundances of Some Italian Meteorites as Determined by Instrumental Activation Analysis, S. Meloni, V. Maxia, and S. Buzzi.

Neutron Activation Analysis of Individual Cosmic Spherules, H. T. Millard, Jr.

Extensions of the Use of Ge(Li) Detectors in Instrumental Neutron Activation Analysis of Geological Samples, G. E. Gordon, J. C. Dran, P. A. Baedecker, and C. F. L. Anderson.

Neutron Techniques for *In Situ* Elemental Analysis, J. W. Mandler and J. H. Reed.

Simultaneous Measurement of Seventeen Trace Elements in Eight Geochemical Standards: A Novel Adaptation of Neutron Activation Analysis, D. R. Case, J. C. Laul, M. A. Wechter, F. Schmidt-Bleek, and M. E. Lipschutz.

On the Feasibility of the Determination of Water, Salt and Sulphur in Crude Oil by Means of Neutron Activation Analysis, L. Gorski, J. Janczyszyn, and L. Loska.

Investigation of Material Transfer by Neutron Activation Analysis, D. Gibbons, D. Lawson, B. Metcalfe, and H. Simpson.

Applications of Activation Analysis to Determination of Cement in Concrete, F. A. Iddings and A. Arman.

Determination of Sodium and Potassium in Solid Propellants, W. H. Barber, O. H. Dengel, R. H. Vogt, and C. V. Strain.

The Application of Isotopic Neutron Sources to Chemical Analysis for Process Control in the Metallurgical Industry, J. Kuusi.

Routine Determination of Major Components by Activation Analysis, J. F. Cosgrove.

Instrumental Neutron Activation Analysis Using Reactor, Ge(Li) Detector and Computer, O. U. Anders.

Substoichiometric Determination of Molybdenum and Palladium by Neutron Activation Analysis, Z. K. Doctor, R. A. Nadkarni, and B. C. Haldar.

Activation Analysis by Standard Addition and Solvent Extraction. Determination of Certain Trace Elements in Antimony, A. Alian.

Nondestructive Determination of Elements in Specific Freshwater Microplankton by Activation Analysis, M. Merlini, O. Ravera, and C. Bigliocca.

Isotopic Analysis of Uranium by Neutron Activation and High Resolution Gamma-Ray Spectrometry, M. Mantel, J. Gilat, and S. Amiel.

Pulsed Neutron Activation Analysis System for Short-Lived Radioisotopes, W. F. Naughton and W. A. Jester.

The Detection and Determination of Fissionable Species by Neutron Activation—Delayed Neutron Counting, J. L. Brownlee, Jr.

A High-Intensity ^{241}Am-Be-^{242}Cm Neutron Source, M. Wahlgren, J. Wing, and D. C. Stewart.

New Facilities for Activation Analysis at the Grenoble Center for Nuclear Studies, J. Laverlochere.

The Nuclear Analysis Program of the NRL Cyclotron Facility, J. A. Eisele and R. E. Larson.

The Localization of Impurities in Activation Analysis Demonstrated by Analyses of Semiconductor Silicon, J. Martin.

The Determination of Copper and Gold Trace Impurities in High Purity Gallium by Activation Analysis with Pretreatment, L. G. Nagy, G. Torok, L. Szokolyi, and J. Giber.

Neutron Activation Analysis of Laser Crystals, R. F. Ortega.

Determination of Traces of Selenium and Tellurium in Sulphur by Neutron Activation, A. Arroyo A. and J. Toro G.

Nondestructive Activation Analysis for Arsenic and Antimony in Soft Soldering Alloys, M. D. Rudelli, H. C. Rocca, and G. B. Baro.

The Application of the Activation Analysis to the Investigation of Sorption and Sublimation Properties of High-Temperature Materials, I. A. Maslov, V. A. Lucknitsky, N. M. Karnauckova, and G. I. Karajanova.

Diversified Instrumental Nuclear Analysis Methods Using a Reactor, H. W. Nass.

Major Constituents Determination in Substances by Activation Analysis, C. Cappadona.

Gas Chromatographic Separations in Neutron Activation Analysis, S. P. Cram and F. T. Varcoe.

Rapid Group Separation Method for Neutron Activation Analysis of Geological Materials, S. F. Peterson, A. Travesi, and G. H. Morrison.

Group Radiochemical Separations: A Practical Approach to Activation Analysis, B. A. Thompson.

Radiochemical Separations by Retention on Inorganic Precipitates, F. Girardi, R. Pietra, and E. Sabbioni.

Chromium Separation by Inorganic Exchangers in Activation Analysis of Biological Materials, S. Meloni, A. Brandone, and V. Maxia.

Determination of the Distribution Coefficients of the Elements of the IB, VB, VIA, and VIB Groups in Anionic Ion Exchange Resin in the Water-Hydrochloric Acid-Acetone Mixture, C. Cleyrergue, N. Deschamps, and P. Albert.

Quantitative Determination of Impurities in Nuclear Graphites by Radioactivation Methods, S. May and G. Pinte.

Radiochemical Separations for Activation Analysis Using Bis(2-Ethyl-Hexyl) Orthophosphoric Acid, I. H. Qureshi, L. T. McClendon, and P. D. LaFleur.

Volume II:

Study of a Beam of Charged Particles: Their Slowing Down, and Their Energy Distribution in a Thick, Complex Target for Activation Analysis, M. D. Tran and J. Tousset.

Range Transformation of Activation Curves and Their Application to Quantitative Charged Particle Activation Analysis, H. L. Rook, E. A. Schweikert, and R. E. Wainerdi.

Contribution to Activation Analysis by Charged Particles: Determination of Carbon and Oxygen in Pure Metals, Possibilities of Sulphur Determination, J. L. Debrun, J. N. Barrandon, and P. Albert.

Influence of Channeling in Customary ^{3}He Activation Analysis, E. Ricci.

Surface Analysis of Gold and Platinum Disks by Activation Methods and by Prompt Radiation from Nuclear Reactions, J. W. Butler and E. A. Wolicki.

Determination of Oxygen Present at the Surface of Metals by Irradiation with 2 MeV Tritons, J. N. Barrandon and P. Albert.

The Determination of Stable Calcium Isotopes by Charged Particle Irradiation, M. Peisach and R. Pretorius.

Cross Sections of ^{18}F Formation by Deuteron Bombardment of Oxygen and Fluorine. Applications to Oxygen Analysis, M. D. Tran, A. Chenaud, H. Giron, and J. Tousset.

Examples of Determination of Light Elements in Various High Purity Materials, by Gamma Photon and Charged Particle Activation, C. Engelmann, J. Gosset, M. Loeuillet, A. Marschal, P. Ossart, and M. Boissier.

Self-Shielding Corrections in Photon Activation Analysis, G. J. Lutz.

Photon Activation Analysis of Oxygen and Carbon in a Eutectic Mixture of Lead and Bismuth Using a Linac, W. D. Mackintosh and R. E. Jervis.

Determination of Carbon in High Purity Iron by Irradiation in Photons, G. Revel, T. Chaudron, J. L. DeBrun, and P. Albert.

Charged Particle Activation Analysis for Carbon, Nitrogen, and Oxygen in Semiconductor Silicon, T. Nozaki, Y. Yatsurugi, N. Akiyama, and I. Imai.

^{7}Be as a Dosimeter During Photon Activation of Iodine, J. A. Cardarelli, E. S. Dell, and B. A. Burrows.

Some Recently Determined Photonuclear Reaction Yields and Cross Sections for Formation of Several Isomers, H. R. Lukens.

Spectrum, Yield and Use of Fast Neutrons Produced by 20 MeV Helium-3 Ions, 14 MeV Protons and 7.5 MeV Deuterons on a Thick Beryllium Target, E. Bruninx.

The Production of Fast Neutrons by Small Cyclotrons, A. A. Fleischer.

Use of a 60 MeV Linac for Fast and Variable Energy Neutron Activation Analysis, P. E. Wilkniss.

Blank Considerations in 14 MeV Neutron Activation Analysis for Trace Oxygen, S. S. Nargolwalla, E. P. Przybylowicz, J. E. Suddueth, and S. L. Birkhead.

Activation Analysis of Chloride and Iodide in Photographic Emulsions Using 14.7 and 2.8 MeV Neutrons, E. P. Przybylowicz, G. W. Smith, J. E. Suddueth, and S. S. Nargolwalla.

Long Term Operating Experience with High Yield, Sealed Tube Neutron Generators, P. L. Jessen.

A 10^{11} Neutrons Per Second Tube for Activation Analysis, D. W. Downton and J. D. L. H. Wood.

A High Output Sealed-Off Neutron Tube with High Reliability and Long Life, O. Reifenschweiler.

On-Stream Activation Analysis Using Sample Recirculation, J. B. Ashe, P. F. Berry, and J. R. Rhodes.

Fast Neutron Continuous Activation Analysis of Dilute Solutions, R. E. Jervis, H. Al-Shahristani, and S. S. Nargolwalla.

Use of Very Short-Lived Nuclides in Nondestructive Activation Analysis with a Fast Shuttle Rabbit, M. Wiernik and S. Amiel.

Cyclic Activation Analysis, W. W. Givens, W. R. Mills, Jr., and R. L. Caldwell.

An Analog Computer Controlled Gamma-Ray Spectrometer for Comparative Activation Analysis, P. C. Jurs and T. L. Isenhour.

Determination of Trace Quantities of Uranium in Biological Materials by the Nuclear Track Technique, B. S. Carpenter.

Surface Analysis of Medium Weight Elements by Prompt Charged Particle Spectrometry, C. Olivier and M. Peisach.

Californium-252: A New Neutron Source for Activation Analysis, W. C. Reinig and A. G. Evans.

Comparison of Solid State and Scintillation Gamma-Ray Spectrometry in Analysis, A. F. Voigt, D. E. Becknell, and L. Menapace.

Measurement and Comparison of Detector Efficiencies, J. A. Dooley.

Instrumentation for Computerized Neutron Activation Analysis, D. D. Tunnicliff, R. C. Bowers, and G. E. A. Wyld.

An Anticoincidence Shielded Ge(Li) Gamma-Ray Spectrometer and its Application to Neutron Activation Analysis, J. A. Cooper, L. A. Rancitelli, R. W. Perkins, W. A. Haller, and A. L. Jackson.

A Coincidence-Anticoincidence System for Activation Analysis Employing a Split NaI(Tl) Annulus and a Large Volume Ge(Li) Detector, R. L. Currie, R. McPherson, and G. H. Morrison.

A Dual Channel Analyzer and Efficient Coincidence Systems for Activation Analysis, R. A. Johnson.

Characteristics and Applications of a Large Sodium Iodide Detector Assembly, J. L. Parker, D. M. Holm, and B. K. Barnes.

A Compton-Suppressed Coincidence Gamma-Ray Scintillation Spectrometer with Large NaI(Tl) Crystals, B. A. Euler, D. F. Covell, and S. Yamamoto.

Computerized Quantitative Analysis of High-Resolution Spectra, J. A. Dooley, J. H. Gorrell, P. Polishuk, and M. Young.

On-Line Data Analysis of Digital Pulse-Height Spectra, J. I. Trombka and R. L. Schmadeback.

Spectral Data Handling Systems, F. P. Brauer and J. E. Schlosser.

"Hevesy", A Computer Program for Analysis of Activation Analysis Gamma-Ray Spectra, H. P. Yule.

Development of a Direct Connection Between an Activation Analysis Laboratory and an IBM 360/65 Computer, F. Girardi, G. Guzzi, G. Di Cola, W. Becker, and A. Termanini.

Developments in the Use of Small Digital Computers in Activation Analysis Systems, T. B. Pierce, R. K. Webster, R. Hallett, and D. Mapper.

On-Line Activation Analysis with a PDP-9 Computer, C. J. Thompson.

Man-Machine Interaction in Analysis of Pulse-Height Spectra, W. R. Burrus.

The NBS Automated Activation Analysis Information Retrieval System, G. J. Lutz, R. J. Boreni, R. S. Maddock, and W. W. Meinke.

Edge-Punched Card Literature Retrieval System for Activation Analysis, T. Braun, E. Bujdoso, and M. Miskei.

Isotopes Information Center, P. S. Baker.

Catalogue of Gamma Rays Emitted by Radionuclides, M. A. Wakat.

Computerized Identification of Reactor-Produced Isotopes, J. A. Dooley, J. H. Gorrell, J. M. Thompson, and E. Hoffman.

Computer Analysis of Gamma-Ray Spectra: Validity of the Results, H. F. Lucas, Jr., and D. N. Edgington.

The Discovery of Errors in the Detection of Trace Components in Gamma Spectral Analysis, L. A. Currie.

Regression Analysis of Gamma-Ray Spectrometer Data with an Application to the Assay of Human Radioactivity Burdens, B. Pasternack and N. Harley.

Computer Gain Changing of Scintillation Spectra, J. J. Steyn and D. G. Andrews.

A Computer Method of Peak Area Determinations from Ge(Li) Gamma Spectra, H. R. Ralston and G. E. Wilcox.

Quantitative Analysis of Unknown Mixtures by Computer Reduction of Ge(Li) Spectra, R. Gunnink and J. B. Niday.

A Computer-Based System for Neutron Activation Analysis, D. D. Tunnicliff and G. E. A. Wyld.

Rapid Manual Resolution of Multi-Component Gamma-Ray Photopeaks, H. R. Lukens.

Computer Studies of Complex Full Energy Peaks Using Second and Third Derivatives, H. P. Yule.

The Precision of Multi-Element Techniques in Activation Analysis, R. F. Coleman.

Contribution to Improvements in Accuracy and Reproducibility of Routine Activation Analysis, F. Dugain.

Precision in the Neutron Activation Analysis for Gold in Standard Rocks G-1 and W-1, K. Fritze and R. Robertson.

High Precision Activation Analysis of Sodium Using an Internal Standard Technique, R. H. Marsh and W. Allie, Jr.

NBS Standard Reference Materials Available for Activation Analysis, W. W. Meinke and J. P. Cali.

The Role of Activation Analysis in the NBS Standard Reference Material Program, J. P. Cali.

An Oxygen Standard for the Determination of Oxygen in Steel by 14 MeV Neutron Activation Analysis, R. Gijbels, A. Speecke, and J. Hoste.

A High Purity Cellulose as a Possible Biological Reference Material, L. A. Rancitelli, T. M. Tanner, and W. A. Haller.

Microstandards for Activation Analysis, D. H. Freeman.

SP313. **Making valuable measurements.** Proceedings of the 1968 Standards Laboratory Conference, H. L. Mason, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 313, 177 pages (May 1969).*

Key words: Metrology management; National Conference of Standards Laboratories; physical measurement.

The National Conference of Standards Laboratories is a nonprofit, laboratory-oriented organization whose purpose is to promote cooperative efforts toward solving the common problems faced by standards laboratories in their organization and operation. Established in 1961 under the sponsorship of the National Bureau of Standards, NCSL has a membership of more than 200 organizations. Three biennial national meetings have been held previously as well as a number of specialized regional workshops.

The theme of the 1968 Standards Laboratory Conference is "Making Valuable Measurements." The papers presented will attempt to answer the Who? When? Where? How? and Why? of making valuable measurements. The conference provides an opportunity for discussion of problems confronting laboratory managers and calibration personnel.

Representatives of member organizations of the National Conference of Standards Laboratories met at the Boulder facility of the National Bureau of Standards August 25-29, 1968. Major addresses were given by A. V. Astin and J. L. Sloop. Reports and discussions at eight sessions covered the management of valuable measurements: the management of equipment and data, measurement agreement comparisons, international practices, Defense Department activities, NBS activities, NCSL liaison, and NCSL committee work.

Measurements for Society, J. L. Sloop.

Activities of the DOD Calibration Coordination Group, R. Y. Bailey.

Metrology and Calibration in DOD Quality and Reliability Operations, M. L. Fruechtenicht.

Metrology and Calibration Considerations in Integrated Logistic Support Plans, S. Crandon.

The Instrumentation and Measurement Group of the Institute of Electrical and Electronic Engineers, F. L. Hermach.

Joint Activities of the Instrument Society of America and NCSL, O. L. Linebrink.

The Precision Measurements Association, R. B. Ernst.

The American Ordnance Association, J. A. Mallison.

Report of the Calibration and Standards Project of the Aerospace Industries Association Quality Assurance Committee, N. D. Smith.

The Economic Value of Making Measurements, H. E. Morgan.

Maximum Use of Existing Accuracy in Measurements, R. S. Powers.

New Directions for NBS Outputs, E. C. Wolzien.
Highlights of the NBS Boulder Laboratories, T. M. Flynn.
Measurement Control as a Valuable National Asset, C. E. White.
Legal Metrology and Establishment of Metrology Centres in India, V. B. Mainkar.
Progess of the British Calibration Service, H. E. Barnett.
Some Reflections Upon Common Measurement Systems, H. F. Monaghan.
Progress in Adopting the Metric System in the United Kingdom, A. H. A. Wynn.
Ireland and the Metric System, M. E. O'Hagan.
The Value of International Meaurements, R. H. C. Foxwell.
Large Problems of Small Countries, L. Frank.
Developments in the Canadian Measurement System, J. G. Cameron.
The Advantages and Disadvantages of Industrialized Nations Developing and Supporting a Dual System of Weights and Measures, J. S. Weber.
Information Committee A-6, P. H. Hunter and J. H. Blount.
Recommended Practices Committee A-9, W. R. Holmes.
Statistical Procedures Committee C-7, D. B. Sharp.
Calibration Procedures Committee C-6, A. R. Baughman.
Measurement Agreement Comparison Committee C-5, H. S. Ingraham, Jr.
Procurement Regulations Committee B-7, F. J. Dyce.
Workload Control Committee B-1, D. J. Greb.
Adjusting Calibration Intervals, R. H. Johnson.
An International Comparison of Power Standards at 3 GHz, P. A. Hudson and G. F. Engen.
Some U.S./U.K. Calibration Laboratory Measurement Comparisons, F. E. Parr.
The NCSL Interlaboratory Comparison of 1965, H. L. Mason.
The Interservice Measurement Audit Program, G. G. May.
An Information System for Standards Laboratories, W. J. Anson.
Administrative Problems in the Introduction of an Automatic Measuring System, G. W. Pentico.
Processing Technical and Administrative Data within the Standards Laboratory, L. Darling.
Is There a Figure of Merit for the Measurement Process?, L. Julie.
Total Instrument Control, L. M. Auxier and L. A. Micco.
Management Measurement Techniques for Calibration Laboratories, E. J. Arsenault.
Detecting Economic Obsolescence in Measurement Equipment, C. R. Duda.
Calibration Data Collection and Utilization, W. L. Bates.
Value Engineering Techniques—A Way of Managing Valuable Measurements, P. I. Harr.
Government's View of Contractor's Management of Valuable Measurements, H. B. Berkowitz.
Some Developments in the Management of Standards Activities in the NBS Institute for Basic Standards, B. W. Birmingham.
Weapon System User Management of Measurements, R. Y. Bailey.
1967-1968 Report of the Chairman, C. E. White.

SP314. **Ion-Selective Electrodes.** Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., January 30-31, 1969, R. A. Durst, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 314, 474 pages (Nov. 1969).*

Key words: Ion-selective electrodes; specific-ion electrodes; review of ion-selective electrodes; symposium proceedings.

This volume contains a review of ion-selective electrodes, emphasizing the non-glass types, and provides a thorough and critical evaluation of the subject. It consists of eleven invited review papers and selected discussions from the Symposium on Ion-Selective Electrodes held at NBS on January 30-31, 1969. This publication provides a comprehensive survey of the field and should prove very valuable in advancing the state of the art. The chapters include discussions on the theory, characteristics, and methodology of all types of ion-selective electrodes; their use in thermodynamic, kinetic, and complex-ion studies; standards; pure and applied research in various biomedical areas of interest; industrial analysis and control systems; and applications to diverse analytical problems. Both the present status and future potential of these sensors are discussed in a wide range of scientific disciplines, from the physical sciences to biomedicine. Extensive bibliographies provide an excellent survey of the literature for anyone using or anticipating the use of these electrodes.

Theory of Membrane Electrode Potentials: An Examination of the Parameters Determining the Selectivity of Solid and Liquid Ion Exchangers and of Neutral Ion-Sequestering Molecules, G. Eisenman.
Solid-State and Liquid Membrane Ion-Selective Electrodes, J. W. Ross, Jr.
Heterogeneous Membrane Electrodes, A. K. Covington.
Reference Electrodes, A. K. Covington.
Thermodynamic Studies, J. N. Butler.
Activity Standards for Ion-Selective Electrodes, R. G. Bates and M. Alfenaar.
Studies with Ion-Exchange Calcium Electrodes in Biological Fluids: Some Applications in Biomedical Research and Clinical Medicine, E. W. Moore.
Ion-Selective Electrodes in Biomedical Research, R. N. Khuri.
Analytical Studies on Ion-Selective Membrane Electrodes, G. A. Rechnitz.
Industrial Analysis and Control with Ion-Selective Electrodes, T. S. Light.
Analytical Techniques and Applications of Ion-Selective Electrodes, R. A. Durst.

SP315. **Bibliography on the high temperature chemistry and physics of materials, October, November, December 1968,** J. J. Diamond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315, 72 pages (Jan. 1969).

Key words: Bibliography, high-temperature chemistry; chemistry at high temperatures, bibliography; high temperature; high-temperature chemistry, bibliography.

A classified collection of references to scientific research performed at temperatures above 1000 °C and published in the world literature during the fourth quarter of 1968.

SP315-1. **Bibliography on the high temperature chemistry and physics of materials, January, February, March 1969,** J. J. Diamond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-1, 81 pages (April 1969).

Key words: Bibliography, high temperature; chemistry, high temperature; high temperature chemistry; materials properties; research at high temperatures; thermophysical properties.

The bibliography consists of references to research involving temperatures above 1000 °C, which were noted by the contributors during the above three-month period. Since this is intended primarily as a current-awareness bibliography, there is no cross-referencing or indexing. This issue contains about 700 references roughly grouped under fifteen subject headings.

SP315-2. **Bibliography on the high temperature chemistry and physics of materials, April, May, June 1969,** J. J. Diamond, Edi-

tor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-2, 74 pages (July 1969).

Key words: Bibliography, high temperature; chemistry, high temperature; high temperature chemistry; materials properties; research at high temperatures; thermophysical properties.

The bibliography consists of references to research involving temperatures above 1000 °C, which were noted by the contributors during the above three-month period. Since this is intended primarily as a current-awareness bibliography, there is no cross-referencing or indexing. This issue contains about 700 references roughly grouped under fifteen subject heading.

SP315-3. **Bibliography on the high temperature chemistry and physics of materials, July, August, September 1969,** J. J. Diamond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-3, 90 pages (Oct. 1969).

Key words: Bibliography, high temperature; chemistry, high temperature; high temperature chemistry; materials properties; research at high temperatures; thermophysical properties.

The bibliography consists of references to research involving temperatures above 1000 °C, which were noted by the contributors during the above three-month period. Since this is intended primarily as a current-awareness bibliography, there is no cross-referencing or indexing. This issue contains about 825 references roughly grouped under fifteen subject headings.

SP315-4. **Bibliography on the high temperature chemistry and physics of materials, October, November, December 1969,** J. J. Diamond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-4, 85 pages (Jan. 1970).

Key words: Bibliography, high temperature; chemistry, high temperature; high temperature chemistry; materials properties; research at high temperatures; thermophysical properties.

The bibliography consists of references to research involving temperatures above 1000 °C, which were noted by the Contributors during the above three-month period. Since this is intended primarily as a current-awareness bibliography, there is no cross-referencing or indexing. This issue contains about 775 references roughly grouped under fifteen subject headings.

SP315-5. **Bibliography on the high temperature chemistry and physics of materials, January, February, March 1970,** J. J. Diamond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 315-5, 82 pages (Apr. 1970).

Key words: Bibliography, high temperature; chemistry, high temperature; high temperature chemistry; materials properties; research at high temperatures; thermophysical properties.

The bibliography consists of references to research involving temperatures above 1000 °C, which were noted by the Contributors during the above three-month period. Since this is intended primarily as a current-awareness bibliography, there is no cross-referencing or indexing. This issue contains about 750 references roughly grouped under fifteen subject headings.

SP316. **Hydraulic research in the United States 1968,** G. Kulin, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 316, 331 pages (June 1969).

Key words: Hydraulic engineering; hydraulic research; hydraulics; hydrodynamics; project summaries.

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1967-1968 are summarized. Projects from more than 200 university, industrial, state and federal government laboratories in the United States and Canada are reported.

SP317. Volumes I and II. **Fundamental aspects of dislocation theory.** Proceedings of a conference held at the National Bureau of Standards, Gaithersburg, Md., April 21-25, 1969. J. A. Simmons, R. deWit, and R. Bullough, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 317, Vol. I, 752 pages, Vol. II, 624 pages (Dec. 1970).

Key words: Conference; continuum mechanics; crystal physics, disclinations; dislocations; elasticity; electron-dislocation interactions; lattice defects; phonon-dislocation interactions; solid-state; theoretical physics; thermally activated processes; twinning.

These Proceedings contain research papers, discussions thereon, and panel discussions for the conference on "Fundamental Aspects of Dislocation Theory," held under the auspices of the Institute for Materials Research, April 21-25, 1969, at the laboratories of the National Bureau of Standards, Gaithersburg, Maryland. Approximately 75 contributed papers and two panel discussions are included. Topics covered are Discrete Dislocations in Continuum Elasticity, Lattice Theories, Dislocation-Phonon Interactions, Applications of the Geometry of Dislocations, Intrinsic Properties of Dislocations, Dislocation Field Theories, Thermally Activated Processes and Statistical Theories, Dislocation-Electron Interactions, and Future Directions for Dislocation Theory. *These proceedings include the following papers (indented):*

Discrete dislocations in continuum elasticity, A. K. Head, *SP317,* pp. 5-9 (Dec. 1970).

Key words: Dislocation observations; dislocation theory; status and problems.

As a framework in which to survey some of the current questions in this long-established part of dislocation theory, the problem of the experimental determination of stacking fault energy is considered. Attention is restricted to those methods which observe and measure in the electron microscope a simple dislocation-stacking fault configuration. It is assumed that the configuration is in equilibrium with the forces between the dislocation balancing the surface tension of the stacking fault. The stacking fault energy then follows if these dislocation forces are known from theory for the observed dimensions of the configuration.

Experimental techniques have improved to the point where a reproducibility of 1 to 5 percent standard deviation is claimed. This calls for theory which has at least a similar standard of accuracy. It is doubtful if the theory which is in current use has this accuracy and this is surveyed under the following headings: (a) The treatment of the core; (b) Elastic anisotropy; (c) Zig-zag instabilities; (d) The effect of the stacking fault; (e) The observation of dislocations by electron microscopy.

The image force on dislocations at free surfaces—comments on the concept of line tension, J. Lothe, *SP317,* pp. 11-22 (Dec. 1970).

Key words: Dislocation nodes; dislocations-image series; dislocation-surface interactions; line tension of dislocations.

It is shown that a straight dislocation emerging at a planar free surface is acted upon by a force distributed according to the law $dF=\lambda^{-1}(-E \cot\theta+\partial E/\partial\theta)d\lambda$. Here θ is angle of inclination to surface. E is dislocation energy factor, and λ is distance from surface along the dislocation. The proof involves use of a slightly generalized version of the energy flow theorem for straight dislocations (Lothe, Phil. Mag. **15,** 9 (1967)). The above formula is the exact linear elasticity law corresponding to the usual approximate line tension

result. According to this law there are certain angles of incidence for which the forces vanish so that the dislocation can be straight. Similarly, when only elastic terms are considered, there are certain node orientations for which the forces on the branches vanish so that the branches can be truly straight (Indenbom and Dubnova, Sovj. Phys. (Solid State) 9, 915 (1967)). In this paper a discussion is given of how core energy terms may modify the results. It is concluded that also for nodes in the characteristic orientation for no elastic forces on the branches, some branch curvature will be present near the node.

Stability and some characteristics of uniformly moving dislocations, K. Malén, *SP317*, pp. 23-33 (Dec. 1970).

Key words: Anisotropic elasticity; Cerenkov waves; dislocation dynamics; dislocation stability.

The stability of uniformly moving dislocations has been studied in the case of elastic anisotropy using computer. The velocity for instability to occur for a screw dislocation in an isotropic medium is so high, 0.98 C_t, with C_t the transverse sound velocity, that it may well be unattainable. Inclusion of anisotropy gives the possibility of more reasonable instability velocities. Some data showing this for Fe, Li and Cr are given.

The stress field around a uniformly moving dislocation has been studied. Increasing the velocity of a dislocation corresponds to some extent to a change in the anisotropy of the crystal.

In uniform motion above the lowest velocity of sound in the direction of motion one can have associated with the moving dislocation 2, 4 or 6 Çerenkov waves, above the next sound velocity 4 or 6 and above the highest sound velocity 6 waves.

The formula developed earlier for the stress field around a uniformly moving planar dislocation loop can be generalized directly to three dimensions using the theorems of Indenbom and Orlov for the fields from three-dimensional sources using data for two-dimensional sources.

The generalization can also be made using the fact that the choice of cut surface is arbitrary.

The dislocation in a semi-infinite isotropic medium, D. J. Bacon and P. P. Groves, *SP317*, pp. 35-45 (Dec. 1970).

Key words: Dislocation loops; elasticity; finite bodies.

The displacement associated with an infinitesimal dislocation loop (displacement dipole) of arbitrary orientation in an isotropic, semi-infinite elastic medium has been obtained, and on integration this yields the displacement associated with a finite dislocation loop. The solution for the infinitesimal loop has been obtained by finding the relationship between point forces and displacement dipoles in an infinite medium, and using the same relations with Mindlin's solution for the point force in an elastic half-space. This approach leads to a rather simpler analysis than that of Steketee, and the expressions for the displacements of all the infinitesimal loops near a free surface are presented here for the first time. The solution is being used to study the stability of a prismatic dislocation loop on a glide prism of square cross-section near a free surface. Preliminary results are presented for the forces on the loop sides and changes in loop energy on rotation for the situation in which the Burgers vector is normal to the surface.

Theoretical considerations on the extension of 1/2⟨110⟩, {111} dislocations in isotropic fcc metals into Shockley partials, Doris Kuhlmann-Wilsdorf and T. R. Duncan, *SP317*, pp. 47-55 (Dec. 1970).

Key words: Dislocation geometry; Shockley partials; stacking faults.

The energy changes and equilibrium separations associated with the extension of 1/2 ⟨110⟩, {111} dislocations in fcc metals into Shockley partials have been calculated and were found considerably smaller than the previous corresponding values due to Seeger and Schöck. The new results may be shown to be credible on the basis of the following simple estimates:

The theoretical shear fracture strength of a crystal may be written as $\tau_{crit} = G/q$, with G the appropriate shear modulus, and the numerical parameter q near 30 for {111} planes in fcc metals. The resolved shear stress required to force the Shockley partials into coincidence at vanishing stacking fault energy, $(\tau_{eq})_{Max}$, must approach but cannot exceed τ_{crit} so that $(\tau_{eq})_{Max} \leqslant G/30$, i.e. much smaller than the value of $\sqrt{6}G/8\pi \simeq G/9$ previously assumed. Similarly, the stacking fault energy cannot exceed the value of $\gamma_{crit} = Ga/\sqrt{6}q$ with a the lattice constant, and the dislocation core energy must be in the order of $E_c \simeq 2r_0\,\gamma_{crit} \simeq 1/4E_D$ where E_D is the total dislocation energy, and the core radius, r_0, is taken to be that distance from the dislocation axis at which the resolved shear stress on the slip plane would become equal to τ_{crit} in linear elastic behavior. Lastly, D_0, the actual equilibrium separation between the partials must be considerably smaller than D_0^*, the separation calculated from linear elastic theory, as long as $D_0^* < 2r_0$. One finds easily that $D_0^* \leqslant 2r_0$ for $\gamma \geqslant \gamma_{crit}/6$ and $\gamma \geqslant \gamma_{crit}/10$ for edge and screw dislocations, respectively, depending somewhat on Poisson's ratio, so that only in silver will edge dislocations have an equilibrium separation a little larger than $2r_0$, but much less than $2r_0$ in the other common pure fcc metals. For $D_0 = 2r_0$, when the core energy is reduced by about 1/3 according to the rule of the square of the Burgers vectors but the elastic energy is virtually unaffected, and remembering that work $2r_0\gamma$ with $\gamma \simeq \gamma_{crit}/6$ must be done to spread out the stacking fault, the relative energy gain due to the extension of edge dislocations is simply estimated as $(\Delta E/E_D)\perp \simeq [1/3E_c/4E_c - 1/6\gamma_{crit}/4\gamma_{crit}] \simeq 4\%$ which may be compared to the calculated value of 4.6% in silver.

Screw dislocations in inhomogeneous solids, G. P. Sendeckyj, *SP317*, pp. 57-69 (Dec. 1970).

Key words: Dislocations-elasticity; dislocation surface interactions; finite elasticity; inhomogeneities.

The problem of screw dislocations interacting with free surfaces and inhomogeneities is reconsidered and a general method is presented for solving a large class of screw dislocation problems. The method is based on knowledge of certain general solutions in the theory of antiplane deformation of elastic solids. It can be shown that all the known screw dislocation solutions for solids undergoing antiplane deformation can be found by using this approach.

As an illustration of the method, three new solutions for screw dislocations near inhomogeneities are given. These are the screw dislocation near (1) an elastic elliptic cylindrical inclusion, (2) two circular cylindrical inclusions, and (3) a *curvilinear* cavity or rigid inclusion. The interaction energy between the dislocation and the inhomogeneities is also computed.

Subsonic, supersonic, and transonic dislocations moving on an interface separating two media of differing elastic properties, H. M. Berg, J. E. Bloom, H. Ishii, R. H. Marion, D. E. Pease, D.

T. Spreng, J. B. Vander Sande, and J. Weertman, *SP317*, pp. 71-82 (Dec. 1970).

Key words: Dislocation dynamics; interface dislocations; supersonic dislocation.

This paper examines the problem of a dislocation moving on an interface separating two isotropic elastic media that have differing elastic constants and densities. This problem has application to the phenomenon of diffusionless transformations. Solutions are found for moving screw dislocations, gliding edge dislocations, and climbing edge dislocations. It is assumed that the dislocation velocity lies in either the subsonic, the transonic, or the supersonic velocity region. We have generalized the analysis that was used in a study of the elastic displacements and stress field of subsonic, transonic, and supersonic dislocations moving in an ordinary elastic medium. The results given in the present paper are formally identical to those obtained in that simpler analysis.

Internal stress and the incompatibility problem in infinite anisotropic elasticity, J. A. Simmons and R. Bullough, *SP317*, pp. 89-124 (Dec. 1970).

Key words: Anisotropic elasticity; dislocations; Green's tensor; incompatibility; internal stress; source kernels; stress functions.

Using the language of integral projection operators, the linear elastic distortion field of an infinite anisotropic body is decomposed into its internal and external components. The kernel of the external projection operator is identified as the elastic field due to force dipoles while that of the internal field corresponds to internal distortion fields due to displacement dipoles.

By integration of the projection operator for the internal distortion field, an alternative description for internal distortion fields in terms of dislocations is given. The Mura-Willis formula as well as the distortion field due to a rational dislocation element (in the sense of Eshelby and Laub) for an anisotropic body are then obtained as integrals of the basic displacement dipole kernel for internal distortions.

Further integration of the displacement dipole kernel provides a description of the internal distortion field due to a rational incompatibility element. The general formula for the stress function due to an incompatibility distribution in a general infinite anisotropic body is then given and shown to reduce to the formulation of Kröner for isotropic bodies.

Finally, explicit methods to compute kernels for internal distortions due to incompatibilities are given and discussed.

Series representations of the elastic Green's tensor for cubic media, D. M. Barnett, *SP317*, pp. 125-134 (Dec. 1970).

Key words: Anisotropy; cubic materials; elasticity; Green's tensor.

Two representations for the cubic Green's tensor components as power series in the anisotropy factor $\omega = 1 - (c_{11} - c_{12})2c_{44}$ are developed, and first order corrections of anisotropy to the Green's tensor and to the interaction energy between two "mechanical" point defects are calculated. It is shown that the best successive approximation scheme is that which constructs the zeroth order (isotropic) approximation to the Green's tensor by identifying the Lamé constants λ and μ as $\lambda = c_{12}, \mu = c_{44}$.

Some problems involving linear dislocation arrays, N. Louat, *SP317*, pp. 135-146 (Dec. 1970).

Key words: Dislocation pileups; dislocations-elasticity; phase boundaries.

Muskhelishvili's inversion formulae for singular integral equations are shown to be special cases of a more general result which is then employed to deal with two types of problems. In the first we consider the distribution of dislocations in a double periodic array of screw pile-ups in an arbitrary stress field. The second type is concerned with screw pile-ups terminating at phase boundaries, again for arbitrary stress fields.

Some recent results on dislocation pileups, J. C. M. Li, *SP317*, pp. 147-150 (Dec. 1970).

Key words: Dislocation pileups; Moutier cycle; stress concentrations.

A few results intended to illustrate the usefulness of orthogonal polynomials and singular integral equations for the problem of dislocation pileups are described. A simple method of solving a few special integral equations is suggested. The usefulness of a Moutier cycle for the calculation of stress concentration is shown.

The behavior of an elastic solid containing distributions of free and fixed dislocations, E. Smith, *SP317*, pp. 151-162 (Dec. 1970).

Key words: Crack nucleation; dislocations-elasticity; internal stresses.

There are many situations in metal physics where the stresses acting on fixed dislocations have an important bearing on a physical phenomenon, and the paper derives a general expression relating these stresses when fixed edge dislocations are contained within an infinite elastic solid in which there are also free edge dislocations that occupy equilibrium positions.

Special cases are considered in detail, particular attention being given to the situation where all the dislocations are of the same type, the free ones having identical Burgers vectors b while there are two fixed dislocations with Burgers vectors pb and qb; all the dislocations lie in the same plane within an infinite solid. This is the most general model for which the stresses on each dislocation and also the equilibrium positions of the free dislocations may be determined analytically. It is indicated how the model degenerates into all the others that have been discussed analytically in terms of classic polynomial functions.

The results are briefly discussed in relation to the problem of cleavage crack nucleation in crystalline solids.

The elastic interaction between grain boundaries and screw dislocation pile-ups, M. O. Tucker, *SP317*, pp. 163-171 (Dec. 1970).

Key words: Anisotropic elasticity; dislocation pileups; dislocations-elasticity; grain boundaries.

The configuration of an array of parallel infinitive straight screw dislocations, in equilibrium under a constant applied stress, and piled-up on a plane inclined to a grain boundary at an arbitrary angle is considered. The model used for the grain boundary is the plane interface between two elastically anisotropic half-spaces welded together. Using this approximation of a continuous distribution of infintesimal dislocations the integral equation expressing the equilibrium conditions is solved using a Wiener-Hopf technique and approximate expressions are presented for the stresses near to the tip of the array when the dislocations are parallel to orthotropic symmetry axes in each half-crystal.

One-electron theories of cohesion on ion-pair potentials in metals, N. W. Ashcroft, *SP317*, pp. 179-200 (Dec. 1970).

Key words: Band structure; cohesion; core-core interactions; electron density; inter-atomie; one-electron potentials; pseudopotentials.

The single particle picture of cohesion in metals is briefly reviewed in the light of modern knowledge of their band structures. Periodic components in the electron density distributions (intimately connected with the same band structures) are important in the determination of the effective potential between ions.

In simple metals, defined to be those with tightly bound core states, the net binding of the metallic state is basically a remnant of a competition between kinetic (Pauli principle) and Madelung energies of ostensibly free conduction electrons. Various corrections (for correlation, for exchange, etc.) must be included, and the Madelung energy (which is normally appropriate to a uniform electron gas in a Coulomb lattice of point ions) can be modified as necessary for departures from Coulomb's law. Terms in the total energy also arise from periodic variations in conduction electron density; for perfect lattices these are naturally dependent on the ionic arrangement and will vary in importance from crystal structure to crystal structure. Electronic density variations arising from disorder (e.g. distributions of defects) also introduce corrections into total energy.

The structurally dependent terms in the total energy can be evaluated to second order in the pseudopotential: to this same order the *total* energy may be written as a sum over pair potentials between ions whose form is quite straight forward to evaluate. As with many inter-atomic potentials, the ion-ion potentials demonstrate "hard-core" effects at small separation, and are rather weak at large distances.

Extending the simple theory to transition metals or metals exhibiting additional band structure more akin to itinerant narrow-band behavior, can be carried through by incorporating Born-Mayer interactions between tight binding atomic states. This procedure is, of course, only valid in situations where the Block method itself is applicable. While the core-core exchange term approximated by the Born-Mayer interaction is quite small in the simple metals it is appreciable for metals like Cu, Ag and Au, and in fact is basically responsible for fixing the equilibrium density. Its addition to the otherwise "simple-metal" like ion pair potentials modifies the behavior at short range.

Localized vibration modes associated with screw dislocations, A. A. Maradudin, *SP317*, pp. 205-217 (Dec. 1970).

Key words: Dislocation-phonon interactions; dispersion relations; lattice of dynamics; localized modes.

The dispersion relation for the one-dimensional continuum of localized modes associated with a screw dislocation is obtained in the long wavelength limit, as a function of the wave vector parallel to the dislocation line. The result has the form $\omega^2(q)=s^2q^2-\omega_0^2\exp(-\text{const.}/q)$ where s is the speed of sound for transverse acoustic waves, and ω_0 is a typical Brillouin zone boundary frequency.

The method of lattice statics, J. W. Flocken and J. R. Hardy, *SP317*, pp. 219-245 (Dec. 1970).

Key words: Computer simulation; Kansaki method; lattice statics; point defects; Schottky pairs.

The formalism of the method of lattice statics for treating the lattice distortions and the formation and interaction energies associated with a defect in a crystal is presented in detail. This approach is based on the Fourier transformation of the set of direct space equilibrium equations to reciprocal space. This results in a set of decoupled equations which can be explicitly solved for the Fourier amplitudes of the displacement field which can then be found by Fourier inversion. A similar approach is used to obtain Fourier transformed expressions for the relaxation and interaction energies associated with the defect.

The solution of the equations of lattice statics for the Fourier amplitudes in the limit of small wave vectors gives expressions for the displacement field identical to those obtained from the theory of continuum elasticity.

Results are presented of recent applications of the method of lattice statics to find the formation energies of Schottky pairs in certain alkali halides. Strain field displacements, relaxation energies and interaction energies associated with vacancies in Na and K are given.

Lattice statics in its asymptotic form has been used to find the displacement field far from cubic point defects and double force defects in a number of metals. Displacement profiles about vacancies in Na and K and about a double force defect in Cu are shown. A comparison of the exact lattice statics results to asymptotic results along a ⟨111⟩ direction in K shows that the elastic limit is only attained at about the 19th or 20th neighbor position from the defect.

Effect of zero-point motion on Peierls stress, H. Suzuki, *SP317*, pp. 253-272 (Dec. 1970).

Key words: Anharmonicity; dislocations in lattices; Peierls stress; zero point motion.

Calculations of the Peierls stress hitherto made are criticized and the following conclusions are obtained. The significant difference in Peierls stress between different materials arises mainly from the difference in crystal structures. The Peierls stress is necessarily high in a rectangular lattice where atoms just above and below the slip plane face each other, while in the lattices where the atoms face alternately along the slip plane it is of the order of one percent of that in the rectangular lattice. The Peierls stress in the body-centered cubic crystal is, however, rather high for a screw dislocation owing to the screw structure of this crystal with the axes parallel to [111] direction. The calculated Peierls stresses are several times of those expected from experiments. The zero-point motion decreases the calculated Peierls stress through two mechanisms. The one is the difference in frequency spectrum of a dislocation line at the bottom of the potential valley and at the top of the potential hill. The other is due to the change in spring constants of atom pairs around the dislocation through anharmonicity.

Point defects and dislocations in copper, A. Englert, H. Tompa, and R. Bullough, *SP317*, pp. 273-283 (Dec. 1970).

Key words: Computer simulation; copper; dislocation structure; pair-potential; point defects.

A new pair potential for copper has been constructed from a set of ten interpolated cubic polynomials. The form of the potential is such that at short range it agrees with the usual Born-Mayer repulsive potential and is in satisfactory agreement with the available phonon dispersion data and the observed stacking fault energy and vacancy formation energy for copper. The potential has been used to study the atomic configuration associated with various point and line defects in copper. In particular, because of its fit to the stacking fault energy, it provides a consistent result for the degree and nature of the dissociation to be expected for an edge dislocation in copper.

Atomistic calculations of dislocations in solid krypton, M. Doyama and R. M. J. Cotterill, *SP317*, pp. 285-289 (Dec. 1970).

Key words: Atomic calculation; interatomic potential; krypton.

The elastic continuum theory treatment usually fails near the core of dislocations. Atomic calculations of edge and screw dislocations in solid krypton were carried out using a pairwise potential. In rare gases, the electron redistribution of the electron density is small, thus, this method is useful in studying the properties of dislocation cores.

A lattice theory model for Peierls-energy calculations, A. Hölzler and R. Siems, *SP317,* pp. 291-298 (Dec. 1970).

Key words: Computer simulation; Green's tensors; interatomic potential; lattice studies; Peierl's energy; screw dislocation.

A lattice theory model for a screw dislocation is discussed which is similar to that of Maradudin. For the forces between neighbouring rows of atoms, however, a sinusoidal, not a linear, dependence of their relative displacements is assumed throughout the whole lattice. The displacements are expanded about the elastic theory values. The conditions of equilibrium then yield a system of linear equations for the deviations of the displacements from the elastic theory values, which is solved by an iteration procedure making use of Green's Function for a plane square lattice. For a number of points in the vicinity of the source point and for points in certain symmetry directions simple exact analytical expressions for the latter are derived, for points at larger distances an asymptotic expansion is given. The displacements thus obtained are then used to calculate the energies of the dislocation at the position of minimum energy and at the saddle point and their difference, the Peierls energy, by direct summation of the interaction energies of neighbouring pairs of atoms.

The interaction between a screw dislocation and carbon in body-centered cubic iron according to an atomic model, R. Chang, *SP317,* pp. 299-303 (Dec. 1970).

Key words: Carbon in iron; computer simulation; dislocation-interstitial interaction; interatomic potentials; lattice defects.

The interaction energy between carbon and a screw dislocation in body-centered cubic iron near the core regions of the dislocation was calculated atomistically using a pairwise interatomic potential matching the elastic properties of the material. In order to avoid the use of the iron-carbon potential, it was assumed that the iron-carbon octahedron of the Johnson configuration (2 iron atoms separated by 1.225 a_0 in the [100] direction and 4 iron atoms separated by 0.958 a_0 in the (100) plane, a_0 being the lattice parameter) remains undistorted whether it is present in a perfect or a defective lattice. Our first calculations yield, depending on site location, binding energies varying from 0.04 to 0.55 eV.

The structure of the ⟨111⟩ screw dislocation in iron, P. C. Gehlen, G. T. Hahn, and A. R. Rosenfield, *SP317,* pp. 305–308 (Dec. 1970).

Key words: Computer simulation; dislocation core structure; interatomic potentials; iron.

The concept of a dissociated $a/2\langle 111\rangle$ screw dislocation has been invoked to explain the slip behavior in b.c.c. materials and particularly the asymmetry of the critical resolved shear stress. No direct experimental evidence of dissociation has been obtained, but the idea has received some albeit conflicting support from discrete lattice calculations of the atomic positions in the core. Chang, using isotropic elasticity for α-iron, found that the dislocation core has three very narrow intrinsic faults. These three faults are symmetric with respect to the screw axis. Bullough and Perrin, on the other hand, found that the screw is split with faults on two {112} planes belonging to the zone of the screw axis. The misfit is spread over a distance of about $3b$. On the third {112} plane no splitting was found to occur.

In view of these discrepancies, the calculations were repeated for anisotropic and isotropic elastic boundary conditions and with different interatomic potentials. Excellent agreement was found with Chang's configuration even though a volume expansion term was added to the displacements associated with the dislocation.

It was shown that the final configuration is strongly dependent on the position of the dislocation line with respect to the lattice and at least two metastable positions were found. Even though the atomic arrangement is quite different, their energy is not more than 0.1 eV larger than the energy of the stable one.

Using the Johnson potential unmodified for long-range electronic effects, the dislocation was found to have the following characteristics: core radius, 4-5.5 A; core energy, 0.20-0.25 eV per atomic plane; and an effective hole radius of 1.35 Å.

It was shown that the final configurations are rather insensitive to the model size and to the boundary conditions used.

Eigenfrequencies in a dislocated crystal, T. Ninomiya, *SP317,* pp. 315-357 (Dec. 1970).

Key words: Dislocation-phonon interactions; dislocation vibration; internal friction; localized modes.

Dynamical theories of dislocation vibration and interactions with phonons are surveyed. Eigenfrequencies of lattice vibrations in a crystal containing a straight dislocation are calculated by using Lagrangian formalism. It is found that there is one eigenfrequency of dislocation vibration (wave number κ) in each of the intervals of the normal mode frequencies of $k_z = \kappa$ in a perfect lattice. It is also found that there is a band of localized dislocation vibration below the phonon band. The mean squared amplitude of the dislocation vibration is determined by the localized mode for an edge dislocation and by the resonance modes for a screw dislocation. Phonon scattering by the fluttering mechanism is next treated by using the above results and the conditions of resonance scattering is given. Finally, the effect of the Peierls potential and the vibration of a dislocation dipole are discussed. In the Appendices the problem of quantization of dislocation vibration and the extension of the above theories to a case of translational motion are briefly described.

Phonon scattering by dislocations and its influence on the lattice thermal conductivity and on the dislocation mobility at low temperatures, P. P. Gruner, *SP317,* pp. 363-389 (Dec. 1970).

Key words: Dislocation mobility; dislocation-phonon interactions; nonlinear elasticity; phonons; thermal conductivity.

On account of the large strains associated with dislocations, the superposition principle is violated. The resulting scattering of phonons limits the lattice thermal conductivity and leads to a friction force which acts on moving dislocations. The phonon-dislocation interaction is treated with nonlinear continuum theory. Terms up to the third order in the strains are retained in the Taylor expansion of the elastic energy density. These third order terms contain the phonon-dislocation interaction and the normal three-phonon interactions. In the case of thermal conductivity, the transport problem is solved with the variational method which leads to a system of linear equations for the phonon occupation numbers. The coefficients of this system of equations contain all the information on the scattering mechanisms. The

influence on the thermal conductivity of special dislocation configurations such as piled-up dislocations and dislocation dipoles will be discussed.

It will be shown that the friction force which acts on moving dislocations on account of the anharmonicity can be obtained from quantities that are known from the calculations of the phonon conductivity. A one to one correspondence between friction force and thermal resistance exists, however, only if the dislocation velocity is small compared with the sound velocity and if all parts of the dislocation move with the same velocity.

Phonon scattering by Cottrell atmospheres, P. G. Klemens, *SP317*, pp. 391-394 (Dec. 1970).

Key words: Cottrell atmospheres; mechanical properties; phonon scattering; thermal resistivity.

The formation of Cottrell atmospheres can change the scattering of phonons by dislocations and in some cases substantially enhance the lattice thermal resistivity due to dislocations. The strength of the atmospheres can be changed by annealing. This changes thermal conductivity values at high temperatures first, since diffusion through shorter distances is involved. The diffusion coefficient can be determined by means of such annealing studies.

Dragging forces on moving defects by strain-field phonon scattering, A. Seeger and H. Engelke, *SP317*, pp. 397-401 (Dec. 1970).

Key words: Dislocation drag; dislocation-phonon interactions; electroresistivity; kink motion; phonon scattering.

An expression for the dragging force on a uniformly moving defect by scattering of phonons at its strain-field has been derived using nonlinear elasticity theory. The quantization procedures and the formulation of the master equation for the phonon distribution follow the techniques developed in the theory of heat conductivity. Numerical calculations have been performed for kinks in screw dislocations in copper. A comparison with numerical results obtained in the theory of heat conductivity shows quite good agreement. The formalism developed should prove useful also for calculations of the electron drag on dislocations in metals.

Thermal energy trapping by moving dislocations, J. H. Weiner, *SP317*, pp. 403-414 (Dec. 1970).

Key words: Computer simulation; dislocation-phonon interaction; Frenkel-Kontorowa model.

The steady motion of a dislocation along a piece-wise harmonic Frenkel-Kontorowa model is considered For suitable model parameters there is one localized mode associated with either the stable or unstable dislocation configuration and the remaining modes are nonlocalized or extended. Because of the piece-wise harmonic character of the model, the set of normal modes of the system changes at discrete instants of time, referred to as transition times, as the dislocation moves along the chain. In particular, the localized modes must move along with the dislocation position and we refer to the localized mode momentum and energy as the dislocation momentum and energy respectively. The particle momentum and energy due to the sum of the extended modes is termed thermal.

At the transition times, it is necessary to expand atomic velocities in terms of the new set of modes appropriate to the forthcoming state of the crystal. It is found that a coordination effect exists between the transition times and the thermal motion such that on the average over many transitions, thermal momentum in the direction of the dislocation motion is transferred to the dislocation momentum.

Dislocation resonance, J. A. Garber and A. V. Granato, *SP317*, pp. 419-421 (Dec. 1970).

Key words: Dislocation damping; dislocation resonance; internal friction.

At low temperatures in insulators and superconductors, only reradiation of elastic waves should limit dislocation resonance. This effect has been calculated using Eshelby's expression for the reradiation. It is found that the resonance is very sharp, and still persists even when a random distribution of dislocation segment lengths is assumed.

Dislocation radiation, R. O. Schwenker and A. V. Granato, *SP317*, pp. 423-426 (Dec. 1970).

Key words: Dislocation radiation; dispersion relations; internal friction.

Thin walls of mobile dislocations have been produced. These can be excited to emit macroscopic plane sound waves. Calculations have been made to predict the properties of the reradiated waves on the basis of a vibrating string model which neglects dislocation interactions. Measurements of the relative modulus change $\Delta G/G$ and the decrement Δ (real and imaginary part of the response) as a function of frequency permit a check of the Kramers-Kronig dispersion relations. In addition, measurements of the amplitude of the reradiated wave provide another check since the amplitude is proportional to $[(\Delta G/G)^2 + (\Delta/\pi)^2]^{1/2}$.

The anharmonic properties of vibrating dislocations, C. Elbaum and A. Hikata, *SP317*, pp. 427-445 (Dec. 1970).

Key words: Anharmonic properties; dislocation dynamics; ultrasonics.

The anharmonic properties of vibrating dislocations are discussed in terms of the nonlinear stress-strain relation and of the higher harmonics of an ultrasonic wave generated when an initially sinusoidal wave propagates in a solid containing (mobile) dislocations. The treatment takes account of both lattice and dislocation contributions to the anharmonic behavior of the solid.

Estimates of the amplitude of the harmonics (these estimates have been confirmed experimentally) indicate that the lattice and dislocation components are comparable for the second harmonic and that the dislocation component is much larger than the lattice component for the third harmonic. Therefore, by investigating the third harmonic, it is possible to obtain detailed information on dislocation dynamics, without the complications of the lattice contribution.

A source of dissipation that produces an internal friction independent of the frequency, W. P. Mason, *SP317*, pp. 447-458 (Dec. 1970).

Key words: Internal friction; kink motion; Peierl's stress.

Many measurements of the internal friction of metals and other materials such as the earth's crust show that there is a component at low frequencies which produces a value independent of the frequency. It has been shown that this component is associated with dislocation motion.

Using a model for which dislocation motion results from the motion of kinks, it is shown that such a loss can be associated with the energy dissipated when kinks cross Peierls barriers. Theoretical calculations have shown that the energy dissipated in mechanical vibrations requires a dissipative force equal to from 0.01 to 0.1 of the Peierls stress to replace the energy lost. At the low stresses used in interna

friction measurements, it requires a thermal activation to cause motions of the kinks. The lag of the motion behind the applied stress produces a drag coefficient B proportional to the temperature. The energy due to kink dissipation produces an internal friction to modulus change ratio β, equal to the ratio of the dynamic to the static kink stress. Measurements in copper and in the alloy Ti-6Al-4V indicate that this ratio is about 0.03, in agreement with calculations.

The meaning of dislocations in crystalline interfaces, W. Bollmann, *SP317*, pp. 465-477 (Dec. 1970).

Key words: Dislocations; grain boundaries; interfaces; twinning.

The extension of the dislocation concept to arbitrary crystalline interfaces is discussed. It is shown that invariance and continuity of the Burgers vector can be conserved and that in high angle boundaries the function of the standard or primary dislocation is the delimitation of ranges of coordination between the two crystals. In certain relative orientations where the superposition of the two crystals forms a highly periodic pattern (which is energetically favorable such that the crystal tends to conserve it) a slight deviation from that optimum pattern is corrected by a network of secondary dislocations. There is complete balance between the Burgers vectors of primary as well as secondary dislocations.

Structural and elastic properties of zonal twin dislocations in anisotropic crystals, M. H. Yoo and B. T. M. Loh, *SP317*, pp. 479-493 (Dec. 1970).

Key words: Dislocation geometry; twinning; zonal dislocations.

A descriptive definition of zonal twin dislocations for compound twin systems is given based on the well established rational crystallographic elements. Geometric characteristics of zonal twin dislocations in double lattice structures are thoroughly discussed. Equilibrium shapes of an incoherent twin boundary have been analyzed by using the anisotropic elastic properties of edge dislocations. Short-ranged structural properties of zonal twin dislocations are discussed based on a Peierls-Nabarro model. It is found that the "anisotropic parameter," $K_e S_{66}$, correctly predicts the active mode of crystallographically nonequivalent conjugate twin systems.

Non-planar dissociations of dislocations, S. Mendelson, *SP317*, pp. 495-529 (Dec. 1970).

Key words: Dislocation dissociation; lattice shuffling; partial dislocations; twinning; zonal dislocations.

Non-planar dissociations of dislocations are studied in hcp, fcc, bcc, diamond lattice, tetragonal and orthorhombic crystal structures. The geometric and energetic conditions are shown to be favorable for various dissociations in each crystal structure. A general equation is formulated for dissociations into partials which are glissile on various twin planes of a common zone. The Burgers vector of the twinning dislocations are expressed in terms of orthogonal unit vectors which lie in the "plane of shear" of the twin mode. The twinning dislocations are generally of the "zonal" type, chosen to be consistent with minimum shear-strain and simple atomic shuffling criteria for twinning, and applied in derivations of the twinning elements and shear-strains for various twin modes. The sign of the shear-strain determines the "stress sense" characteristics for dislocation resistance and twinning and are shown to be consistent with behavior in various hcp and bcc metals. The maximum repulsive force on the twinning partials γ_m is computed using anisotropic elasticity, and compared with evaluations of twin lamella energies γ. In many cases it is found that $\gamma_m/\gamma > 1$, leading to an increase in dislocation resistance, locking, or twinning at lower temperatures. In the cases where $0 < \gamma_m/\gamma < 1$ the partialized dislocation model reduces to the "modified pseudo-Peierls-Nabarro model" for dislocation resistance.

Among various effects, the dissociations account for all twin modes in hcp metals and for the extreme difference in the flow behavior of Cd and Zn on one hand and Ti and Zr on the other. The stress dependent activation energies for motion of dissociated 60° dislocations in germanium are computed and compare favorably with the data of Kabler. A "lock" for kinks on 60° dislocations is described which can account for dragging points in the model of Celli et al.

Propagation of glide through internal boundaries, M. J. Marcinkowski, *SP317*, pp. 531-545 (Dec. 1970).

Key words: Boundary dislocations; glide propagation; grain boundaries; virtual dislocations.

It has been shown that when an internal boundary such as a grain boundary is cut by a crystal glide dislocation, a disturbance is left at the boundary. This disturbance closely resembles that about a crystal dislocation with the exception that (a) there is no extra half plane associated with the dislocation and (b) the Burgers vector associated with this disturbance is a variable which depends on the nature of the internal boundary. These boundary dislocations have been termed virtual dislocations.

The nature of the virtual boundary dislocations has been treated in detail for the symmetrical tilt boundary. Both homogeneous and heterogeneous type glide across these boundaries have in turn been applied to grain boundary crack formation and propagation, grain boundary rotation, preferred orientation, etc.

Kinks, vacancies, and screw dislocations, R. M. Thomson, *SP317*, pp. 563-576 (Dec. 1970).

Key words: Dislocation geometry; dislocations; kinks; pipe diffusion; vacancies in dislocations.

A vacancy on a nonsplit pure screw dislocation can dissociate into a set of kinks. This dissociation is demonstrated geometrically for the NaCl lattice, showing that no geometrical constraints are violated by the dissociation. The kinks thus generated also splinter and spread the charge of the vacancy along the line. The effective vacancy association energy on the line is thus much higher than has been supposed hitherto, and is partly due to the delocalization of the charge singularity of the point defect and partly due to the delocalization of elastic singularity. When the Peierls energy is low, the vacancy will always dissociate, while if it is high, the dissociation will occur only when the total kink energy is less than the vacancy energy. Vacancy contributions to both climb and pipe diffusion are discussed in terms of the kink dissociation process. Results are that interstitial pipe diffusion is entirely symmetric to vacancy pipe diffusion, no motion energy is needed, and the formation energy for diffusion is related to the Peierls energy.

Topological restriction on the distribution of defects in surface crystals and possible biophysical application, W. F. Harris, *SP317*, pp. 579-592 (Dec. 1970).

Key words: Dislocations in biophysics; protein structure; surface crystals; surface dislocations.

Many thin biological structures such as some plasma membranes and virus capsids appear to be made up of units packed in two-dimensional lattices. Such structures are termed *surface crystals*. Dislocations and disclinations are observable in some of these crystals. The perfect surface crystal is described by a *pair* of basis vectors and the conventional crystal by a *triplet* of basis vectors; both are re-

garded as embedded in three-dimensional space. This difference allows the existence of defects which have no counterpart in conventional crystals. The various defects are classified as local or global, intrinsic or extrinsic. Surface crystals that form closed surfaces are considered and it is shown that the sum of the rotations of intrinsic (screw) disclinations in them must equal $2\pi X$ where X is the Euler-Poincaré characteristic of the surface. The biophysical consequences are discussed briefly.

Disclinations in surfaces, F. R. N. Nabarro, *SP317*, pp. 593-606 (Dec. 1970).

Key words: Crystal surface imperfections; disclinations; screw disclinations.

The screw disclination is essentially a 2-dimensional object. Screw disclinations provide a convenient classification of star polygons. By considering the disclinations in vector fields lying on surfaces, it is possible to relate Euler's theorem for polyhedra inscribed on a sphere (faces − edges + corners = 2) to the fixed-point theorem for continuously-varying small displacements of points on a sphere. The changes in the Euler characteristic produced by the addition of holes, handles and cross caps are related to the disclinations which these singularities introduce into vector fields lying on the surface. These disclinations may be localized into the neighbourhood of their corresponding singularities.

Application of dislocation theory to liquid crystals, J. Friedel and M. Kléman, *SP317*, pp. 607-636 (Dec. 1970).

Key words: Cholesteric crystals; faulted ribbon; liquid crystals; nematic crystals; smectic crystals.

After an introduction which recalls some of the properties of liquid crystals, a general theory of dislocations in a mesomorphic medium is outlined. On the basis of their symmetry properties, and of viscosity relaxation, it is first shown that perfect disclinations in nematic crystals may take any shape, are restricted to straight lines in smectic crystals, and that both types exist in cholesteric crystals, where there are two possible axes of rotation. The second part is specialized to the case of cholesteric crystals for which a mechanism of pairing of dislocations is proposed which allows a multiple disclination to take any shape, at the expense of a small increase of energy in the faulted ribbon.

Nonmetric connexions, quasidislocations and quasidisclinations. A contribution to the theory of nonmechanical stresses in crystals, K. H. Anthony, *SP317*, pp. 637-649 (Dec. 1970).

Key words: Affine connexions; continuum mechanics; curvature tensor; disclination; internal stresses; quasidisclination.

Nonmechanical stresses produced, for instance, by a temperature gradient or by an internal magnetic field are related to an affine lattice connexion, which is nonmetric with respect to the elastic metric. The covariant derivative of the elastic metric with respect to the lattice connexion is regarded as source-function for this kind of internal stresses. It may easily be determined from experimental data. The calculation of mechanical stresses is based on this quantity.

Instead of describing nonmechanical stresses by a nonmetric lattice connexion we alternatively may use an elastic connexion which is metric with respect to the elastic metric. In the elastic connexion are involved the tensors of quasiplastic torsion and of quasidisclination-density, which are regarded as source functions of nonmechanical stresses. Both tensors are intimately connected. They are a natural generalization of the quasidislocation tensor of the linear theory of nonmechanical stresses.

From the theory of quasidisclinations we obtain the following statement: In general, nonmechanical stresses cannot be eliminated solely by a dislocation movement. An additional distribution of crystal disclinations is necessary.

Linear theory of static disclinations, R. deWit, *SP317*, pp. 651-673 (Dec. 1970).

Key words: Burgers vector; compatibility; continuum; contortion; Cosserat; couple-stress; defect; deformation; disclination; dislocation; dualism; elasticity; incompatibility; motor calculus; plasticity.

A brief review of compatible and incompatible elasticity theory is given. It is shown how dislocation theory was developed from classical compatible elasticity. Then disclination theory is developed from dislocation theory in an analogous way. The disclination and dislocation density tensors are defined from the plastic deformation. The total deformation satisfies the classical condition of compatibility. By combining these two concepts the geometric basic laws or field equations are found, which relate the elastic deformation to the defect content. The contortion or Nye curvature tensor is found to be a useful equivalent for the dislocation density. Weingarten's theorem motivates the generalization of the Burgers vector and the definition of the analogous rotation vector of disclinations. Finally the dualism between the geometry of disclination theory and the statics of couple-stress theory, as well as the relation of disclination theory to "motor calculus" are pointed out.

Introduction to the panel discussion "intrinsic properties of dislocations," J. P. Hirth, *SP317*, pp. 683-685 (Dec. 1970).

The problem of non-locality in the mechanics of solids: review on present status, E. Kröner, *SP317*, pp. 729-736 (Dec. 1970).

Key words: Dilatation centers; lattice statics; non-local theories; solid mechanics; wave propagation.

The concept of non-locality, in particular with reference to the mechanics of solids, is discussed. A brief report is given on the derivation of the non-local theory of elasticity from atomic lattice theory. In addition some simple solutions of this theory, concerning the interaction of dilatation centers and wave propagation, are quoted. A generalization of the theory which would include dislocations is indicated.

Non-local theory of elasticity for a finite inhomogeneous medium—a derivation from lattice theory, E. Kröner and B. K. Datta, *SP317*, pp. 737-746 (Dec. 1970).

Key words: Green's tensor; Hooke's elasticity; non-local elasticity; solid mechanics.

In the linear theory of non-local elasticity the strain energy can be written as a double volume integral summing up the interactions of pairs of mass elements. The properties of the material, in this case, are described by a two-point-tensor function $c_{ijkl}(\mathbf{r},\mathbf{r}')$. It is found that for finite bodies $c_{ijkl}(\mathbf{r},\mathbf{r}')$ does not have the symmetries of the (Hooke's) elasticity tensor C_{ijkl} of the local theory. However, the symmetries of this tensor function are sufficient to exclude the rotations from the strain energy expression. It is shown that with the help of the elastic Green's function one can express $c_{ijkl}(\mathbf{r},\mathbf{r}')$ in terms of force constants of the lattice. It is also shown that an infinite homogeneous body is not a suitable model either for the non-local or for the local theory, because in this case $c_{ijkl}(\mathbf{r},\mathbf{r}')$ as well as C_{ijkl} obey the Cauchy relations.

On problems of the non-local theory of elasticity, I. A. Kunin and A. M. Waisman, *SP317*, pp. 747-759 (Dec. 1970).

Key words: Green's tensor; non-local elasticity; solid mechanics; surface waves.

The paper contains new results concerning the linear theory of an elastic medium with non-local interactions:

I. *The structure of the general solution of the equations of motion.* The dependence of the general solution on the distribution of energy operator zeroes. Specific effects of the non-locality: new types of damped and undamped waves, the existence of a maximum frequency for the latter ones. the space dispersion. The Green's function.

II. *Approximate models.* Two types of approximate models: the long-wave approximations and the first zeroes approximations. Domains of their applicability.

III. *Boundary value problems.* The replacing of the boundary by a boundary layer of width of the interaction radius. Generalized Green's formula. Fundamental boundary value problems, their correct formulation for first zeroes approximations. The comparison with couple-stress theories. Examples of exact and approximate solutions. The existence of new types of surface waves different from Rayleigh waves.

A non-Riemannian construction of variational criteria for plastic manifolds with special reference to the theory of yielding, K. Kondo, *SP317*, pp. 761-784 (Dec. 1970).

Key words: Continuum mechanics; non-Riemannian theories; plasticity; yielding.

The variational formalism is viewed not as an independent assumption but as a natural consequence following from a more fundamental penetration into the recognition of nature and this is shown in regard to the static aspects of plasticity. The energy is defined as the necessary quantity for the geometrical construction. With the Riemannian and non-Riemannian picture, a bridge is sought between the theory of yielding and the theory of dislocations, as also between the theory of dual yielding and theory of couple stresses. The standpoint of the theory of yielding and dual yielding is explained constitutively with a statistical construction to reconfirm the formulae which have been proposed. The meaning of the plastic constants involved in the theory is clarified by the construction.

Derivation of a continuum theory of dislocations on the basis of an estimative analysis of crystal lattices, M. Mişicu, *SP317*, pp. 785-816 (Dec. 1970).

Key words: Continuum mechanics; dislocation field theory; statistical methods.

Starting from the non-primitive crystal lattice model, a continuum theory is derived by means of an interpolation procedure which takes into account the variability of kinematic and dynamic fields. The non-holonomy of the fields of displacements, energy and entropy is considered in order to elaborate the analysis of dislocation and irreversible effects.

The elastic generalized Cosserat continuum with incompatible strains, R. Stojanović, *SP317*, pp. 817-829 (Dec. 1970).

Key words: Continuum mechanics; Cosserat continua; dislocation field theory; oriented media.

Considered is a continuum with deformable directors. Dislocations are regarded as sources of incompatibilities and internal strains. Established are the relations between the dislocation density tensor and the gradients of directors. The conservation law for dislocations (i.e. the law that the dislocation lines cannot end inside a body) appears as the integrability condition for the dislocation density – gradients of directors relation. In a linearly connected space L_3 in which the directors of a dislocated medium represent fields of absolutely parallel vectors the equality of the dislocation density tensor with the torsion tensor of the space L_3 follows as an immediate consequence. It is also proved that the geometry of L_3 is equivalent to the geometry of the linearly connected space L_3 which is defined in terms of the distorsions, introduced in the theories based on the non-oriented continuum models. From the principle of virtual work are derived the general (non-linear) relations for stress and hyperstress. The stress tensor is not symmetric. In the appendix are presented the modified divergence theorem and the expressions for the variations of the gradients of directors in the absence of a displacement field, i.e., in the case when the compatibility conditions for the strain tensor are not satisfied.

A dynamic theory of dislocations and its applications to the theory of the elastic-plastic continuum, C. Teodosiu, *SP317*, pp. 837-876 (Dec. 1970).

Key words: Anisotropic elasticity; anisotropic plasticity dislocations; constitutive relations; dislocation dynamics; non-linear elasticity.

The starting point of this study is a paper by Kröner (J. Math. Phys. **42**, p. 27, 1963), who proposed the replacement of the loading history variables in the yield criterion and in the work-hardening equation by state variables, such as the dislocation density and the density of dislocation loops.

The first part of the work summarizes the formulation recently given by the author for the dynamic non-linear theory of dislocations in anisotropic media. The relations connecting the continuum kinematic quantities to the discrete dislocation arrangement and to the dislocation velocities are emphasized.

To construct a theory of the elasto-plasticity, the system of kinematic equations is completed by postulating a yield condition and a work-hardening equation, which contain as independent variables the stress, the dislocation density, the density of dislocation loops, and the temperature.

Making constitutive assumptions for the free energy, the specific entropy, and the heat conduction vector, and using the principle of material indifference and the thermodynamical restrictions, a definite theory of the elastic-plastic continuum is obtained.

Non-linear dynamic problems for anisotropic elastic bodies in the continuum theory of dislocations, C. Teodosiu and A. Seeger, *SP317*, pp. 877-905 (Dec. 1970).

Key words: Anisotropic elasticity; dislocation dynamics; dislocation; elasticity; non-linear elasticity.

The non-linear continuum theory of dislocations has been used to solve a number of problems for isotropic materials, including the determination of stresses produced by dislocations, the scattering of elastic waves by straight dislocations and kinks, and the small-angle scattering of x-rays by dislocation lines and rings. For the application of these results it is necessary to know the elastic constants of third or higher order entering the constitutive equations. Third-order elastic constants have recently become available for a large class of single crystals with an accuracy that exceeds considerably the earlier polycrystalline data. It appears therefore desirable to develop a formulation of the theory that may be applied to anisotropic materials.

The present work aims at developing approximate methods for solving non-linear problems such as the determination of the strains produced by stationary or uniformly moving dislocations in anisotropic media and of their effects on a superimposed infinitesimal motion.

The non-linear problems are solved by reduction to a series of linear problems using expansions in terms of small parameters. Three such parameters appear naturally: the magnitude of the distortion produced by dislocations, the magnitude of the deformation gradient of the superimposed motion, and the ratio between the dislocation and sound velocities. To obtain definite approximation algorithms, hypotheses concerning the relative order of magnitude of these three parameters are introduced.

On the thermodynamics of inhomogeneous bodies, C. C. Wang, *SP317*, pp. 907-924 (Dec. 1970).

Key words: Constitutive relations; continuum mechanics; dislocations; inhomogeneous elastic bodies.

This paper concerns the thermodynamics of inhomogeneous elastic bodies. I adopt the constitutive equations for thermoelastic materials given by Coleman & Noll (1963) and develop a theory for bodies made up of such materials. The general scheme of this theory is based on my paper on Generalized Simple Bodies (1969). The main result is the explicit field equations for the deformation and the temperature on a thermoelastic body.

Elastic-plastic plane bending of a single crystal, C. S. Hartley and M. A. Eisenberg, *SP317*, pp. 925-941 (Dec. 1970).

Key words: Dislocation distributions; mechanical properties; plane blending.

The elastic-plastic bending of a single crystal beam which deforms by single slip on a plane containing the axis of bending and in a direction normal to the axis of bending is analyzed. Both continuum plasticity and dislocation approaches are used to obtain stresses and/or displacements in the elastic and plastic regions. The relation between the applied bending moment and the curvature of the neutral axis is also obtained. The approaches are compared and correspondences between the two theories are discussed.

Generalized stress and non-Riemannian geometry, S. I. Ben-Abraham, *SP317*, pp. 943-962 (Dec. 1970).

Key words: Affine connection; continuum mechanics; non-Riemannian geometry; stress.

The general non-Riemannian approach to the geometry of a solid with lattice defects is briefly discussed. Non-Riemannian geometry is applied to the treatment of statics. The "stress" curvature tensor has the meaning of a generalized stress tensor with 27 components, while the associated Einstein tensor represents the classical stress tensor. The "stress" connexion expresses the generalized moment stress having 27 components. Its torsion tensor is the classical couple stress tensor.

The identities of the curvature tensors are identified with the static equilibrium conditions. Using a stress function density instead of a metric tensor, it is shown that the equilibrium conditions can always be identically fulfilled. A consistent theory involving lattice defects must necessarily involve also generalized moment stresses and generalized stresses.

The elastic field of moving dislocations and disclinations, T. Mura, *SP317*, pp. 977-996 (Dec. 1970).

Key words: Anisotropic elasticity; dislocation dynamics; dislocations; Green's tensors.

The previous work and the present state of study on the elastic field of moving dislocations and disclinations are reviewed. Emphasis will be placed upon the general method and approach using Green's tensor functions and Fourier integrals. The previous solutions for individual problems are reviewed as examples of this unified approach.

Kinematics of continuously distributed dislocations, S. I. Ben-Abraham, *SP317*, pp. 999-1020 (Dec. 1970).

Key words: Affine connection; continuum mechanics; kinematics; non-Riemannian geometry.

The general non-Riemannian approach to the geometry of a solid with lattice defects is extended to include the kinematics. The treatment is valid for both the motion of old defects and the creation of new ones. The change in a geometric quantity is described by a corresponding rate. The main quantities dealt with are distortion rates, stretching tensors and connexion rates, and new quantities called fluxions are introduced. In terms of these a fundamental kinematic law and continuity equations for the defect currents are set up and are found to be consistent with earlier results valid in special cases.

A micromorphic approach to dislocation theory and its relation to several existing theories, A. C. Eringen and W. D. Claus, Jr., *SP317*, pp. 1023-1040 (Dec. 1970).

Key words: Continuum mechanics; dislocation distributions; micromorphic dislocations; micropolar dislocations.

Two separate continuum dislocation theories are presented; one dealing with static, incompatible, micropolar dislocations and disclinations, as encountered in initial stress problems, and the other with a dynamical theory of micromorphic solids, containing continuous distributions of dislocations.

Relationships between several continuum dislocation theories and micromorphic mechanics are established by providing extensions and new interpretations of the micromorphic theory. First both micromorphic and micropolar theories of elastic solids are summarized, and then the theories of Kröner, Fox, and Berdichevskii and Sedov are discussed in some detail within this framework. In the last section, by use of micromorphic kinematics, dislocation density, strain, and microstrain tensors are introduced and constitutive equations are constructed. Together with the balance laws this constitutes a complete dynamical theory. The theory is intended for predictions of motions and micromotions of a solid containing dislocations undergoing elastic deformations. From the micromotion, the dislocation density and first stress moments can be calculated.

On the continuum theory of dislocations, N. Fox, *SP317*, pp. 1041-1052 (Dec. 1970).

Key words: Constitutive relations; continuum mechanics; dislocation kinematics; dislocations; oriented media; thermodynamics and dislocation motion.

The kinematics of an oriented medium are discussed with reference to the continuum theory of dislocations. The concepts of dislocation density dislocation flux and slip velocity are introduced and a corresponding constitutive theory is developed.

Dislocation dynamics in the presence of a multiple spectrum of thermally surmountable barriers, W. Frank, *SP317*, pp. 1065-1076 (Dec. 1970).

Key words: Arrhenius rate theory; dislocation dynamics; statistical theory of dislocation; thermal acceleration.

A theoretical treatment is given of the thermally activated motion of dislocations in the presence of dislocation barriers with different heights. The height of a barrier is allowed to depend on an arbitrary number of characteristic parameters (multiple obstacle spectrum). Under the assumptions which are usually made for the derivation of an Arrhenius equation for the slip rate $\dot{a}$ in the case of a uniform array of dislocation barriers, $\dot{a}$ is calculated for a multiple spectrum of barriers.

It is found that even under these conditions the validity of an Arrhenius equation $\dot{a} = \dot{a}_0 \exp(-\Delta\overline{G}/kT)$ (a_0 = const., $\Delta\overline{G}$ = mean free enthalpy of activation) is preserved. An application of the "spectrum theory" is discussed.

Flow and the Arrhenius equation in the statistical framework, U. F. Kocks, *SP317*, pp. 1077-1082 (Dec. 1970).

Key words: Arrhenius law; mechanical properties; precipitation hardening; thermal activation.

The rate equation of plastic flow and a general work-hardening law are combined into a single equation of flow. It degenerates into the Arrhenius law only under certain specified conditions. A single Arrhenius term with temperature insensitive pre-exponential (and entropy) terms adequately describes the rate dependence of dislocation motion through a slip plane studded with obstacles of any spectrum of strengths and spacings. In this case, the mobile dislocation density in the slip plane generally does not enter the flow equation; only the density of slip plane does.

Movement of a dislocation through random arrays of point and parallel line obstacles, A. J. E. Foreman, P. B. Hirsch, and F. J. Humphreys, *SP317*, pp. 1083-1098 (Dec. 1970).

Key words: Computer simulation; dislocation motion; mechanical properties; precipitation hardening.

The motion of a dislocation through random arrays of impenetrable point and parallel line obstacles is considered. For impenetrable point obstacles the difference in line tension for edges and screws, and the elliptical equilibrium shape of the bowing-out loop are taken into account, and the yield stress for screws and edges is found to be the same. The results of a calculation of the effect of interaction between neighboring segments of the dislocation on the critical breaking angle and on the yield stress are presented. Computer calculations on the motion of dislocations through random arrays of parallel line obstacles show that the dislocations move by the generation and motion of large "kinks." The yield stress is found to increase approximately linearly with the obstacle length. These calculations are relevant to and are compared with the hardening in the early stages of the work hardening curve of dispersion hardened alloys containing small particles, in which rows of prismatic loops are formed at the particles, which act as linear obstacles to the gliding dislocations.

Strain rates in dislocation dynamics, W. de Rosset and A. V. Granato, *SP317*, pp. 1099-1106 (Dec. 1970).

Key words: Dislocation kinetics; mobile dislocations, stress rates.

Since the success by Johnston and Gilman in relating yield phenomena in LiF to direct measurements of dislocation velocities and densities, the Λbv expression for the strain rate has been used almost exclusively, where Λ is the mobile dislocation density, b the Burgers vector, and v is the average dislocation velocity. We note that there are cases for which the strain rate is independent of dislocation velocity. When the velocity is large enough the strain rate is given in a simplified model by $\Lambda b\bar{x}$, where $\bar{x}$ is the average distance traveled by a dislocation. The strain rate is eventually determined, then, by the rate at which new dislocations are created and not necessarily by the rate at which old dislocations expand or by the dislocation velocity.

On the mechanism of cross-slip of dislocations at particles, M. S. Duesbery and P. B. Hirsch, *SP317*, pp. 1115-1134 (Dec. 1970).

Key words: Activation energy; cross slip; mechanical properties; misfit strain; precipitation hardening.

The effect of the misfit strain field upon the mechanism of cross-slip of dislocations at impenetrable particles in two-phase alloys is considered. The strain field is found to have a profound effect of the activation energy for cross-slip.

Theories of thermally activated processes and their application to dislocation motions in crystals, H. Engelke, *SP317*, pp. 1137-1156 (Dec. 1970).

Key words: Bordoni-peaks; dislocation motion; kink relaxation; mechanical properties; thermal activation.

Thermally activated processes involving dislocations are usually treated by applying the theory of absolute reaction rates and the string approximation of dislocations. In the first part of this paper the limits of validity of these treatments are discussed. A paper of T. Geszti is briefly reviewed in which it is shown that in processes involving *point defects* deviations from the rate theory must be expected if the energy exchange between defect and lattice waves is slow compared with the average time between jumps, e.g. if localized or quasi-local vibrations contribute essentially to the defect motion. It is pointed out that the localized modes of dislocations may also lead to deviations from the rate theory.

In the second part a treatment of the double kink relaxation (Bordoni relaxation) based on the Kramers-Brinkman diffusion theory of chemical reactions is given. After showing that in f.c.c. metals the influence of the Peierls potential is so small that on dislocation loops only one kink pair must be considered explicitly whereas the remaining parts of the loops may be described by the string approximations, diffusion equations for the loop motion are derived. Under certain conditions these equations are equivalent to a system of reaction rate equations. Exact solutions of this system are not yet available. However, the behaviour of dislocation loops in the amplitude independent region of internal friction measurements may be extrapolated combining results of two limiting cases: a double well model and a simplified multi-well model.

The relaxation strength and the preexponential factor of the relaxation time calculated have the same orders of magnitude as in measurements of the Bordoni peak. The loop length dependence of the damping peak is in good agreement with neutron-irradiation measurements. The characteristic half-width of the Bordoni peak may partly be explained using loop length and stress distributions.

Slightly dissociated dislocations, R. Hobart, *SP317*, pp. 1157-1161 (Dec. 1970).

Key words: Dislocation stacking faults; Peierls-Nabarro model.

A modified Peierls-Nabarro model is used to calculate the relation between the separation of partials and stacking fault energy for an idealized dislocation dissociated into two equal pure screw partials. The resulting expression agrees with the inverse dependence obtained by equating the elastic repulsion of the partials to the attraction of the stacking fault, but unlike that result does not break down at zero separation. Also an argument is given that the width of such a dissociated dislocation should be considered as a complex quantity, with the imaginary part corresponding to the separation of the partials.

The broadening of resonance lines by dislocations, A. M. Stoneham, *SP317*, pp. 1169-1173 (Dec. 1970).

Key words: Line broadening; optical zero phonon line; spin resonance; statistical methods for dislocations.

Dislocations and other defects in solids broaden sharp resonance lines in solids, such as spin resonance and optical

zero phonon lines. The broadening is a result of the random strain fields produced, and the shape of the resonance line is a measure of the distribution of internal strains. Measurement of line shapes can give information which is different from that given by the more usual mechanical and transport studies of dislocations. We calculate the shapes of the resonance lines in terms of the properties of the individual defects which cause broadening, their density and their statistical distribution. The theory is applied to straight dislocations, infinitesimal loops, dislocation dipoles and to point defects.

Dislocation pair interaction in a finite body, R. O. Scattergood and U. F. Kocks, *SP317,* pp. 1179-1189 (Dec. 1970).

Key words: Dislocation surface; dislocations; elastic interactions; finite elasticity; interactions.

The elastic interaction between dislocations in a finite body shows important features not found in an infinite body. For example, two like dislocations parallel to the axis of a cylinder repel each other only when they are close, but attract each other when their distance is comparable to the cylinder radius. Contours of the pair interaction energy are given for both screw and edge dislocations in a circular cylinder.

These new features appear not only when free surface conditions are demanded on the entire body, but even when approximate stress fields are used that demand some surface tractions, so long as no torques are transmitted through the body.

The relevant torques (bending moments) associated with an edge dislocation in a circular cylinder, which vanish when the mantle is traction free, may be made to vanish in general by a simple modification of the stress field of the edge dislocation.

The mean square stresses $\langle \sigma^2 \rangle$ for a completely random and a restrictedly random distribution of dislocations in a cylindrical body, M. Wilkens, *SP317,* pp. 1191-1193 (Dec. 1970).

Key words: Dislocations; elasticity; statistical methods.

The paper gives a full proof of the author's earlier statement according to which the elastic interaction energy of completely randomly distributed dislocations vanishes. As a consequence the outer cut-off radius in the logarithmic factor of the elastic energy coincides with the external cylinder radius rather than with the mean dislocation spacing. The proof takes into account the elastomechanical boundary conditions which were neglected in the earlier paper. Further it is shown that for a restrictedly random distribution the outer cut-off radius is equivalent to the radius of the areas small compared with the cylinder cross-section, each of which contains the same number of dislocations randomly distributed over the corresponding area. In the special case that each area contains only one dislocation with arbitrary inside the area the outer cut-off radius degenerates to the mean dislocation spacing.

Theoretical aspects of kinematical x-ray diffraction profiles from crystals containing dislocation distributions, M. Wilkens, *SP317,* pp. 1195-1221 (Dec. 1970).

Key words: Diffraction profiles; dislocation diffraction; kinematic x-ray diffraction; statistical methods for dislocations.

The paper deals with a theoretical study of the Fourier transform of the x-ray diffraction line profiles from crystals containing dislocation distributions. The theory is based mainly on a calculation of spatial averages of powers of the strains ϵ_n, where ϵ_n means the differential strain perpendicular to the reflecting planes averaged over a certain length $n(n$ = variable of the Fourier transform). The second power average $\langle \epsilon_n^2 \rangle$ is calculated in a closed form for a restrictedly random dislocation distribution. However, the result is approximately valid also for other distributions. The contributions of the averages of higher powers of ϵ_n are taken into account in an approximate manner. The expression derived for the Fourier transform depends on the two parameters ρ and R_e, where ρ is the dislocation density. R_e is equivalent to the effective outer cut-off radius which appears for instance in the logarithmic factor of the elastically stored energy. The result which is applicable for $R_e \geq \rho^{-1/2}$ is discussed in comparison with the theory of Krivoglaz and Ryaboshapka, in which a completely random dislocation distribution is assumed, and with the theory of diffraction from distorted crystals mainly developed by Warren and Averbach.

Thermodynamic properties of solids containing dislocations, J. Holder and A. V. Granato, *SP317,* pp. 1223-1225 (Dec. 1970).

Key words: Bulk modulus; dislocations and thermodynamics; entropy; specific heat; thermal expansion; thermodynamics and expansions.

Using thermodynamics and elasticity theory, a unified treatment of the changes in the thermodynamic properties of solids containing dislocations is given. The results are expressed in terms of temperature and pressure derivatives of the formation energy of the dislocations. The required pressure and temperature dependence of the energy is given by the measured pressure and temperature dependence of the elastic constants appearing in the energy expression found at zero pressure and temperature. The method is not restricted to calculations of volume changes, or to isotropic, static or even elastic systems at zero pressure. Changes in entropy, specific heat, thermal expansion and bulk modulus due to dislocations are easily calculated.

Charged dislocations in the diamond structure, P. Haasen and W. Schröter, *SP317,* pp. 1231-1253 (Dec. 1970).

Key words: Band structures; charged dislocations; diamond lattice; dislocation-electron interactions; semiconductors.

The electronic states at dislocations in elemental semiconductors are reviewed in the light of new experimental and theoretical work. Evidence is produced for the existence of a one-dimensional energy band along edge as well as screw dislocations. This explains quantitatively their ability to act as donors as well as acceptors depending on temperature, doping, and dislocation density. The degree of charging has been recalculated from the free energy of a system of charged dislocations screened by free carriers. The dislocation charge limits the Hall mobility in addition to the strain field of the dislocation. Measurements of photoconductivity of deformed semiconductors support the above model of the charged dislocation. The dislocation charge influences the Peierls force and thus the mobility of dislocations in the diamond structure. The occupation limit of the neutral dislocation, measured from the valence band edge, lies at 0.09 eV in germanium, and at 0.3 eV in silicon.

Electronic effects associated with stacking faults in normal metals, C. Nourtier and G. Saada, *SP317,* pp. 1259-1277 (Dec. 1970).

Key words: Dislocation-electron interactions; interatomic potentials; stacking faults.

The authors use a simple pair interaction model to make the following calculations. (1) Stacking fault energy of simple metals. (2) Interaction energy between a stacking fault and an impurity atom or a vacancy, and application to the study of segregation effects. (3) Interaction energy of parallel stacking faults.

Numerical results are given. Consequences of the long range interaction between defects are discussed.

Theory of surface states on stacking faults, R. M. Thomson, *SP317*, pp. 1279-1288 (Dec. 1970).

Key words: Dislocation-electron interactions; Slater-Koster method; stacking fault.

The Slater-Koster method in the Bloch representation is applied to a model for a stacking fault in an idealized crystal leading to a type of Shockley surface state. A series expansion is obtained for the energy which is worked out for the simplified case of a constant matrix element, with the result that for a tight binding nonoverlapping band, there are surface waves which split off from both the top and bottom of the band. Contrary to Shockley's results for external surfaces, and to the Slater-Koster theory of the localized impurity, localized states occur on the stacking fault for a single nonoverlapping band and for arbitrary potential values. A constant matrix approximation is worked out for the case of the simple metals.

Interactions of dislocations with electrons in metals, C. Elbaum and A. Hikata, *SP317*, pp. 1291-1292 (Dec. 1970).

Key words: Dislocation dynamics; dislocation-electron interactions; phonons.

Physical arguments are given to show that the interaction of moving (vibrating) dislocations with conduction electrons in metals is independent of temperature. Calculations based on the assumption that the Fourier components of the displacement field of a moving dislocation can be treated as pseudo-phonons give the same result. These conclusions were confirmed by the results of recent experiments.

Electronic energy states of dislocations; the case of covalent-ionic solids, C. Elbaum and R. R. Holmes, *SP317*, pp. 1293-1302 (Dec. 1970).

Key words: Band structure; covalent-ionic solids; dislocation-electron interactions; Fermi energy; semiconductors.

It is shown that electronic energy bands are associated with dislocations in wide-band-gap, compound semiconductors. The eigenvalue problem for the dislocation band edge is solved for CdS-type crystals, and the occupation of the band is calculated. The Fermi energy is then determined for crystals containing many deep-lying discrete levels as well as dislocation bands. It is predicted that when a crystal is illuminated with light of appropriate wavelength and increasing intensity, the thermal activation energy governing the electrical conductivity passes through a series of energy plateaus which are equal to the energy of the discrete levels. In a dislocation-free crystal, these plateaus are connected by step changes, while in a crystal with dislocations they are connected by broad transition regions. The above predictions have been verified experimentally.

Interactions between electrons and moving dislocations, G. P. Huffman and N. Louat, *SP317*, pp. 1303-1322 (Dec. 1970).

Key words: Dislocation damping; dislocation-electron interactions; electroresistivity.

A moving dislocation in a metal induces an electric field which causes currents in the conduction electron gas. The energy dissipation associated with these fields and currents is calculated from the Boltzmann equation in a manner analogous to theories of acoustical attenuation. It is found that the applied stress required for steady motion is proportional to the dislocation velocity divided by the electrical resistivity, in good agreement with low temperature yield and flow stress measurements on bcc metals. The concept of a large electronic component of drag which increases with decreasing temperature is used to give a qualitative explanation of the observed mechanical properties of b.c.c. metals. When one considers electronically damped dislocations impeded by pinning points, it is found that: (1) the dislocation velocity depends only on the mean strength of the pinning obstacles; (2) the stress required to overcome an obstacle dynamically is less than that required statically and is, in fact, the electronic drag stress; and (3) the apparent dislocation velocity should vary rapidly with applied stress. The displacement field of a dislocation is significantly wider and more gradual in a f.c.c. than in a b.c.c. lattice, and this feature can be incorporated into the calculation by assuming that the electronic screening of the positive charge shift of the dislocation is essentially perfect in a f.c.c. lattice. The Boltzmann formation then gives a temperature independent stress or drag coefficient in agreement with experiment and with Holstein's scattering calculation. The problem of a dislocation moving in an applied magnetic field directed along its length and perpendicular to its direction of motion is also treated. Under suitable conditions it is found that the stress or drag coefficients exhibit oscillations of the cyclotron resonance type which could be as large as 10 to 30% of the zero field values.

SP318. **Report of the 54th National Conference on Weights and Measures 1969,** R. L. Koeser, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 318, 270 pages (Nov. 1969).*

Key words: Conference, weights and measures—laws; weights and measures—regulations; weights and measures—technical requirements; weights and measures—history; weights and measures.

This is a report of the proceedings (edited) of the Fifty-fourth National Conference on Weights and Measures, sponsored by the National Bureau of Standards, held in Washington, D.C., June 9-13, 1969 and attended by State, county, and city weights and measures officials and representatives of the Federal Government, business, industry, railroads, and associations.

To Save Your Life, P. J. Brown.
Activities of the Office of Weights and Measures, T. M. Stabler.
Weights and Measures Inspection in Federal Establishments:
Department of Defense, A. L. Borchers.
Post Office Department, J. W. Duchesne.
The Development and Use of National Voluntary Standards, D. L. Peyton and D. R. Mackay.
The Role of Weights and Measures Officials in the Metric Study, A. G. McNish.
Panel on Fair Packaging and Labeling:
Department of Commerce, E. A. Vadelund.
Food and Drug Administration, J. Gomiila.
Federal Trade Commission, E. W. Johnson.
Department of Agriculture, W. J. Minor.
Internal Revenue Service, R. O. Jolin.
Weights and Measures—What's That?, M. Dana.
The Coming Trends in Produce Merchandising, R. B. Crosset, Jr.

SP319. **Man, his job, and the environment: A review and annotated bibliography of selected recent research on human performance,** W. G. Mather, III, B. V. Kit, G. A. Bloch, and M. F. Herman. Nat. Bur. Stand. (U.S.), Spec. Publ. 319, 107 pages (Oct. 1970).

Key words: Bibliography; effort; environment; fatigue; human performance; human physiology; psychology; psychophysics; stress (physiological); stress (psychological) work.

Recent scientific literature was searched to review procedures currently being used to study human reactions to work and environmental stress. An ecological context is followed, considering task variables, environmental conditions, individual variations in subjects, and physiological, psychophysical, psychological, and sociological responses. The different types of research reviewed included analyses of on-the-job performance, simulations of real-life situations, laboratory experiments with human and nonhuman subjects, and clinical studies. A methodological program is suggested for measuring the expenditure of effort in work situations. In addition to an extensive bibliography, detailed abstracts of 190 research reports are presented.

SP320. **Bibliography on atomic transition probabilities, January 1916 through June 1969,** B. M. Miles and W. L. Wiese, Nat. Bur. Stand. (U.S.), Spec. Publ. 320, 111 pages (Feb. 1970).

Key words: Atomic; discrete; forbidden; permitted; transition probability.

A revised and updated bibliography on atomic transition probabilities including all new references up to July 1, 1969 is presented. The papers, except for a number of comprehensive articles, are arranged according to elements and stages of ionization. In addition to the literature reference the employed experimental or theoretical method is indicated. For the 20 lightest elements and Ba I and II the literature is presented on a critically selected basis. To keep the bibliography to a compact size, a number of comprehensive papers which contain numerical results throughout extended isoelectronic sequences are listed in a separate section. Also included in this bibliography is a supplementary list of selected important papers dealing with the subject of transition probabilities from a general point of view.

SP320. Supplement 1. **Bibliography on atomic transition probabilities, July 1969 through June 1971,** J. R. Fuhr and W. L. Wiese, Nat. Bur. Stand. (U.S.), Spec. Publ. 320, Suppl. 1, 67 pages (Sept. 1971).

Key words: Allowed; atomic; discrete; forbidden; transition probability.

This is the first supplement to the NBS Special Publication 320, "Bibliography on Atomic Transition Probabilities," and it covers the most recent literature on the subject from July 1969 through June 1971. The papers are arranged according to elements and stages of ionization, and the method employed and classification of transitions are indicated for each reference. Only articles on discrete transitions, both allowed and forbidden, are listed. Papers containing data for many elements within isoelectronic sequences are collected separately in front of the list in order to keep this bibliography to a reasonable size. Also included is a selected list of new papers dealing with the subject of atomic transition probabilities from a general point of view.

SP320. Supplement 2. **Bibliography on atomic transition probabilities July 1971 through June 1973,** J. R. Fuhr and W. L. Wiese, Nat. Bur. Stand. (U.S.), Spec. Publ. 320 Suppl. 2, 63 pages (Nov. 1973) 95 cents, SD Catalog No. C13.10:320.

Key words: Allowed; atomic; discrete; forbidden; transition probability.

This is the second supplement to the NBS Special Publication 320, "Bibliography on Atomic Transition Probabilities," and it covers the most recent literature on the subject from July 1971 through June 1973. The papers are arranged according to elements and stages of ionization, and the method employed and classification of transitions are indicated for each reference. Only articles on discrete transitions, both allowed and forbidden, are listed. Papers containing data for many elements within isoelectronic sequences are collected separately in front of the list in order to keep this bibliography to a reasonable size. Also included is a selected list of new papers dealing with the subject of atomic transition probabilities from a general point of view.

SP321. **An author and permuted title index to selected statistical journals,** B. L. Joiner, N. F. Laubscher, E. S. Brown, and B. Levy, Nat. Bur. Stand. (U.S.), Spec. Publ. 321, 510 pages (Sept. 1970).

Key words: Bibliography; computer indexing; index; key word in context; KWIC; permuted title index; statistics.

Over 5,000 articles appearing in the indicated issues of the following journals are indexed: *Annals of Mathematical Statistics* (1961-1969), *Biometrics* (1965-1969 #3), *Biometrike* (1951-1969), *Journal of the American Statistical Association* (1956-1969), *Journal of the Royal Statistical Society, Series B* (1954-1969 #2). *South African Statistical Journal* (1967-1969 #2), *Technometrics* (1959-1969). The articles indexed correspond to those appearing since the most recent cumulative subject index was published for the first six named journals, while for *Technometrics* all articles have been included even though a subject index exists for the first seven volumes. The index consists of three sections, an author index, a permuted title index and a bibliographic listing. In the permuted title index each article is listed under every important word appearing in its title. This index should consequently serve many of the functions of a conventional subject index. The author index is similar to a conventional author index.

SP322, Superseded by Special Publication 380.

SP323. **Electronic density of states.** Based on invited and contributed papers and discussion, 3d Materials Research Symposium held at Gaithersburg, Md., Nov. 3-6, 1969, L. H. Bennett, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 323, 834 pages (Dec. 1971).

Key words: Band structure: disordered systems; electronic density of states; ion neutralization; Knight shift; magnetic susceptibility; many-body effects; optical properties; photoemission; soft x-ray; specific heat; superconductivity; transport properties; tunneling.

This volume is based on materials presented at the Third Materials Research Symposium of the National Bureau of Standards, held November 3-6, 1969. It provides a review of various experimental and theoretical techniques applied to the study of the electronic density of states in solids and liquids. The topics covered in a series of invited and contributed papers include theory of and experiments to obtain the one-electron density-of-states; many-body effects; optical properties; spectroscopic methods such as photoemission (x-ray and UV), ion neutralization, and soft x-ray; obtaining the density-of-states at the Fermi level by specific heat, magnetic susceptibility, and the Knight shift; the disordered systems of alloys, liquids, dirty semiconductors, and amorphous systems; and superconducting tunneling and the application of density of states to properties such as phase stability.

An edited discussion follows many of the papers. *These proceedings include the following papers (indented):*

The band structure problem, J. M. Ziman, *SP323,* pp. 1-12 (Dec. 1971).

Key words: APW; band structure; density of states; disordered systems; KKR; *t*-matrix; molecular crystals; pseudopotential.

The numerical solution of the Schrödinger equation for an electron in a dense assembly of atoms (*i.e.* a solid or liquid metal or semiconductor) has made great progress in the past ten years. This is not merely a consequence of greater computing power; we now have a much better grasp of the mathematical theory of such solutions.

By 1960 a number of practical methods had been devised for the computation of the electronic structure of ordered crystals, but these lacked intuitive interpretation. The first advance was to rewrite the OPW method in terms of pseudopotentials, thus making sense of the free-electron theory of metals. This development has proved particularly valuable in semiquantitative and empirical investigations of Fermi surfaces, transport properties, lattice dynamics, cohesion, *etc.*, but we have had to wait until recently for a rigorous analysis of the criteria for convergence of the various types of model potential or pseudopotential that have been postulated.

The next step was to show that the KKR (Green function) method could also be expressed as a pseudopotential, and then to demonstrate that this was also a form of APW expansion. The relative computational power of these two methods can thus be analyzed, and questions answered concerning the fulfillment of the empty lattice test, the apparent lack of uniqueness of the expansions, the advantages of "folding" matrix elements from distant points of the reciprocal lattice, and the introduction of contributions from the interstitial potential.

At this stage, the connections between the band structure problem and the *t*-matrix theory of scattering were uncovered, and *d*-bands were seen to arise as resonances of the muffin-tin wells. The KKR matrix could now be rewritten as a mixture of pseudopotential and tight-binding elements, in harmony with the empirical model Hamiltonian representations of hybridised *s-p* and *d*-bands. This method not only permits more rapid computations, but shows clearly how the width and position of such bands should depend on the atomic potential.

Some problems still remain. For example, present techniques do not seem adequate for first-principles calculations on molecular crystals, where the anisotropy of the interstitial potential (*i.e.* easy channels along bonds, but high hills between layers or chains) is probably the dominant feature.

As for disordered systems – we know little for certain and nothing quantitatively. The linear chain model has been fully studied but is quite irrelevant to the three-dimensional case. The present theoretical confusion is exemplified by the equiconcentration substitutional alloy in the tight-binding limit; some formulae give only one band, others allow two. Again, the very possibility of producing band gaps by diffraction of free electrons in a topologically disordered system (*e.g.* amorphous Ge) has not been demonstrated mathematically with any rigor.

Electronic density of states of transition, noble, and actinide metals, F. M. Mueller, *SP323*, p. 17 (Dec. 1971).

Key words: Electronic density of states; histogram representations; QUAD scheme.

Electronic densities of states and optical properties of CsCl type intermetallic compounds, J. W. D. Connolly and K. H. Johnson, *SP323*, pp. 19-25 (Dec. 1971).

Key words: AuZn; CsCl-type intermetallic compounds; direct interband transitions; electronic density of states; NiAl; optical properties.

The electronic band structures and densities of states have been calculated from first principles for two intermetallic compounds having the CsCl structure. The nonrelativistic augmented plane wave method has been used in conjunction with an LCAO interpolation technique to determine the band structure and density of states of β'NiAl to a high degree of accuracy. These theoretical results are in excellent agreement with the measured optical properties if k-conserving (direct) interband transitions are assumed to be dominant. A similar study has been carried out for β'AuZn, using as a basis the energy bands determined by the relativistic Korringa-Kohn-Rostoker method. The band profiles and density of states of β'AuZn are qualitatively similar to those of β'NiAl, except for the appearance of relativistic effects in the former alloy and differences in the relative positions and widths of the respective Au and Ni *d*-bands. The β'AuZn results have also been compared with the measured optical properties and are again consistent with these measurements if direct interband transitions are assumed.

The calculation of densities of states by LCAO interpolation of energy bands with application to iron and chromium, J. W. D. Connolly, *SP323*, pp. 27-32 (Dec. 1971).

Key words: Chromium; electronic density of states; interpolation method; iron; photoemission.

The LCAO (linear combination of atomic orbitals) interpolation method is described as a means of calculating the density of states curves of a crystalline solid. This method is shown to be more straightforward and convenient to use than the composite (LCAO-OPW) techniques that have recently been proposed for transition metals. A computer program is described which determines the LCAO interaction integrals from an *ab initio* energy band calculation by a nonlinear least squares procedure, and then uses these parameters to sample the Brillouin zone at a large number of points in order to calculate the density of states curve to a high degree of accuracy. As examples of the application of this program, the results of calculations on chromium (in both the nonmagnetic and antiferromagnetic states) and iron (nonmagnetic and ferromagnetic) are presented and compared with the recent photoemission data.

Optical properties of aluminum, G. Dresselhaus, M. S. Dresselhaus, and D. Beaglehole, *SP323*, pp. 33-36 (Dec. 1971).

Key words: Aluminum (Al); dielectric constant; electronic density of states; interband transition; optical properties; pseudopotential.

The Ashcroft energy band model which provides a good representation of the measured Fermi surface of aluminum is used here to calculate the optical properties. New reflectivity measurements in aluminum have also been carried out between 2μ and 3000 Å using a sensitive continuous frequency scanning technique. A Kramers-Kronig analysis of the reflectivity data yields a frequency dependent dielectric constant which is essentially in agreement with the results of the calculation. This comparison suggests that the optical properties of aluminum can be described in terms of a one-electron energy band model.

On the optical properties and the density of states in arsenic, R. W. Brodersen and M. S. Dresselhaus, *SP323*, pp. 39-44 (Dec. 1971).

Key words: Arsenic (As); electronic density of states; Fermi surface; interband transition; Landau levels; magneto-reflection.

The infrared reflectivity of arsenic is calculated and correlated with Fermi surface, magnetoreflection and optical reflectivity measurements. These infrared properties are

strongly affected by interband transitions across a small spin-orbit induced bandgap. The unusually large intensity of this interband transition for light incident along the trigonal direction is due to the simultaneous occurrence of a strong interband momentum matrix element and a large density of states. By considering this interband transition explicitly, good agreement is obtained with the experimental data of Riccius.

Density of states and ferromagnetism in iron, K. J. Duff and T. P. Das, *SP323*, pp. 47-52 (Dec. 1971).

Key words: Electronic density of states; ferromagnetism; iron; optical reflection; photoemission; x-ray emission.

The band structure of ferromagnetic iron has been calculated by a variational method using a basis of tight-binding functions and orthogonalized plane waves. Exchange matrix elements are evaluated without approximation by a local potential. Correlation effects are explicitly included. Histograms for the density of states are constructed and compared with photoemission and optical reflection and x-ray emission data. The calculation leads self-consistently to the observed magnetic moment. The relative importance of intra-atomic exchange and itinerancy to the origin of iron's ferromagnetism is discussed.

Calculation of density of states in W, Ta, and Mo, I. Petroff and C. R. Viswanathan, *SP323*, pp. 53-56 (Dec. 1971).

Key words: Electronic density of states; Fermi energy; molybdenum; photoemission; tantalum; tungsten.

Density of states curves were calculated for tungsten, tantalum and molybdenum from corresponding energy band structures obtained by a nonrelativistic APW calculation. The Fermi energy and the density of states at the Fermi energy were obtained for each material. The calculations were part of a study intended to calculate theoretical photoemission yield curves which could be compared with experimental results.

Adjustment of calculated band structures for calcium by use of low-temperature specific heat data, R. W. Williams and H. L. Davis, *SP323*, pp. 57-61 (Dec. 1971).

Key words: Calcium; de Haas-van Alphen; electronic density of states; low-temperature specific heat; pseudopotential; transition-metal behavior.

The electronic band structure of calcium has been studied theoretically by employing the Korringa-Kohn-Rostoker method. The crystal potentials used in our calculation were obtained by means of a standard superposition of free-atom charge densities. E_k vs **k** curves and the density of states at the Fermi energy were calculated for various potentials, with the measured low-temperature electronic specific heat coefficient, γ, being used as an empirical aid to adjust the exchange portion of the crystal potential. The important feature of the potentials used is that they all give band structures which have definite *d*-band character in the vicinity of the Fermi surface. These *d* bands or their corresponding *d* scattering resonances vary rapidly in energy for small changes in the exchange, resulting in values of γ which are extremely sensitive to exchange.

Fermi surface properties of the noble metals at normal volume and as a function of pressure, W. J. O'Sullivan, A. C. Switendick, and J. E. Schirber, *SP323*, pp. 63-65 (Dec. 1971).

Key words: Crystal potential; effective masses; electronic density of states; electronic specific heat; noble metals; pressure effects.

We present the results of nonrelativistic KKR calculations of the Fermi surface properties of Cu, Ag, and Au at normal volume and as a function of pressure. In particular we compare electronic specific heats, effective masses and the associated pressure shifts with the corresponding experimental results for the noble metals. In contrast to the results of previous calculations we find that the Herman-Skillman-Mattheiss crystal potential is an excellent effective potential for both Cu and Ag.

Calculated effects of compression upon the band structure and density of states of several metals, E. A. Kmetko, *SP323*, pp. 67-73 (Dec. 1971).

Key words: Alkali and alkaline earth metals; augmented plane wave method (APW); cerium; compressibility; electronic density of states; lanthanides.

Energy bands were obtained self-consistently by the augmented plane wave method for the following metals: Li, Cs, Ca, Sr, Ba, La, Ce, U, Pu, W and Fe. The density of states and the electronic charge were resolved into *s*-, *p*-, *d*-, and *f*-like components. Under compression the charges associated with the higher values of ℓ increase, mainly at the expense of the *s*-like component, and a more compact overall distribution is thereby achieved. The present results indicate that such "electronic transitions" are of general occurrence and probably play a significant role in determining the compressibility of metals.

Optical properties and electronic density of states, M. Cardona, *SP323*, pp. 77-89 (Dec. 1971).

Key words: Critical points; density of states; dielectric constant; modulated reflectance; optical absorption.

The fundamental absorption spectrum of a solid yields information about critical points in the optical density of states. This information can be used to adjust parameters of the band structure. Once the adjusted band structure is known, the optical properties and the density of states can be generated by numerical integration. We review in this paper the parametrization techniques used for obtaining band structures suitable for density of states calculations. The calculated optical constants are compared with experimental results. The energy derivative of these optical constants is discussed in connection with results of modulated reflectance measurements. It is also shown that information about density of empty states can be obtained from optical experiments involving excitation from deep core levels to the conduction band.

A detailed comparison of the calculated one-electron optical line shapes with experiment reveals deviations which can be interpreted as exciton effects. The accumulating experimental evidence pointing in this direction is reviewed together with the existing theory of these effects.

A number of simple models for the complicated interband density of states of an insulator have been proposed. We review in particular the Penn model, which can be used to account for response functions at zero frequency, and the parabolic model, which can be used to account for the dispersion of response functions in the immediate vicinity of the fundamental absorption edge.

Theoretical electron density of states study of tetrahedrally bonded semiconductors, D. J. Stukel, T. C. Collins, and R. N. Euwema, *SP323*, pp. 93-102 (Dec. 1971).

Key words: Aluminum phosphide (AlP); electronic density of states; exchange potential; gallium arsenide (GaAs); germanium; self-consistent orthogonalized plane wave model (SCOPW); semiconductors, tetrahedrally bonded; silicon; zincblende; ZnSe.

The electron density of states has been calculated using a self-consistent orthogonalized plane wave (SCOPW) model for compounds in the isoelectronic sequences Si-AlP and Ge-GaAs-ZnSe. The valence and conduction band density of states are presented. The location of the core states is also given. The effect upon the density of states of using the exchange approximations of Slater, Kohn-Sham, and Liberman is displayed.

Electronic density of states in Eu-chalcogenides, S. J. Cho, *SP323*, pp. 105-108 (Dec. 1971).

Key words: Augmented plane wave method (APW); electronic density of states; europium-chalcogenides; exchange potential; *f* bands; photoemission.

The spin-polarized energy bands and the electronic density of states in the Eu-chalcogenides have been obtained by the augmented-plane-wave (APW) method. The results show that the *f* bands are extremely sensitive to the exchange potential used, and the $f(\uparrow)$ bands become the highest valence bands with a band width of the order of 0.5 eV. Our results have been compared with the recent photoemission spectroscopy data. The UPS data show too large *f* band width and too small relative peak intensities of the *f* bands, which disagree with our results. The 4*f* bands in the Eu and Gd could be located within 3.0 eV below their Fermi energies.

Energy band structure and density of states in tetragonal GeO_2, F. J. Arlinghaus and W. A. Albers, Jr., *SP323*, pp. 111-113 (Dec. 1971).

Key words: Augmented plane wave method (APW); electron densities of states; GeO_2; indirect transition; optical properties; Slater exchange; vacuum ultraviolet reflectance spectra.

The electronic energy bands of tetragonal GeO_2 have been calculated and correlated with optical properties of single crystals of this material. The agreement between theory and experiment is sufficiently good to warrant calculations of densities of states and conduction band effective masses preparatory to the determination of the dielectric constant as a function of energy. The calculated energy bands, density of states, and the experimental optical absorption edge data are presented and discussed.

Calculation of the density of states and optical properties of PbTe from APW-LCAO energy bands, D. D. Buss and V. E. Schirf, *SP323*, pp. 115-123 (Dec. 1971).

Key words: Augmented plane wave method (APW); electronic density of states; k·p method; LCAO; lead telluride (PbTe); optical properties; pseudopotential; random phase approximation; tight-binding.

The overlap integrals in the tight-binding secular equation for the relativistic *p*-bands in PbTe have been adjusted to give the best representation of the APW results at high symmetry points. The resulting LCAO bands have been used to calculate the density of states in energy and the optical constants of PbTe. The calculated density of states is found to have peaks which correspond closely to the four peaks measured by Spicer and Lapeyre. However, the assignment of peaks to bands is found to be different from that proposed previously. The method of Dresselhaus and Dresselhaus has been used to obtain the oscillator strengths for optical transitions, and these are found to agree with previous calculations. The interband electronic contribution to the optical constants has been calculated for photon energy less than 5 eV.

Plasmon-induced structure in the optical interband absorption of free-electron like metals, B. I. Lundqvist and C. Lydén, *SP323*, pp. 125-127 (Dec. 1971).

Key words: Electronic density of states; free-electron like metals; interband absorption; optical properties; plasmon; pseudopotential; quasi-particle; satellite structure.

We have extended Butcher's method to include the spectrum of interacting electrons, which contains satellite structure. The calculated optical conductivity shows a weak additional absorption, starting at about the frequency $\omega_t + \omega_p$, where ω_t is the interband threshold frequency and ω_p the plasma frequency.

Theory of the photoelectric effect and its relation to the band structure of metals, N. W. Ashcroft and W. L. Schaich, *SP323*, pp. 129-134 (Dec. 1971).

Key words: Electronic density of states; electron-electron scattering; electrons in a box; joint density of states; Kronig-Penney model; photoelectric effect.

We develop the theory of the external photoelectric effect in terms of quadratic response to the incident electromagnetic field. Electrons in the solid are in states determined by their interactions with themselves, the ions and the surface. We denote by H_0 the Hamiltonian for this part. In the presence of the electromagnetic field we have a coupling term:

$$H_1 = -\frac{1}{c}\int d\mathbf{r}\mathbf{A}(r,t)\cdot\mathbf{J}(\mathbf{r})e^{\eta t}, \qquad (\eta = 0^+)$$

where $\mathbf{A}(\mathbf{r}, t)$ is the vector potential, and $\mathbf{J}(\mathbf{r})$ is the current density operator for the electrons. Let $\mathbf{R}$ be a point exterior to the solid. Then the expectation value of the operator measuring the external current density at $\mathbf{R}$ in the states of $(H_0 + H_1)$ is, to second order:

$$\langle J_\alpha(\mathbf{R},t)\rangle = \left(\frac{1}{\hbar c}\right)^2 \int_{-\infty}^{\infty} d\tau_1\theta(t-\tau_1)\int_{-\infty}^{\infty} d\tau_2\theta(t-\tau_2)\cdot$$

$$\sum_{\mu,\nu}\int d^3x_1\int d^3x_2 A_\mu(\mathbf{x}_1,\tau_1)A_\nu(\mathbf{x}_2,\tau_2)\cdot$$

$$\langle\langle J_\mu(\mathbf{x}_1,\tau_1)J_\alpha(\mathbf{R},t)J_\nu(\mathbf{x}_2,\tau_2)\rangle\rangle.$$

There is no linear response and no other terms to order A^2 giving a measurable result. We show that $\langle J_\alpha(\mathbf{R}, t)\rangle$ may be related to the expectation value of the time ordered product of three current operators. This alternative description can be evaluated in the independent particle model (no scattering) and leads to a compact formulation of photoemission. There need not be a simple dependence of $\langle J_\alpha(\mathbf{R}, t)\rangle$ or of its spectral reduction $\langle J_\alpha(\mathbf{R}, t, e)\rangle$ (corresponding to measured electron distribution curves) on the joint density of states. Rather $\langle J_\alpha(\mathbf{R}, t, E)\rangle$ depends on the density of bound states but is not at all simply related to the density of states above the vacuum level. This emerges quite clearly from an analysis carried out in the well known constant matrix element approximation. A careful examination of the terms appearing in the photoelectric current shows that it is not always correct to interpret photoemission in terms of a "volume effect" or a "surface effect." The contributions from these two interfere. The usual explanations of the processes involved (i.e., the sequential operations of excitation, transport, and transmission) are also somewhat blurred.

The effect of electron-electron scattering is well known to be important and will be discussed both in terms of its manifestation in the observed electron distribution curves and its ability to limit the contribution of the conventional volume effect.

Optical density of states ultraviolet photoelectric spectroscopy, W. E. Spicer, *SP323*, pp. 139-157 (Dec. 1971).

Key words: Copper; copper nickel alloys; density of states; GaAs; Ge; nondirect transitions; optical density of states; PbTe; ultraviolet photoemission.

The use of ultraviolet photoemission to determine the density of valence and conduction states is reviewed. Two approaches are recognized. In one, the photoemission as well as other studies are used to locate experimentally a limited number of features of the band structure. Once these are fixed, band structure calculations could be carried out throughout the zone and checked against other features of the photoemission data. If the agreement is sufficiently good, the density of states is then calculated from the band structure. The second method depends only on experimental data. Using this approach, features of the density of states are determined directly by the photoemission experiment without recourse to band calculations. In cases where bands are wide and **k** clearly provides an empirically important optical selection rule, this is possible only for portions of the bands which are relatively flat. Successful determinations of this type are cited for PbTe, and GaAs. In metals with narrow *d* bands such as Cu, it has been found empirically that one may explain fairly well the experimental energy distribution curves in terms of transitions between a density of initial and final states (the optical density of states, ODS) requiring only conservation of energy.

The ODS determined by such ultraviolet photoemission studies have more strong detailed structure than the density of states determined by any other experimental method. Studies on a large number of materials indicate that the position in energy of this structure correlates rather well with the position in energy of structure in the calculated density of states. It is suggested, following the very recent theoretical work of Doniach, that **k** conservation becomes less important (and nondirect transitions more important) as the mass of the hole becomes larger. This is due to the change in **k** of electrons in states near the Fermi level as they attempt to screen the hole left in the optical excitation process. These electrons take up the excess momentum. One would expect the **k** conservation selection rule to play an increasingly important role as the mass of the hole decreases. This is in agreement with experiment.

The density of states and photoemission from indium and aluminum, R. Y. Koyama and W. E. Spicer, *SP323*, pp. 159-161 (Dec. 1971).

Key words: Aluminum (Al); direct and nondirect transitions; electronic density of states; indium (In); nondirect transitions; optical density-of-states; photoemission.

Experimental photoemission data from indium and aluminum are briefly described and can be understood in terms of a density of states model. In contrast to this, a direct transition model based on calculated band structures is found to yield photoelectron spectra which are fair reproductions of the density of states. This suggests that for these two metals, conclusions drawn concerning the density of states are independent of the model used to explain the photoemission data.

Electronic densities of states from x-ray photoelectron spectroscopy, C. S. Fadley and D. A. Shirley, *SP323*, pp. 163-178 (Dec. 1971).

Key words: $CdCl_2$; density of states; HgO; noble metals; rigid band model; transition metals; x-ray photoemission; ZnS.

In x-ray photoelectron spectroscopy (XPS), a sample is exposed to low energy x rays (approximately 1 keV), and the resultant photoelectrons are analyzed with high precision for kinetic energy. After correction for inelastic scattering, the measured photoelectron spectrum should reflect the valence band density of states, as well as the binding energies of several core electronic levels. All features in this spectrum will be modulated by appropriate photoelectric cross sections, and there are several types of final-state effects which could complicate the interpretation further.

In comparison with ultraviolet photoelectron spectroscopy (UPS), XPS has the following advantages: (1) the effects of inelastic scattering are less pronounced and can be corrected for by using a core reference level, (2) core levels can also be used to monitor the chemical state of the sample, (3) the free electron states in the photoemission process do not introduce significant distortion of the photoelectron spectrum, and (4) the surface condition of the sample does not appear to be as critical as in UPS. XPS seems to be capable of giving a very good description of the general shape of the density-of-states function. A decided advantage of UPS at the present time, however, is approximately a fourfold higher resolution.

We have used XPS to study the densities of states of the metals Fe, Co, Ni, Cu, Ru, Rh, Pd, Ag, Os, Ir, Pt, and Au, and also the compounds ZnS, $CdCl_2$, and HgO. The *d* bands of these solids are observed to have systematic behavior with changes in atomic number, and to agree qualitatively with the results of theory and other experiments. A rigid band model is found to work reasonably well for Ir, Pt and Au. The *d* bands of Ag, Ir, Pt, Au and HgO are found to have a similar two-component shape.

Direct-transition analysis of photoemission from palladium, J. F. Janak, D. E. Eastman, and A. R. Williams, *SP323*, pp. 181-189 (Dec. 1971).

Key words: Copper; dielectric constant; direct interband transitions; electronic density of states; interband transition; Korringa-Kohn-Rostoker (KKR); "muffin-tin" potential; palladium (Pd); photoemission; plasmon; secondary emission; silver (Ag).

The energy distribution of optically excited electrons in Pd arising from direct interband transitions has been calculated assuming constant momentum matrix elements. Principal features of new photoemission data (*d*-band structure with four peaks at 0.15, 1.2, 2.2, and 3.5 eV below the Fermi level and a *d*-band width of ~ 3.8 eV) are successfully explained by these calculations. The data can be analyzed with comparable success using the nondirect-transition model, but only by assuming a free-electron density of unoccupied states, which is shown to be unjustified for Pd. In addition to the photoemission spectra and the density of states, the imaginary part of the dielectric constant is computed and compared with experiment.

Photoemission determination of the energy distribution of the joint density of states in copper, N. V. Smith, *SP323*, pp. 191-197 (Dec. 1971).

Key words: Aluminum-insulator-palladium (Al-Pd); augmented plane wave method (APW); cesium; copper; direct transitions; electronic density of states; joint density of states; nondirect transitions; optical density of states; optical properties; photoemission.

Measurements have been made of the photoemission properties of cesiated copper, with improved sample preparation over the previous work by Berglund and Spicer. The

energy distribution curves (EDCs) of photoemitted electrons show structure in the region associated with the copper *d* bands which was not seen in the previous data. The behavior in the photon energy range 6 to 8 eV is particularly interesting in that some of these new peaks in the EDCs are observed to move, appear and disappear in a manner characteristic of direct transitions.

Parallel calculations have been performed of the energy distribution of the joint density of states (EDJDOS) similar to those reported recently by Smith and Spicer. The band structure used was the interpolation scheme of Hodges, Ehrenreich, and Lang fitted to the APW calculation of Burdick. In a constant matrix element approximation, the EDJDOS represents the energy distribution of photo*excited* electrons. This was converted to an energy distribution of photo*emitted* electrons by introducing appropriate threshold and escape factors. The overall agreement with experiment is good. In particular, some of the peaks in the theoretical EDCs are predicted to disappear and reappear on varying the photon energy, and there are strong similarities with the change observed experimentally.

It is found, therefore, that the optical transitions from parts of the copper *d* bands can be identified as direct. Theoretical calculations based on the EDJDOS work quite well for these and other transitions. Photoemission provides a very sensitive tool for verifying and even determining the EDJDOS. Burdick's bands for copper appear to be essentially correct over a wide range of energies including the whole of the *d*-band region, although minor modifications of a few tenths of an eV would improve agreement. It is found that the most persistent peaks in the calculated EDJDOS tend to coincide with the peaks in the calculated true density of states. This indicates that when a phenomenological "optical density of states" can be obtained, it may well be a good approximation to the true density of states even if transitions are direct.

The band structure of tungsten as determined by ultraviolet photoelectric spectroscopy, C. R. Zeisse, *SP323,* pp. 199-203 (Dec. 1971).

Key words: Carbon contamination; electronic density of states; photoemission; tungsten (W); UV photoemission; work function.

The technique of photoelectron spectroscopy has been used to probe the band structure of tungsten in the energy region where the *5d* bands are most prominent. The work function of the clean sample, a 25 micron thick polycrystalline foil, was found to be 4.36 ± 0.02 eV, and the yield rose by three orders of magnitude from 5.0 to 11.3 eV without showing prominent structure of any other sort. The electron energy spectra, on the other hand, contain two pieces of reliable structure which are found to increase in energy at the same rate as the exciting photon energy. A simple analysis of the data gives evidence that the density of *d* states in tungsten consists of a shoulder just below the Fermi level, a peak located about 1.5 eV below the shoulder, and a broad peak which extends at least 7 eV below the Fermi level.

Photoemission studies of scandium, titanium, and zirconium, D. E. Eastman, *SP323,* pp. 205-208 (Dec. 1971).

Key words: Copper; direct versus nondirect transitions; electronic density of states; gold (Au); nondirect transitions; optical density-of-states; photoemission; scandium (Sc); silver (Ag); titanium (Ti); zirconium (Zr).

Photoemission spectroscopy studies of the hexagonal metals Sc, Ti and Zr in the 4 to 11.6 eV range have resolved *d*-band structure and have determined occupied *d*-band widths (at 1/2 maximum) of 1.6, 2.0 and 2.3 eV respectively. Resolved structure for all three metals correlates with structure in energy band density of states; however, the observed band widths for Ti and Zr are much narrower than previously calculated band widths. The relation of the data to the controversy concerning the nature of optical excitations in transition and noble metals (direct *vs* nondirect transitions) is discussed.

Photoemission and reflectance studies of the electronic structure of molybdenum, K. A. Kress and G. J. Lapeyre, *SP323,* pp. 209-215 (Dec. 1971).

Key words: Dielectric constant; electronic density of states; molybdenum (Mo); optical density of states; optical properties; photoemission; reflectivity; tungsten (W); zinc (Zn).

Normalized energy distributions of photoemitted electrons for $4.3 < h\nu < 11.8$ eV (threshold is 4.3 eV) and near normal reflectance for $0.5 < h\nu < 11.8$ eV are measured for molybdenum films prepared with ultra high vacuum. The nondirect transition model with constant matrix elements is found to be consistent with the photoemission data. The above model, in conjunction with calculations for the emission of scattered electrons, is used to obtain the optical density of states (ODS) for the occupied states. Three peaks due to *d*-electrons are observed at $E - E_F = -0.5$, -1.6, and -3.9 eV where E_F is the Fermi energy. No structure is observed for $E - E_F > 4.3$ eV. The imaginary part of the dielectric constant, ϵ_2, is obtained by Kramers-Kronig analysis, and the occupied ODS are used to obtain the ODS for $0 < E - E_F < 4.3$ eV. The latter analysis is done by writing the finite difference approximation for the integral expression of ϵ_2 and solving for the empty ODS. The ODS is compared to the band calculations of Mattheiss where a molybdenum density of states is obtained by scaling his tungsten (W) results. Both the measured and calculated occupied densities of states have three peaks and both empty states have one dominant peak. The calculations predict a low density of states for $-1 < E - E_F < 0$ eV which is not observed in the data. The absorption coefficient has a minimum at 11.3 eV which correlates with a dip in the quantum yield. The energy distributions of the photoemitted electrons show small structural changes above the spectral range of the peak in the energy loss function at 10.8 eV. The relation of these data to the explanations based on the electron density of states for the anomalous isotopic mass dependence of the superconducting transition temperature is discussed.

Ultraviolet and x-ray photoemission from europium and barium, G. Brodén, S. B. M. Hagström, P. O. Hedén, and C. Norris, *SP323,* pp. 217-220 (Dec. 1971).

Key words: Barium (Ba); β-tungsten compounds; effects of oxidation; electronic density of states; europium (Eu); lanthanides; matrix elements; photoemission; rare-earth metals; UV and x-ray photoemission; x-ray photoemission.

Europium and barium are predicted to have very similar outer electronic structures with the exception that europium has a partially filled *4f* shell. Measurements are reported on photoemission from thin films excited with both vacuum ultraviolet and soft x-ray radiation. The results obtained using the low energy excitation indicate the similarity of the materials. Both show structure close to the leading edge in agreement with band structure calculations which indicate an increase in the density of states immediately below the Fermi level. Only a very small feature is observed with europium films which can be associated with the *4f* electrons. On the other hand using soft x-ray excitation a large peak corresponding to *4f* states lying 2.5 eV below the Fermi level is observed. The difference in the magnitudes is attributed to the size of the matrix elements involved.

What is a quasi-particle?, J. R. Schrieffer, *SP323*, pp. 227-231 (Dec. 1971).

Key words: Density of states; Green's function; mass enhancement; quasi-particle; superconductors.

The concept of a quasi-particle excitation in an interacting many-body system will be discussed from both the physical and the mathematical points of view. The physical origin of mass enhancement, wave function renormalization, interactions between quasi-particles, etc. will be presented. Landau's Fermi liquid theory, including the quasi-particle kinetic equation, will be reviewed. Finally, the domain of validity of the quasi-particle approximation will be discussed.

Beyond the one-electron approximation: Density of states for interacting electrons, L. Hedin, B. I. Lundqvist, and S. Lundqvist, *SP323*, pp. 233-247 (Dec. 1971).

Key words: Density of states; interacting electrons; one-particle Green function; oscillator strengths; quasi particle density of states; x-ray emission and absorption.

The concept "density of states" can be given many different meanings when we go beyond the one-electron approximation. In this survey we concentrate on the definition tied to excitation processes, where one electron is added or removed from the solid. We discuss the one-particle spectral function for conduction and core electrons in metals, how it can be approximately calculated, and how it can be related to different types of experiments like x-ray photoemission, x-ray emission and absorption, photoemission and optical absorption in the ultraviolet, and the Compton effect. We also discuss the form of the exchange-correlation potential for use in band structure calculations.

Excitonic effects in x-ray transitions in metals, G. D. Mahan, *SP323*, pp. 253-258 (Dec. 1971).

Key words: Density of states; exciton; many body effects; phase shifts; soft x-ray; transition probability.

In the study of soft x-ray transitions in solids, there has always been some hope that the results provide a direct measure of the density of states. This assumes that (a) matrix element variations over the band and (b) final state interactions are small. Both of these assumptions are known to be incorrect. To illustrate the possible strength of these effects, two approximate calculations are presented: the one electron oscillator strength of a simple bcc metal as a function of energy; and the strength of the Nozieres – DeDominicis singularity at threshold, with phase shifts estimated from an assumed Yukawa interaction between conduction electrons and core hole.

Vibronic exciton density of states in some molecular crystals, R. Kopelman and J. C. Laufer, *SP323*, pp. 261-267 (Dec. 1971).

Key words: Anthracene; aromatic crystals; benzene; excitonic density of states; molecular crystals; naphthalene.

Excited states of molecular crystals, which happen to be the majority of known crystals, are almost always classified as excitonic. The largest class of well studied systems are very closely described by the Frenkel model, and a majority of these systems can actually be described by a special case of the Frenkel model, one with steeply falling-off intersite (intermolecular) interactions. In this specific model the expression for the band structure depends only on the interchange symmetry of the crystal, with a small number of intersite parameters. Examples are given for some aromatic crystals, comparing band structures derived from theoretically calculated parameters, experimentally derived parameters, and completely experimentally derived band structure.

Effect of the core hole on soft x-ray emission in metals, L. Hedin and R. Sjöström, *SP323*, pp. 269-270 (Dec. 1971).

Key words: Aluminum; core hole; electronic density of states; Fermi edge singularity; pseudopotential; sodium (Na); soft x-ray emission.

We report a simple type of calculation to estimate the enhancement on the intensity of soft x-ray emission in free-electron like metals due to the effect of the core hole. We consider an electron gas in the presence of a perturbing potential and calculate the x-ray intensity assuming the dipole matrix elements to be constant. The calculation is based on a simple type of trial function for the initial state of the valence electron system and the coefficients are determined from the variation principle. The calculation does not give the Fermi edge singularity, which has recently aroused such a large interest, but instead aims at giving the gross effects for the whole spectrum. The results indicate an increase in the intensity by 25 to 50% at metallic densities. The enhancement factor is found to vary roughly linearly over the main band, increasing about 50% in going from the bottom of the band to the Fermi edge.

Cancellation effects in the emission and absorption spectra of light metals, B. Bergersen and F. Brouers, *SP323*, pp. 273-274 (Dec. 1971).

Key words: Electronic density of states; light metals; many-body effects; plasmon satellite; soft x-ray.

Photoabsorption measurement of Li, Be, Na, Mg, and Al in the vicinity of K and $L_{II,III}$ edges, C. Kunz, R. Haensel, G. Keitel, P. Schreiber, and B. Sonntag, *SP323*, pp. 275-277 (Dec. 1971).

Key words: Aluminum (Al); beryllium (Be); electronic density of states; electron synchrotron light; K spectra; light metals; lithium (Li); L spectra; magnesium (Mg); photoabsorption; sodium (Na); transmission measurements.

The absorption structure of five light metals has been measured in the vicinity of the onset of K shell respectively $L_{II,III}$ shell absorption. In accord with recent theoretical investigations a peaking of the cross section at the edge is observed for the $L_{II,III}$ edges of Na, Mg, and less pronounced for Al. There is structure of a different type at the K edges of Li and Be.

Optical absorption of solid krypton and xenon in the far ultraviolet, C. Kunz, R. Haensel, G. Keitel, and P. Schreiber, *SP323*, p. 279 (Dec. 1971).

Key words: Electronic density of states; electron synchrotron light; krypton; optical absorption; xenon.

The piezo soft x-ray effect, R. H. Willens, *SP323*, pp. 281-285 (Dec. 1971).

Key words: Copper; electronic density of states; mechanical strain; modulation technique; nickel; soft x-ray.

In principle the soft x-ray emission spectrum should reveal the electronic structure of a material below the Fermi surface. In general, but for a few exceptions, the beginning and termination of the band structure are masked by low and high energy tails. The Van Hove singularities and critical points are unresolved due to effects such as Auger, lifetime and instrumental broadening.

The modulation of the L_{III} emission band of polycrystalline copper by an alternating elastic strain has recently been measured. Two effects are observed. First, there is an overall band shift which gives a measure of the deformation potentials. The band shift is not uniform as different subbands can shift varying degrees. For an applied load of 12,000 psi in uniaxial tension, the shift of the high energy side of the band is 0.015 eV and the low energy side is 0.010 eV. Because of the preferred orientation and polycrystalline nature of the sample, the exact microscopic sample is isotropic with a Young's modulus of 20×10^6 psi, the average deformation potential is 25 eV at the top of the band and 17 eV at the bottom of the band. Secondly, superimposed on this band shift is structure which is unresolved in the normal emission spectrum. The origin of this structure is presumed to be from positions in the electronic structure which are extra sensitive to strain as far as altering the x-ray emission. This would be at Van Hove singularities or critical points where a high degree of degeneracy and wave function mixing is prevalent which can be changed by the symmetry alteration of the lattice due to strain. Comparison between the theoretical band structure calculations of copper and the emission structure due to strain modulation show several similarities.

The application of this technique to alloys should be useful for studying their electronic structure.

Soft x-ray band spectra and their relationship to the density of states, G. A. Rooke, *SP323*, pp. 287-293 (Dec. 1971).

Key words: Alloys; auger transitions; density of states; many-body interactions; plasmons; singularities; soft x rays.

The paper concentrates on the similarities and differences between the one-electron spectrum and the density of states; many-body effects, although important, are listed but they are not considered in detail. It is shown that the only reliable information about the density of states that can be obtained from soft x-ray spectroscopy are the energies of the Fermi surface and the van-Hove singularities, although the shape of the density of states can be derived indirectly from the energies of the van-Hove singularities.

It is the differences between the density of states and the one-electron spectra that may prove to be most important. These differences can give information about the symmetry and the local nature of the screening electrons. This is particularly interesting when studying alloys.

The Li K, the Al L_{23} and the Zn L_3 spectra are given as examples which illustrate the above arguments. Finally, a brief discussion on the soft x-ray spectra from the Al-Mg system show how the results may be used to study alloys.

Orbital symmetry contributions to electronic density of states of AuAl, A. C. Switendick, *SP323*, pp. 297-301 (Dec. 1971).

Key words: Augmented plane wave method (APW); electronic density of states; electronic specific heat; gold aluminide ($AuAl_2$); "muffin-tin" potential; orbital density of states; soft x-ray emission.

From an augmented plane wave calculation of the valence and conduction bands of $AuAl_2$ we have constructed density of states histograms. From further calculations of the wave functions, one can attribute atomic-like character of the band states, e.g., Au 5*d*-bands, Al 3*s*-band, Al 3*p*-band. One can then partition the total density of states into atomic-like components according to the fractional atomic-like character of each state.

From the total density of states an electronic specific heat coefficient of 2.81 mJ/mole K^2 was calculated compared with the experimental value 3.03. The aluminum 3*s* density of states is compared with the aluminum $L_{2,3}$ soft x-ray emission spectra. Excellent agreement with experiment is obtained for the absolute location, and location relative to the Fermi energy, of the low energy peak. About half the calculated peak is attributable to tails of wave functions associated with the gold *d*-bands. Additional structure in the experimental curve is quite well reproduced in the calculation. This we take to be confirmation of the overall correctness of our bands.

Soft x-ray emission spectrum of Al in $AuAl_2$, M. L. Williams, R. C. Dobbyn, J. R. Cuthill, and A. J. McAlister, *SP323*, pp. 303-305 (Dec. 1971).

Key words: Electron density of states; gold aluminide ($AuAl_2$); gold-gallium ($AuGa_2$); gold-indium ($AuIn_2$); intermetallic compounds CsCl structure; L spectra; silver-aluminum alloys (AgAl); soft x-ray emission; *s*-orbital density of states.

Recently, Switendick and Narath have reported results of a systematic calculation of the electronic band structure of the compound series AuX_2(X = Al,Ga,In). We have measured the $L_{2,3}$ soft x-ray emission spectrum of Al in $AuAl_2$ and from it, estimated the Al L_3 emission profile. We compare the latter to the distribution in energy of *s*-like charge at Al sites, estimated by Switendick from his band calculation. This *s* density is the dominant factor in a one-electron estimate of the soft x-ray emission rate. Quite good agreement is found, lending strong support to the calculations for $AuAl_2$. This result also supports interpretation of a recently observed low energy peak in the $L_{2,3}$ emission spectrum of Al in Ag-Al alloys in terms of Ag *d* and Al *s-p* hybridization.

Soft x-ray emission from alloys of aluminum with silver, copper, and zinc, D. J. Fabian, G. Mc D. Lindsay, and L. M. Watson, *SP323*, pp. 307-312 (Dec. 1971).

Key words: Aluminum-copper alloys (AlCu); aluminum-zinc alloys (Al-Zn); electron density of states; silver aluminum alloys (Ag-Al); soft x-ray emission.

Measurements of the soft x-ray emission from the alloys Al-Ag, Al-Cu and Al-Zn are reported, and the effect of the *d*-bands of the metals Ag, Cu and Zn on the Al $L_{2,3}$-emission for these alloys is examined. For Al-Ag and Al-Cu alloys, sharp resonance peaks are observed in the Al $L_{2,3}$-spectra and are attributed to transitions from states in the hybridized silver and copper *d*-bands to core states of the aluminums atoms. The observations agree with the general theoretical considerations discussed by Harrison for a simple metal alloyed with a noble metal. For the Al-Zn alloys the *d*-bands of Zn do not contribute to the Al $L_{2,3}$-emission.

Soft x-ray emission spectra of Al-Mg alloys, H. Neddermeyer, *SP323*, pp. 313-317 (Dec. 1971).

Key words: Aluminum (Al); aluminum-magnesium alloys (Al-Mg); charging effect; electronic density of states; emission spectra; magnesium (Mg); rigid-band approximation; soft x-ray emission.

In recent years the interpretation of soft x-ray emission band spectra has made good progress. With a detailed knowledge of the electronic band structure, of transition probabilities, and of lifetime broadening effects, it has been possible to calculate the shape of emission band spectra of a few pure elements. However, the situation is much more complicated in the case of alloys where the problems are far from being solved. The different shapes of emission band spectra of the components of an alloy make the applicability of the usual model to alloy spectra doubtful.

As a contribution to these problems we have remeasured the soft x-ray emission band spectra of Al-Mg alloys using improved experimental techniques. The Al $L_{2,3}$- and Mg $L_{2,3}$-emission spectra lying in the same wavelength region can be studied in the same spectrometer. Since the spectra of the pure metals have characteristic details and the energy resolution in this wavelength region is good, shapes and changes of shape can be registered very precisely.

An L-series x-ray spectroscopic study of the valence bands in iron, cobalt, nickel, copper, and zinc, S. Hanzely and R. J. Liefeld, *SP323*, pp. 319-326 (Dec. 1971).

Key words: Cobalt; copper; electronic density of states; iron; nickel; satellite emissions; self absorption; soft x-ray emission; x-ray spectroscopy; zinc (Zn).

This paper presents the results of an attempt to evaluate the merits of the soft x-ray spectroscopic method by examining a group of neighboring elements possessing a variety of valence band properties. The emission lines studied were the threshold level L_α (valence $\rightarrow L_{III}$ shell) lines obtained from high purity, polycrystalline bulk samples under bombardment by a nearly monoenergetic ($\Delta E \sim 1$ eV) electron beam. The associated L_{III} absorption spectra were obtained in this work as self-absorption curves from the same anode samples. Experimental and instrumental distortions were either eliminated, minimized or explicitly corrected for. The results indicate the presence of some anomalous emissions on the high energy side of the L_α line in elements possessing a large density of unfilled valence levels just above the Fermi energy. The valence band emission line shape for these elements (iron, cobalt, and nickel) is found to be strongly dependent on the incident electron beam energy even for near-threshold-level excitations. Analysis of the emission and self-absorption curves demonstrates that the x-ray spectroscopic method is capable of exposing meaningful differences among the valence band energy structures of the solids examined here.

The electronic properties of titanium interstitial and intermetallic compounds from soft x-ray spectroscopy, J. E. Holliday, *SP323*, pp. 329-333 (Dec. 1971).

Key words: Electron concentration; electronic density of states; localized states; soft x ray; titanium compounds.

The $TiL_{II,III}$ emission bands ($3d+4s \rightarrow 2p$ transition) have been obtained from $TiC_{0.95}$ and TiN_x ($x = 0.2$ to 0.8) interstitial compounds and $TiCr_2$, TiCo, TiNi and intermetallic compounds. Additional peaks on the low energy side of the TiL_{III} band from TiC and TiN_x appear to be cross transitions from the $2s$ and $2p$ bands of the nonmetal to the $2p$ level of titanium. Agreement was found between the soft x-ray band spectra and the band calculations of Ern and Switendick on TiC and TiN. The soft x-ray emission spectra from TiC indicated strong admixture of the titanium $3d$ and carbon $2p$ bands which is in disagreement with LCAO band calculations of Lye and Logothetis. However, the $2p$ band of nitrogen was shown to be below the Ti $3d$ band indicating a localized state and a possible transfer of electrons from titanium to nitrogen.

The $TiL_{II,III}$ bands from $TiCr_2$, TiCo and TiNi show a progressive change with increasing electronegativity difference between titanium and the combining element indicating possible ionic character to the bond. No peaks were observed in the low energy side of the TiL_{III} bands, but a distinct splitting was observed in the peak of the TiL_{III} band from TiNi.

Soft x-ray emission spectrum and valence-band structure of silicon, and emission-band studies of germanium, G. Wiech and E. Zöpf, *SP323*, pp. 335-337 (Dec. 1971).

Key words: Carbon; diamond; electronic density of states; germanium; kp method; orthogonalized plane wave (OPW) method; silicon; soft x-ray emission.

With a photon-counting concave grating spectrometer the $L_{2,3}$-emission band of silicon and the energy range of the $M_{2,3}$-emission band of germanium were investigated. The Si L spectrum shows new structural details. The measured intensity distribution for both the K- and L-emission bands of silicon are compared with recent calculations of the K- and L-emission spectra and with the density-of-states curve.

Density of states in α and β brass by positron annihilation, W. Triftshäuser and A. T. Stewart, *SP323*, pp. 339-342 (Dec. 1971).

Key words: Angular correlation; brass; electronic density of states; positron annihilation.

Positron annihilation experiments using a long slit angular correlation apparatus have been performed to investigate the momentum distribution of photons resulting from positron annihilating with electrons in brass. Single crystals of α and β brass which had been oriented along the 100, 110 and 111 directions respectively, were used for the measurements. The counter slits subtended an angle of 0.32 mrad at the sample. Thus, keeping the samples at liquid nitrogen temperature to reduce the positron motion, a total resolution of 0.42 mrad was achieved. The results show clearly deviations from a spherical Fermi surface. The observed anisotropies are found to agree very well with the theoretical predictions based on cross-sectional areas of the Fermi surface.

Compton scattering from lithium and sodium, P. Eisenberger and P. H. Schmidt, *SP323*, p. 345 (Dec. 1971).

Key words: Compton scattering; electronic linear momentum distribution function; lithium; potassium; sodium.

Ion-neutralization spectroscopy, H. D. Hagstrum, *SP323*, pp. 349-357 (Dec. 1971).

Key words: Auger processes; autoionization; density of states; ion-neutralization; transition probability.

The ion-neutralization spectroscopy (INS) is discussed in comparison with other spectroscopies of solids. It is shown that INS probes the local density of the solid at or just outside the solid surface. It is believed that this accounts for the clear-cut differences between INS results and those of other spectroscopies. Because of its unique specificity to the surface region INS is particularly useful in studying the surface electronic structure of atomically clean surfaces and of surfaces having ordered arrays of known atoms adsorbed upon them. In the latter case INS determines a portion of the molecular orbital spectrum of surface molecules formed from the adsorbed foreign atom and surface atoms of the bulk crystal. Such spectra provide information on local bonding symmetry and structure and electrical charging within the surface molecule which is as yet unavailable by any other method. INS is the first attempt to base a spectroscopy of electronic states on a two-electron process. More recent work on experimental and mathematical problems which such a spectroscopy entails are also briefly mentioned in this paper.

Potential and charge density near the interface of a transition metal, E. Kennard and J. T. Waber, *SP323*, pp. 359-373 (Dec. 1971).

Key words: Absorption potential; charge density; metal-vacuum interface; platinum; surface energy.

The early literature on methods of calculating surface energy and charge density and of dealing with potential barriers at an interface are reviewed.

The three dimensional potentials and charge densities were obtained by superimposing the relevant atomic information which had been obtained from Dirac-Slater self-consistent field calculations on free atoms.

The total charge density at each point P was found by summing the contributions from atoms located within a sphere of radius R centered at P. The local exchange was estimated at P by means of Slater's $\rho^{1/3}$ method. This was included with the overlapped atomic Coulomb potentials to obtain the crystal potential near the surface.

Virtual impurity level density of states as investigated by resonance tunneling, J. W. Gadzuk, E. W. Plummer, H. E. Clark, and R. D. Young, *SP323*, pp. 375-379 (Dec. 1971).

Key words: Anderson Hamiltonian; barium (Ba); calcium; chemisorption; electron density of states; field-emission resonance tunneling; germanium; tungsten (W); tunneling; zirconium.

The analogy between a virtual electronic state of an atom adsorbed on a metal surface and an Anderson type magnetic impurity state is pointed out. The density of states of the impurity can be characterized through a knowledge of the host induced shift and broadening of the atomic state. This density of states can be related to the current-voltage characteristics in a field-emission resonance tunneling experiment in the same manner as Appelbaum has done for describing spin flip Kondo type resonance tunneling in junctions.

Experimental current-voltage (field-emission total energy distribution) characteristics for single zirconium, barium, and calcium atoms on atomically perfect tungsten surfaces are analyzed in terms of the resonance tunneling theory described here and the virtual impurity level density of states is thus determined. Preliminary results for a metal-thin semiconductor-vacuum junction are also discussed.

What properties should the density of states have in order that the system undergoes a phase transition?, P. H. E. Meijer, *SP323*, pp. 381-384 (Dec. 1971).

Key words: Density of states; Ising model; Onsager model; partition function; phase transition; Weiss model.

We have solved nothing that needs to be solved regarding the density of states problem in a system that undergoes a phase transition. We, however, raise the question of what conditions the density of state function of the total system (*not* the temperature dependent quasiparticle spectrum) should have in order that we are observing a phase transition. In general, one needs an extremely strong increase in the density—how strong can only be illustrated by using models. From these models we tried to obtain the density of states using the inverse Laplace transform. The results reveal that a vertical slope seems to be a necessary condition. There are reasons to believe that the condition is not sufficient.

On deriving density of states information from chemical bond considerations, F. L. Carter, *SP323*, pp. 385-405 (Dec. 1971).

Key words: Aromatic compounds; chemical bond; electronic density of states; Fermi surface; Pauling radii; transition metals; rare earth intermetallic compounds.

The chemical picture of bond formation between neighboring atoms in crystalline solids can give valuable electronic density of states information including the rough shape and relative filling of bands. In addition, from the representation of the chemical bond in momentum space one can readily predict the distortion of the Fermi surface from sphericity. This latter approach appears to provide an alternate explanation of the apparent attraction of the Fermi surface to the Brillouin zone faces.

The first relationship is best demonstrated in cases where relatively unique schemes of bond formation can be devised. This is possible in many intermetallic compounds having high coordination by the use of orthogonal sets of bidirectional orbitals; their use leads to multicenter bonds or cycles which are approximately orthogonal. Via the Fourier transform, the series of Slater determinants (representing the multicenter bond) can be transformed into momentum p space and then related to the usual band picture. The occupation or filling of bands can be estimated from bond orders of the associated bonds and obtained from known interatomic distances by using Pauling's metallic radii. Bond hybridization is obtained from orthogonality requirements and bond angle considerations characteristic of valence bond theory. These ideas can be applied to FCC and HCP transition metals. For copper one would expect a sharp peak in the density of states corresponding to two unshared filled local d orbitals. In addition there would be a broad bonding band filled with electrons (6 per atom) containing large amounts of p character; and a half-filled s band. As one moves downward through the periodic table to iron while maintaining either FCC or HCP structures the high melting points of the elements involved indicate that the broad bonding band remains relatively unchanged (filled) while the number of electrons in the narrow d band is steadily decreased.

In the rare earth cubic Laves phases of composition AB_2, this relatively simple chemical approach suggests the presence of four bands. The two more important bands are: (1) a large narrow-width density of states band associated with two unshared local d orbitals per B atoms, and (2) a band which is generally more than half-filled associated with all the transition metal B—B as well as the A—B bonds. The other bands include an s band associated with the B atoms which is less than half-filled due to the transfer of electrons from the hyper-electronic B atom, and a band of unusually high d character associated with the A—A bonds and probably not occupied for the lighter rare earth compounds.

From the study of simple σ bonds, Coulson has shown that the momentum distribution function is compressed in the direction of the internuclear axis. By using this idea in conjunction with the Fourier transform of hydrogenic atomic orbitals it is comparatively easy to show that for a CCP transition metal like copper the momentum distribution function has its principal projections in the ⟨111⟩ directions while the BCC transition metals should have projections in the ⟨110⟩ directions. Projections in more complicated structures can be obtained from considerations of bond hybridization and bond order. In summary, we see that the valence bond concepts of bond hybridization and bond order coupled with known structures and bond distances can be used to suggest band shapes, filling, and hybridization. It is apparent that the increased use of chemical concepts in the interpretation of information concerning the electronic density of states is an area of promise.

Electroreflectance observation of band population effects in InSb, R. Glosser, B. O. Seraphin, and J. E. Fischer, *SP323*, pp. 407-410 (Dec. 1971).

Key words: Band population effects; electroreflectance; Fermi level shifts; indium antimonide (InSb); optical transitions; surface potential.

It is found that bias changes applied to *n*-InSb produce shifts in portions of the electroreflectance spectra. We attribute this to changes in the conduction band population produced as the separation between the Fermi level and the bottom of the conduction band is varied. Spectra which displays red, blue, or no shift correlates to electronic transitions starting from, ending at, or bridging the Fermi level. These observations permit a band structure identification of the shifting spectra and optical monitoring of the surface potential.

Spin-orbit effects in the electroreflectance spectra of semiconductors, B. J. Parsons and H. Piller, *SP323*, pp. 411-415 (Dec. 1971).

Key words: Critical points; diamond semiconductors; electroreflectance; gallium antimonide (GaSb); gallium arsenide (GaAs); germanium; semiconductors, diamond; semiconductors, zinc blende; spin-orbit splittings.

Measurements have been made of the electroreflectance spectra of germanium, gallium arsenide and gallium antimonide in the range of photon energies from 0.6 to 6.7 eV. Special attention has been paid to the resolution of multiplicity within the E_0' and E_1' structures. The identification of these structures in terms of critical point interband transitions involving the second conduction band has an important bearing on the band structure of these materials. The data is discussed in terms of the possible identification, within these higher energy multiplets, of spin-orbit splittings associated with the valence band states at Γ and L.

Experimental verification of the predictions of the Franz-Keldysh theory as shown by the interference of light and heavy hole contributions to the electroreflectance spectrum of germanium, P. Handler, S. Jasperson, and S. Koeppen, *SP323*, pp. 417-421 (Dec. 1971).

Key words: Electro-absorption techniques; electroreflectance; Franz-Keldysh theory; germanium; oscillatory dielectric function.

By the use of improved experimental techniques and samples of particular impurity concentration, we have been able to observe as many as eleven half oscillations in electroreflectance spectra of germanium at the direct edge ($\Gamma_8^+ \rightarrow \Gamma_7^-$) at room temperature. In addition, near the experimental sixth half oscillation where the light and heavy hole contributions are of opposite signs, we observe destructive interference which greatly modifies the signal lineshape in that region. The unique characteristics of the resultant lineshape allow the determination of the relative magnitudes of the dipole matrix elements and reduced masses for the two bands in a region of k-space somewhat removed from the Γ-point. The experimental results also demonstrate that neither thermal broadening nor field inhomogeneity need be a problem in electroreflectance measurements.

Variations of infrared cyclotron resonance and the density of states near the conduction band edge of InSb, E. J. Johnson and D. H. Dickey, *SP323*, pp. 423-430 (Dec. 1971).

Key words: Cyclotron resonance; electronic density of states; electron-phonon interaction; InSb; interband transitions; Landau levels.

The electronic density of states near the conduction band edge of InSb with and without a magnetic field is obtained from dispersion relations based upon $k \cdot p$ interactions with nearby bands and parameters determined and confirmed by several intraband experiments including fundamental cyclotron resonance, spin resonance, spin-flip cyclotron resonance, phonon assisted cyclotron resonance and harmonics of cyclotron resonance. The density of states displays effects due to nearby band interactions and due to electron-phonon interaction.

Cyclotron resonances of holes in Ge at noncentral magnetic critical points, J. C. Hensel and K. Suzuki, *SP323*, pp. 431-435 (Dec. 1971).

Key words: Cyclotron resonances; germanium; joint density of states; Landau levels; magnetic; magnetic critical points.

The anomalous, "quantum" cyclotron resonance spectrum of holes in the degenerate valence bands of Ge is analyzed utilizing the concept of a critical point in the magnetic joint density of states. Contrary to previous work done for $k_H = 0$ (where k_H is the hole wave vector along the magnetic field) our results indicate that cyclotron resonance lines originating at critical points away from $k_H = 0$ are responsible for most of the prominent features of the observed quantum spectrum in Ge.

Landau level broadening in the magneto-optical density o states, B. H. Sacks and B. Lax, *SP323*, pp. 437-450 (Dec 1971).

Key words: Delta-function formulation of density of states Green effect; k-conserving transitions; Landau levels; laser semiconductor; magneto-optical density of states; optica density of states; semiconductor laser.

In this paper we derive a convolution integral expressio of the optical density of states for k-conserving transition between broadened Landau levels in crystalline solids. Th convolution is between single Landau level densities o states expressed in a form derived by Kubo. The expressio includes as parameters the reduced mass, magnetic fiel strength, and the strength of the broadening mechanism. W present the results of numerical evaluation of this expres sion for various values of the parameters.

Our consideration is directed to dipolar transition between the $n = 0$ Landau levels of the valence and conduc tion bands, and we assume that the dominant broadening ef fects are intraband scattering processes. This assumption i reasonable in view of the comparative intraband and inter band lifetimes.

The resulting optical density of states function has an ap pearance identical to that of the single band function, bu with the frequency measured from the gap energy replacin the energy measured from the band edge, the reduced mas replacing the single band mass, and a reduced broadenin parameter replacing the single band parameter. Our expres sion for this last parameter is shown to be a consequence o a mutual consistency requirement between the single ban and optical densities of states, and this same requiremen also leads to the reduced lifetime expression encountered i the more conventional Lorentzian formulation.

The electronic structure of disordered alloys, J. L. Beeby *SP323*, pp. 453-463 (Dec. 1971).

Key words: Density of states; disordered alloys; one-elec tron propagator; perturbation expansion; sum rule.

The problem of calculating the electronic density of state in an alloy is considered from first principles. Choosing

suitably simplified model potential a diagrammatic expansion is discussed within which the various existing theories can be compared. Some comments are made on the comparison with experiment.

Local theory of disordered systems, W. H. Butler and W. ohn, *SP323*, pp. 465-469 (Dec. 1971).

Key words: Binary alloys; density of states; disordered systems; periodically continued neighborhood.

The most striking characteristic of crystalline solids is their periodicity. As a result of this feature, theoretical descriptions of physical phenomena in such systems are usually given in wave number or *momentum* space. The reciprocal lattice of a crystal and the Fermi surface of a metal are examples. In a disordered system, on the other hand, there is no such periodicity and momentum space descriptions are much less natural. However, in such systems, physical conditions near a point **r**, in *coordinate* space, become independent of the conditions at a distant point **r'**, provided that $|\mathbf{r}'-\mathbf{r}|$ is large compared to either a characteristic mean free path or some other appropriate length. This suggests that one can analyze a macroscopic disordered system by averaging over the properties of microscopic neighborhoods.

In the present paper we report some details of such a program. Although the point of view is of quite general applicability we have, for the sake of definiteness, studied so far only one type of system: Noninteracting electrons moving in the field of interacting, disordered scattering centers. We have focused especially on the electronic density of states. The macroscopic system is represented by an average over small neighborhoods. If one did not take special precautions, one would encounter one class of errors of the order of d/L where L is a characteristic dimension of the neighborhood, and d is a characteristic atomic dimension; and another class of errors of the order of $1/N$ where N is the number of ions. Both are too large to be tolerable for practical purposes. However, by an appropriate treatment of the statistical mechanics of the scatterers and by periodic repetition of the small neighborhoods, these errors can be avoided. The remaining errors are exponentially small in the ratio $\gamma(L/R)$ where γ is of order unity and R is the smaller of the electronic mean free path or the deBroglie wavelength of the electrons. This exponential convergence of the small neighborhood theory promises to make it a useful practical method for the study of disordered systems, especially very highly disordered ones.

Numerical examples are presented and discussed.

Density of electron levels for small particles, L. N. Cooper nd S. Hu, *SP323*, pp. 473-475 (Dec. 1971).

Key words: Diffusion equation; electronic density of states; "muffin-tin" potential; small particles; two dimensional classical membrane.

The density of electronic levels for small particles is calculated. This differs from the usual expression which is valid as the volume of the sample becomes very large. The leading term of the correction is proportional to the surface/volume of the sample. Depending on the environment the density of electronic levels may be increased or decreased.

One-dimensional relativistic theory of impurity states, M. tęślicka, S. G. Davison, and A. G. Brown, *SP323*, pp. 477-80 (Dec. 1971).

Key words: Impurity states; Kronig-Penney model; one-dimensional Dirac equation.

The one-dimensional Dirac equation is solved for the Kronig-Penney model containing a δ-potential impurity. Depending on certain existence conditions, the impurity states can be classified into two types called relativistic and Dirac impurity states. In the nonrelativistic limit, the Dirac states disappear and the relativistic ones become the ordinary impurity states. A detailed discussion is given of the complete energy spectrum.

The influence of generalized order-disorder on the electron states in five classes of compound-forming binary alloy systems, E. W. Collings, J. E. Enderby, and J. C. Ho, *SP323*, pp. 483-492 (Dec. 1971).

Key words: Binary alloys; Bi_2Te_3; CdSb; copper-gold (Cu-Au); Cu_3Au; CuPt; Cu_3Pt; ductility; electrical resistivity; Hall effect; magnesium bismide (Mg_3Bi_2); mechanical behavior; melting; model potential of Heine and Abarenkov; nickel aluminide; order-disorder; Peierls barriers; Pt-Cu; silver$_2$ tellurium (Ag_2Te); Ti-Al; TiCo; TiFe; TiNi; Tl_2Te.

The influence of generalized order-disorder (including solid-state order-disorder, and melting) on electronic structures will be discussed for various types of binary intermetallic compounds which, for the purpose of discussion, will be arbitrarily subdivided into five classes. Classes A and B exhibit solid-state order-disorder (O-D) reactions. In the first of these the atomic potentials are sufficiently similar that the use of low-order perturbation theory at all concentrations is valid. The effect of O-D on such alloys will be described in relationship to the density-of-states, as measured by low-temperature specific heat and magnetic susceptibility, and to the electrical transport properties, particularly the conductivity and Hall coefficient. We then consider from the same standpoint a second type of system in which the potentials are sufficiently different as to produce bound states which appear in the *ordered* form. The disappearance of these bound states when the alloy disorders gives rise to characteristic electronic behavior.

The effect of O-D on the experimental parameters referred to above will be compared for the two types of systems. In particular, published data for Cu-Au, as a representative example of the first type of system, will be contrasted with new electronic property data for Ti-Al, and compared with recent experimental results for Pt-Cu, which occupies an intermediate position. In class C, which is metallic in the solid, and in classes D and E which are semiconducting in the solid, structural order persists up to the melting point. For D the liquid is metallic, and data are presented for Bi_2Te_3, a typical system of this class. The conditions for the existence of intermetallics of class E are extreme, and give rise to nonmetallic behavior in the liquid.

These various systems will be discussed in terms of differences in atomic potentials. The major problems involved in giving precise estimates of the required differences will be outlined and a critical account of the use of concepts like the electronegativity parameter will be presented.

Localized states in narrow band and amorphous semiconductors, D. Adler and J. Feinleib, *SP323*, pp. 493-503 (Dec. 1971).

Key words: Amorphous semiconductors; Anderson transition; augmented plane wave method (APW); chalcogenide glasses; electronic density of states; Franck-Condon principle; localized states; Mott insulator; NiO; optical density-of-states; photoconductivity; photoemission; polaron.

The electronic density-of-states is discussed in situations where some of the states near the Fermi energy are local-

ized, due to either intraionic Coulomb repulsion or disorder. When localized states are present, the Franck-Condon principle necessitates separate electrical and optical densities-of-states. In the case of ionic Mott insulators, it is shown that doping or nonstoichiometry drastically affects the energy-band structure. For the particular example of NiO, introduction of Li^+ impurities or excess oxygen leads to a large upward displacement of the $2p$ band associated with the oxygen ions, moving it sufficiently near the Fermi level that hole conduction in the $2p$ band predominates above 200 K, in agreement with the available experimental data. In the case of amorphous semiconductors, it is shown that introduction of electron-electron and electron-phonon interactions results in a shift of the relative position of the localized parts of the valence and conduction bands, as well as shifts of the localized states relative to the itinerant states. However, the qualitative features of the model of Cohen et al. are preserved.

A cluster theory of the electronic structure of disordered systems, K. F. Freed and M. H. Cohen, *SP323*, pp. 505-507 (Dec. 1971).

Key words: Amorphous semiconductors; band tail of localized states; cluster theory; coherent potential approximation; disorder systems; electronic structure; Neel temperature.

The equation of motion for the averaged Green's function in an alloy couples the latter to the Green's function for which the average is restricted so that the composition of one atom is held fixed. The average Green's function may be regarded as the Green's function for a zero-atom cluster, and it is coupled to the Green's function for a one-atom cluster. There is thus an infinite hierarchy of equations of motion in which the n-atom functions are coupled to the $(n+1)$-atom functions. The coherent potential approximation of Soven corresponds to truncation in the equation of motion of the one-atom function. We have generalized the coherent potential theory to a theory the n-atom functions with truncation in the equation of motion of the $(n+1)$-atom function. The formalism is developed and a few of the results obtained thus far are presented in this paper.

***T* matrix theory of density of states in disordered alloys—application to beta brass,** M. M. Pant and S. K. Joshi, *SP323*, pp. 509-514 (Dec. 1971).

Key words: Alloys; brass; delta-function potential; disordered systems; Green's functions; Korringa-Kohn Rostoker (KKR); "muffin-tin" potential; short-range-order parameters; spectral density of states; t-matrices.

The T matrix theory of electronic states in disordered systems, has been used to determine the spectral density for states of various symmetries, for binary alloys. Soven's averaged t matrix procedure is improved by retaining the distinction between the t matrices of the constituents, and introducing partial Greenians of the Pant-Joshi theory. Information about the pair-correlation function obtained by critical neutron scattering method is used to evaluate the partial Greenians, as well as the crystalline potentials for the constituents. In order to facilitate computation of the t matrices, these potentials have been replaced by energy-dependent model potentials. The parameters of the model potentials are determined by the requirement that they yield logarithmic derivatives (of the radial wave function at the muffin-tin spheres) identical with those generated by the real potentials. The scheme has been applied to disordered beta-brass. The separation in energy of the peaks of the spectral density of states at the high symmetry points of the Brillouin zone, are compared with experimental results, and with the results obtained by the virtual crystal approximation.

On the terms excluded in the multiple-scattering series, R. M. More, *SP323*, pp. 515-518 (Dec. 1971).

Key words: Delta-function potential; excluded terms; Green's functions; multiple-scattering series; rigid-band approximation; scattering phase-shifts; t-matrices.

We have evaluated certain of the excluded terms in the multiple-scattering series for a simple soluble potential. We discuss three aspects of the result: first, the reduction to "on-shell" quantities; second, the numerical contribution of the excluded terms; and third, the analytic properties of these terms.

On non-localization at the centre of a disordered bound band, F. Brouers, *SP323*, pp. 521-526 (Dec. 1971).

Key words: Cellular disorder; disordered systems; electronic density of states; localization life-time; quasi-localized state; tight-binding.

It is shown for a three dimensional model of tightly bound electrons with cellular disorder that the electronic states at the middle of a continuous band cannot be strictly localized. This conclusion is just the opposite of what has often been suggested.

Nevertheless, an approximate calculation of the electron localization "life-time" suggests that with increasing disorder the localized character of the electron states become more pronounced.

It is argued that in such a system there is no sharp transition between localized and non-localized regions of the energy spectrum.

The half-filled narrow energy band, L. G. Caron and G. Kemeny, *SP323*, pp. 527-541 (Dec. 1971).

Key words: Antiferromagnetic insulator; first order phase transition; half-filled narrow energy band; Mott state paramagnetic metal; t-matrix.

The antiferromagnetic and paramagnetic states of a half-filled narrow energy band are investigated using a t-matrix approach. This method is justified despite the high particle density in the system. A phase diagram including the Mott state is given. Employing the gap of the antiferromagnetic insulator as a variational parameter, it is shown that the increase of the band width potential energy ratio leads to a first order phase transition into the paramagnetic metal state, nearly where Mott has estimated it to occur.

Electronic structure of gold and its changes on alloying, E. Erlbach and D. Beaglehole, *SP323*, pp. 545-549 (Dec. 1971).

Key words: Electronic constant; electronic density of states; gold (Au); gold-copper alloys (Au-Cu); gold-iron alloys (Au-Fe); gold-silver alloys (Au-Ag); optical constants; reflectivity.

We have measured the changes in reflectivity upon alloying small amounts of Ag, Cu and Fe into Au. By means of Kramers-Kronig analysis, we have deduced the changes in ϵ_2 produced by this alloying. We relate these changes to shifts in the position and character of the electron energy bands in gold.

Density of states of AgAu, AgPd, and AgIn alloys studied by means of the photoemission technique, P. O. Nilsson, *SP323*, pp. 551-554 (Dec. 1971).

Key words: Coherent potential approximation; electronic density of states; Friedel screening theory; photoemission; silver-gold alloys (AgAu); silver-indium alloys (AgIn); silver-palladium alloys (AgPd); virtual crystal approximation.

The density of states of AgAu, AgPd, and AgIn alloys have been studied by means of the photoemission technique. General trends of the results are compared with the predictions from simple models of alloys. The rigid-band or virtual-crystal approximation cannot explain the results, while model calculations in the coherent potential approximation reproduces the observed density of states. The Friedel screening theory explains the shift of the Fermi level on alloying.

Density of states information from low temperature specific heat measurements, P. A. Beck and H. Claus, *SP323*, pp. 557-562 (Dec. 1971).

Key words: Alloys; density of states; low temperature specific heat; magnetic specific heat; many-body effects; superconductivity.

The calculation of one-electron density of state values from the coefficient γ of the term of the low temperature specific heat linear in temperature is complicated by many-body effects. In particular, the electron-phonon interaction may enhance the measured γ as much as twofold. The enhancement factor can be evaluated in the case of superconducting metals and alloys. In the presence of magnetic moments, additional complications arise. A magnetic contribution to the measured γ was identified in the case of dilute alloys and also of concentrated alloys where parasitic antiferromagnetism is superimposed on an over-all ferromagnetic order. No method has as yet been devised to evaluate this magnetic part of γ. The separation of the temperature-linear term of the specific heat may itself be complicated by the appearance of a specific heat anomaly due to magnetic clusters in superparamagnetic or weakly ferromagnetic alloys.

Electronic density of states determined by electronic specific heat measurements, T. Mamiya and Y. Masuda, *SP323*, pp. 565-568 (Dec. 1971).

Key words: Augmented plane wave method (APW); Debye temperatures; electronic density of states; electron-phonon coupling constant; electronic specific heat; superconducting transition temperatures; tantalum (Ta); tantalum-rhenium (Ta-Re) alloys; Ta-Re alloys.

The superconducting transition temperatures, electronic specific heats, and Debye temperatures have been recently measured by us for 5*d* transition-metal alloy series Ta-Re. By making use of these data and the theoretical predictions by McMillan, we have deduced the electron-phonon coupling constant and bare electronic density of states. The density of states is compared with the theoretical one derived from band-structure calculations of Ta using the augmented-plane-wave (APW) method by Mattheiss.

Low-temperature specific heats of hexagonal close-packed erbium-thulium alloys, A. V. S. Satya and C. T. Wei, *SP323*, pp. 571-577 (Dec. 1971).

Key words: Anti-ferromagnet; anti-phase domain; augmented plane wave method (APW); Curie temperature; electronic density of states; enhancement factors; erbium; erbium-thulium alloys; ferro-magnetic spiral structure; gadolinium; itinerant 4*f*-band model; lanthanides; low-temperature specific heat; rare-earth lanthanides; specific heats; spin-wave theory; thulium.

The specific heats of hexagonal close-packed erbium and thulium metals, and three of their isostructural alloys were measured in the liquid-helium temperature range between 1.3 and 4.2 K for examining the validity of the localized 4*f*-band model, on which the current theories of the rare-earth metals are based. Barring possible uncertainties in the magnetic properties of the samples and their impurity contents, the coefficients of the specific-heat component linear in temperature calculated from the present data range in values approximately two to twenty times the constant electronic specific-heat coefficient predicted by the above model for all the hexagonal close-packed rare-earth lanthanides. Possible explanations for such discrepancies are discussed. An itinerant 4*f*-band model based on the one-electron-band model suggested by Mott is proposed for the lanthanides as an alternative to the localized 4*f*-band model.

Low-temperature specific heats of face-centered cubic Ru-Rh and Rh-Pd alloys, P. J. M. Tsang and C. T. Wei, *SP323*, pp. 579-585 (Dec. 1971).

Key words: Electronic density of states; electronic specific heat; palladium (Pd); Rh; Rh-Pd alloys; Ru-Rh alloys; specific heat; tight-binding approximation.

The specific heats of Rh, Pd, and a number of face-centered cubic Ru-Rh and Rh-Pd alloys were determined between approximately 1.4 and 4.2 K. Whereas the C/T vs. T^2 plots for the Ru-Rh alloys show a straight-line behavior, a low temperature anomaly is observed in similar plots for Pd and the Rh-Pd alloys below 2.2 K. This low temperature anomaly appears to be most pronounced in the alloy $Rh_{0.78}Pd_{0.22}$, and diminishes with increasing Rh or Pd. The electronic specific heats of these alloys are generally high with a minimum occurring at $Ru_{0.30}Rh_{0.70}$. A portion of the total density-of-states curve for the outer electronics in face-centered cubic transition metals is derived numerically from the present results and those available in the literature as a first approximation. Such a curve shows qualitative agreement with the first peak below Fermi level of the theoretical total *s-d* energy of Pd calculated by Janak et al.

Density of states of transition metal binary alloys in the electron-to-atom ratio range 4.0 to 6.0, E. W. Collings and J. C. Ho, *SP323*, pp. 587-596 (Dec. 1971).

Key words: Alloys; bcc transition metal alloys; charging effect; electronic density of states; Ginzburg-Landau coherence length; G.P. zone; Hf-Ta; low-temperature specific heat; magnetic susceptibility; omega phase; rigid-band approximation; superconducting transition temperatures; tantalum-tungsten (Ta-W); Ti-Mo; titanium-molybdenum (Ti-Mo) alloy; tungsten (W); W-Re.

Using Ti-Mo as a prototype of binary bcc transition metal alloys for $4 < e/a < 6$, densities-of-states at the Fermi level, $n(E_F)$, have been studied using low-temperature specific heat augmented by magnetic susceptibility (χ) measurements. A survey of the literature has revealed that the principal descriptors of density of states, γ (the electronic specific heat coefficient), and T_c (the superconducting critical temperature), generally decrease as e/a decreases below about $e/a \sim 4.3$ to 4.5. The maxima in γ and T_c so induced have usually been interpreted as indicating the existence of maxima in $n(E_F)$ near $e/a \cong 4.5$ for bcc alloys. But since the region $e/a \lesssim 4.5$ also corresponds to that in which a submicroscopic hexagonal-structured precipitate (ω-phase) always appears in quenched alloys, a detailed study of microstructure was undertaken in conjunction with the electronic property measurements. It was concluded that a steadily increasing abundance of an ω-phase precipitate was responsi-

ble for the observed drops in γ, T_c, and χ below $e/a \cong 4.5$. Because of the fineness of the precipitate (70-330 Å) the physical property results themselves are indistinguishable from those usually associated with single-phase materials. Using magnetic susceptibility at elevated temperatures, where the prototype Ti-Mo alloy is known to be single phase bcc, it has been shown that $n(E_F)_{bcc}$ increases monotonically as e/a is reduced from 6 to 4, in agreement with deductions based on the results of recent band-structure calculations on bcc $3d$ transition metals.

Specific heat of vanadium carbide, 1-20 K, D. H. Lowndes, Jr., L. Finegold, D. W. Bloom, and R. G. Lye, *SP323*, p. 597 (Dec. 1971).

Key words: Electronic density of states; specific heat vanadium carbide.

Relevance of Knight shift measurements to the electronic density of states, L. H. Bennett, R. E. Watson, and G. C. Carter, *SP323*, pp. 601-642 (Dec. 1971).

Key words: Electronic density of states; hyperfine fields; Knight shift; nuclear magnetic resonance; susceptibility; wave functions.

The Knight shift, $\mathscr{K}$, measures the magnetic hyperfine field at the nucleus produced by the conduction electrons which are polarized in a magnetic field. Knight shifts are often dominated by the Pauli term and, in its most simple form, can be written as $\mathscr{K} = \langle a \rangle \chi_p$. Here χ_p is the conduction electron Pauli spin susceptibility which depends on the density of states at the Fermi level, $N(E_F)$, and $\langle a \rangle$ is an average magnetic hyperfine coupling constant associated with the wave function character at the nucleus, $|\psi_F(0)|^2$, for conduction electrons at the Fermi surface.

The Knight shift therefore provides, through $\langle a \rangle$, insight into the wave-function character associated with $N(E_F)$. Calculations of $\langle a \rangle$ involving an averaging over k-space have been attempted for a few simple metals up to the present time. For alloys and intermetallic compounds, rather different $\langle a \rangle$'s are experimentally observed for different local environments, indicating that $\mathscr{K}$ samples the variation in *local* wave-function character, or a variation in *local* density of states. There is no unique way of separating the local variation of $N(E_F)$ from $|\psi_F|(0)|^2$.

In this article the methods developed for relating $\mathscr{K}$ to the electronic properties for most of the types of cases encountered in the literature are reviewed. We discuss "simple" metals including problems of orbital magnetism and changes in $\mathscr{K}$ caused by electronic transitions such as melting. Knight shifts and their temperature dependence in metals and intermetallic compounds involving unfilled d shells, are discussed. We give estimates of atomic hyperfine fields due to single electrons, appropriate to those cases where problems due to electronic configurations do not make deductions from experiment too ambiguous. A density of states curve calculated for Cu is given, showing the relative importance of s-p, and d character for that metal. In a qualitative sense this Cu curve implies such information for other transition metals. We discuss alloy solid solutions for the cases where a "rigid" band model might be used to explain the results, and for cases where local effects have to be taken into account. The charge oscillation and RKKY approaches and their limitations are reviewed for cases of dilute nonmagnetic and d- or f-type impurities.

Pauli paramagnetism in metals with high densities of states, S. Foner, *SP323*, p. 645 (Dec. 1971).

Calculation of the Knight shift in beryllium, J. Gerstner and P. H. Cutler, *SP323*, p. 649 (Dec. 1971).

Key words: Beryllium; Knight shift; orthogonalized plane wave (OPW); pseudopotential.

Knight shifts of the alkali metals, A. Meyer, G. M. Stocks, and W. H. Young, *SP323*, pp. 651-657 (Dec. 1971).

Key words: Alkali metals; alloys; cesium; Knight shift; lithium; potassium; pressure dependences; pseudopotential; resistivity ratios; rubidium; sodium; thermoelement power.

K, Rb and Cs, being leading members of transition series, have pseudoatoms with virtual bound d states; Li has a somewhat analogous p state. By contrast, Na has no such states. Evidence is offered of how the associated scattering accounts for the following observed electron transport properties: (a) Under pressure, the resistance of Li rises and, eventually, so do those of Cs, Rb and K, (b) the thermopower of Li is anomalous (positive) and stays so under pressure while that for Cs very quickly becomes positive when pressure is applied.

The same features can now be used in the theory of Knight shifts to explain the following observations. (c) The conduction electron susceptibility for Li is enhanced very significantly above that for free (and even interacting) electrons, (d) the nuclear contact density in Li is much lower than that predicted by one-OPW theory, (e) the Knight shifts of Li and Na decrease and those for Rb and Cs increase when pressure is applied, (f) the Knight shift for a given ion increases when it is successively resonated in Na, K, Rb, and Cs matrices. The key to the interpretation of (e) and (f) is the variation in the density of states (and therefore susceptibility) under conditions of pressure change and alloying.

Role of exchange effects on the relationship between spin susceptibility and density of states of divalent metals, P. Jena, T. P. Das, S. D. Mahanti, and G. D. Gaspari, *SP323*, pp. 659-662 (Dec. 1971).

Key words: Be; Cd; density of states; divalent metals; exchange enhancement; Mg; spin susceptibility.

The influence of exchange and correlation of conduction electrons on the spin susceptibility, χ_s, is well understood in alkali metals. There is reasonable agreement between theoretical and experimental results where the latter are available. No such comparison has been reported for the divalent metals, mainly because of a lack of experimental information. Only for Be is χ_s known (from spin resonance measurements). We have made semi-empirical estimates of χ_s for Mg and Cd by adjusting the measured Knight shifts with theoretical values of the core polarization and $\langle \psi^2(0) \rangle$. The values of χ_s so deduced are compared to theoretical estimates made by the method of Silverstein, who treated the exchange enhancement by an interpolation procedure analogous to that of Nozières and Pines for calculating correlation energies, and included the effects of band structure through the calculated thermal (band) effective mass. Agreement is good for Mg, which behaves more like a free electron metal, and poor for Be and Cd. Possible sources of the discrepancies are discussed.

Correlation of changes in Knight shift and soft x-ray emission edge height upon alloying, L. H. Bennett, A. J. McAlister, J. R. Cuthill, and R. C. Dobbyn, *SP323*, pp. 665-670 (Dec. 1971).

Key words: Aluminum oxide (Al_2O_3); electronic density of states; gold aluminide ($AuAl_2$); Knight shift; magnesium-aluminum alloy phases; nickel aluminide (NiAl); soft x-ray emission.

In simple metals and alloys—those having no significant local *d*-character at or near the Fermi level—the Knight shift provides a measure of the local *s*-electron density of states. If the particular atom under study has a *p*-like core level, then soft x-ray emission arising from transitions of electrons at the Fermi level into *p*-like core vacancies should provide a similar measure. Using Al as the example, we compare results of these two techniques by studying fractional changes, relative to Al metal, of the Knight shift and $L_{2,3}$ soft x-ray emission edge height of Al in NiAl, $AuAl_2$, Mg_2Al_3, $Mg_{17}Al_{12}$, and Al_2O_3. A distinct correlation is observed.

Tunneling measurements of superconducting quasi-particle density of states and calculation of phonon spectra, J. M. Rowell, *SP323*, pp. 673-679 (Dec. 1971).

Key words: Density of states; phonons; semiconductors; superconductivity; tunneling.

It is an unfortunate fact that the tunneling technique, which has proved incredibly successful in the study of superconductivity, has given little information about the normal state properties of metals and semiconductors. It will be shown that, in the determination of the superconducting quasi-particle density of states, it is the change in density induced by the onset of superconductivity which is measured rather than the total density.

Returning to the problem of normal materials, a review of the limited achievements and failures of tunneling will be presented. This will include the influence of band edges on tunneling in *p-n* diodes and metal-semiconductor contacts, the structures observed in tunneling into bismuth and the negative results obtained in nickel and palladium. The dominant effect of the change in barrier shape in most of these tunneling characteristics will be illustrated.

Density of states from superconducting critical field measurements, G. Dummer and D. E. Mapother, *SP323*, pp. 681-684 (Dec. 1971).

Key words: Critical field; density of states; In; pressure dependence; superconductivity; Tl.

For a superconducting metal, the entropy difference, ΔS, between the normal and superconducting states is thermodynamically related to the critical field, H_c, by the equation

$$\Delta S = S_n - S_s = 1\ (VH_c/4\pi)\ (dH_c/dT),$$

where V is the molar volume and T is the absolute temperature. As the temperature approaches 0 K, it can be shown that ΔS is dominated by the normal electronic entropy, γT, where γ is the temperature coefficient of the normal electronic specific heat. This behavior has been known for a long time but its application has been largely confined to inferences based on conjectural extrapolations of H_c data measured about 1 K. In the limit of very low temperatures where $\Delta S = \gamma T$, it follows that

$$H_c^2(T) = H_0^2 - (4\pi\gamma/V)T^2,$$

where H_0 is the limiting value of H_c at 0 K. For most superconductors the range of validity of this expression lies below 1 K but new techniques have made this range relatively accessible in recent years. Within this range precise static measurements of H_c and T permit determination of the ratio, $\gamma^* = (\gamma/V)$, with a relative accuracy of about 1:3000. This is considerably better than the accuracies typically obtained in low temperature calorimetry. This method has been used to study the change in γ^* under hydryostatic pressures up to 1000 atm for In and Tl. Nonlinear changes in γ^* are clearly resolved for the first time, despite the relatively low values of applied pressure. For In the values of γ^* show a parabolic decrease with increasing pressure. The results for Tl show an initial increase in γ^* which reaches a maximum near $p =$ 500 atm. For larger pressures the value of γ^* shows the normal decrease with increasing p.

Temperature dependence in transport phenomena and electronic density of states for transition metals, M. Shimizu, *SP323*, pp. 685-690 (Dec. 1971).

Key words: Chromium; electronic density of states; iridium; low-temperature specific heat; magnetic susceptibility; molybdenum; niobium; palladium (Pd); platinum; rhenium; rhodium; rigid band approximation; tantalum (Ta); thermal conductivity; thermoelectric power; transition metal; transport properties; tungsten (W).

The calculated results of the temperature variations of electronic specific heat and spin susceptibility and their comparison with the experimental results for various transition metals are briefly summarized. In these calculations the empirical densities of states, which were determined in the rigid band model from the experimental data of low temperature specific heat coefficient, were made use of. In a model similar to the Mott model of *s-d* scattering, the electrical resistivity, thermal conductivity, and thermoelectric power have been calculated at high temperatures for palladium, platinum, rhodium, iridium, molybdenum, and tungsten, by assuming appropriate electronic structures and making use of the same empirical densities of states. The calculated temperature dependences of electrical resistivity, thermal conductivity, and thermoelectric power and the sign of the thermoelectric power at high temperatures are found to be strongly dependent on the shape of the density of states and the position of the Fermi level. It is shown that all of these temperature dependences and the sign of the thermoelectric power are consistent with the experimental results. It is confirmed that there is a strong correlation between these temperature dependences and those of the electronic specific heat and spin susceptibility.

Metal-semiconductor barrier junction tunneling study of the heavily doped n-type silicon density of states function, Y. Hsia and T. F. Tao, *SP323*, pp. 693-712 (Dec. 1971).

Key words: Antimony-doped silicon; arsenic-doped silicon (As doped Si); band absorption; band tailing; depletion layer barrier tunneling; electronic density of states; Esaki diode; gallium-arsenide (GaAs); heavy doping with As, Ga, P, Sb; luminescence experiments; P doped Si; Schottky-barrier; silicon; transport properties; tunneling.

Experimental and analytic techniques and procedure used in the study are described. Experimental data showing the dependency of the Fermi level on the dopant types of the heavily doped *n*-type silicon are reported. A dopant type dependent density of states effective mass is postulated to describe the effect of different dopants on the Fermi level. The deviation of the experimental data curve from the calculated curve is ascribed to the effect of degenerate semiconductor band tailing. In addition, through interpretation of incremental conductance versus applied bias characteristic curves of the different tunnel junction evaluated, a consistent description of the density of states function of the heavily doped silicon is obtained. The density of states function, dependent on the dopant type and dopant concentration, is generally parabolic above the band edge, but towards the band edge, band tailing can be severe.

The effect of hydrostatic pressure on the galvano-magnetic properties of graphite, I. L. Spain, *SP323*, pp. 717-725 (Dec. 1971).

Key words: Electronic density of states; galvano-magnetic properties; graphite; Hall Effect; magneto-resistance; pressure effects.

Measurements of the Hall Effect and magneto-resistance in crystals of graphite with current flow in the basal planes at high pressures are described. Galvano-magnetic measurements enable the magneto conductivity tensor components σ_{xx} and σ_{xy} to be obtained, and from them the electron and hole densities and mobilities. The results are compared with the band model for the semi-metal graphite proposed by Slonczewski and Weiss. Of particular interest at the present time is the information that these results give about the assignment of carriers at the symmetry point K in the Brillouin zone of graphite and the properties of mobile minority carriers.

Electrical resistivity as a function of hydrogen concentration in a series of palladium-gold alloys, A. J. Maeland, *SP323,* pp. 727-729 (Dec. 1971).

Key words: Electron donation model; electronic density of states; gold-palladium alloys; hydrogen absorption; hydrogen in palladium-gold alloys; palladium-gold alloys; rigid-band approximation.

The changes occurring in the electrical resistance of a series of gold-palladium alloys during hydrogen absorption have been measured. The results are presented for each alloy in the form of relative resistance, R/R_0 vs. hydrogen concentration H/M; R is the resistance of a particular gold-palladium alloy containing a certain amount of hydrogen, given by H/M, the atomic ratio of hydrogen to metal, and R_0 is the resistance of the same *hydrogen free* alloy. For pure palladium the relative resistance increases as a function of hydrogen concentration to a maximum value of ~ 1.80 at $H/M \simeq 0.75$; further hydrogen absorption results in a decrease in R/R_0. Similar maxima are found in some gold-palladium alloys; however, the maxima occurs at decreasing R/R_0 values and also shifts to lower H/M values with increasing gold concentrations. At sufficiently high gold contents the maximum disappears and a continuous decrease in resistance with increasing hydrogen content occurs. The results are evaluated in terms of the band model.

The volume dependence of the electronic density of states in superconductors, R. I. Boughton, J. L. Olsen, and C. Palmy, *SP323,* pp. 731-734 (Dec. 1971).

Key words: Aluminum (Al); electronic density of states; electronic specific heat; gallium; Gruneisen parameter, electronic; superconductivity; thermal expansion; thorium; volume dependence of density-of-states.

The volume dependence of the electronic specific heat coefficient γ can be obtained from measurements of the low temperature thermal expansion, from observations on the pressure dependence of the superconducting threshold curve, and from the volume change occurring at transition. We make use of recent theoretical results to obtain values of the change in the density of states with volume from the existing experimental data for a number of metals.

Alloy Fermi surface topology information from superconductivity measurements, H. D. Kaehn and R. J. Higgins, *SP323,* pp. 735-736 (Dec. 1971).

Key words: Electronic density of states; Fermi surface; In-Cd alloys; pressure; strain; superconductivity.

Hydrogenation effects on palladium tunnel junctions, W. N. Grant, R. C. Barker, and A. Yelon, *SP323,* pp. 737-739 (Dec. 1971).

Key words: Al-oxide-Pd; electronic density of states; hydrogen in palladium; rigid-band approximation; tunnel junctions.

The effects of hydrogenation on the electron tunneling characteristics of Al-oxide-Pd junctions have been investigated. It is found that the impedance of the junctions increases from 1 to 5 percent with increasing hydrogenation, with the greatest increase occurring at large positive bias on the Pd. We attribute this effect to the introduction of electrons from hydrogen into the *d* bands of palladium.

Calculation of thermodynamic information based on the density of states curves of two allotropes of iron, D. Koskimaki and J. T. Waber, *SP323,* pp. 741-752 (Dec. 1971).

Key words: Electronic density of states; iron; phase transitions; thermodynamic information.

The use of density of states curves to obtain thermodynamic information associated with the allotropic phase transitions in iron is discussed. The density of states curves for both body-centered cubic and face-centered cubic iron are determined using a program which randomly interpolates between previously calculated eigenvalues to generate a large number of new energy solutions. These new eigenvalues enable a more accurate determination of density of states curves than is possible by plotting and averaging the original eigenvalues themselves. The density of states curves determined for each phase are used to obtain the energy sum of the eigenvalues of the valence electrons, the shift in the Fermi potential with temperature for the two curves, and the electronic specific heat versus temperature curves for both phases of iron over the temperature range from 0 K to the melting point.

Potential-independent features of crystal band-structure, M. M. Saffren, *SP323,* p. 755 (Dec. 1971).

Key words: Band structure; crystal potential; electronic density of states; pseudopotential.

Nonlinear optical susceptibility of semiconductors with zinc blende structure, M. I. Bell, *SP323,* pp. 757-766 (Dec. 1971).

Key words: Electronic density of states; gallium arsenide (GaAs); indium antimony (InSb); indium arsenide (InAs); joint density of states; nonlinear optical susceptibility; optical properties; semiconductors; zincblende structure; ZnTe.

A simple model for the band structure and electronic density of states in zincblende semiconductors has been used to calculate the dispersion of the nonlinear susceptibility responsible for second-harmonic generation. The calculation. A surprising result of this calculation was the position of the "gold *d*-band" states. These states were located at about -7 eV in $AuAl_2$ and at similar energies in $AuGa_2$ and $AuIn_2$. The interesting optical properties of gold intermetallic compounds (e.g., $AuAl_2$ is violet) are often attributed to the proximity of the gold *d*-bands to the Fermi energy, E_F. If these states really lay at E_F-7 eV, and were as flat (i.e., the $\rho(E)$ peak was as narrow) as the calculation indicated, then they could scarcely affect the compounds' optical properties. To help resolve this "*d*-band dilemma," we undertook measurements of the valence-band spectra of $AuAl_2$ and $AuGa_2$ by x-ray photoelectron spectroscopy (XPS). This method has been described elsewhere: accordingly we describe below only those experimental features of this work that were peculiar to the $AuAl_2$-$AuGa_2$ problem. The two compounds are first treated in separate sections. The results are then discussed in the final section

The reliability of estimating density of states curves from energy band calculations, E. B. Kennard, D. Koskimaki, J. T. Vaber, and F. M. Mueller, *SP323*, pp. 795-800 (Dec. 1971).

Key words: Aluminum; electronic density of states; free electron parabola; QUAD scheme; reliability of smoothing procedures.

The density of states curve for aluminum was calculated for different initial energy bands using the quadratic interpolation method (QUAD) developed by Mueller et al. In one case, a true parabolic energy band was used as input and in the second, the $E(\mathbf{k})$ values were those obtained for aluminum by Snow using the APW method. Deviations from the parabolic density of states curve were found to be inversely proportional to the number of $E(k)$ values per histogram box and hence inversely proportional to the square root of the number of **k** points in the Brillouin zone. It was necessary to use 100,000 points to obtain a relative deviation of 0.3%. In the second case, the self consistent band calculations for 2048 points in the full Brillouin zone and for a subset of 256 of these were used as input data. The effect of increasing the number of input values was assessed for 25,000 random points in the Brillouin zone. The relative errors were 26 and 9 respectively for 256 and 2048 points.

The effects of "smoothing" as an alternative method of reducing statistical error in computing density of states curves are also discussed.

tion requires no adjustable parameters, and results have been obtained for GaAs, InAs, ZnTe, and InSb in substantial agreement with experiment in the energy range 0-2.0 eV.

Model density of states for high transition temperatures beta-ungsten superconductors, R. W. Cohen, G. D. Cody, and L. J. ieland, *SP323*, pp. 767-773 (Dec. 1971).

Key words: Beta-tungsten; lattice transformation; model electronic density of states; superconductivity.

We have applied a simple density of states model to the problem of superconductivity in high T_c beta-tungsten superconductors. If we assume that the interaction responsible for superconductivity is predominately between d-band carriers and acoustic phonons via a deformation potential matrix element, simple analytic expressions for the effective electron-electron coupling constant λ and $T_c(\lambda)$ can be obtained. The quantities λ and T_c can then be estimated using parameters determined from an application of the density of states model to the cubic state constants. We are able to establish the simple condition $\lambda > \lambda_{crit} \approx 0.7$ for the existence of a cubic-tetragonal lattice transformation in these materials. Using our result for T_c, we find $T_c \gtrsim 15$ K for all materials which exhibit a lattice transformation. Thus, we have established the relation between high T_c superconductivity and lattice transformation in the β-W compounds.

Summary of the conference on electronic density of states, H. hrenreich, *SP323*, pp. 775-781 (Dec. 1971).

Thermal electron effective mass of rubidium and cesium, D. . Martin, *SP323*, p. 783 (Dec. 1971).

Key words: Cesium; effective mass; electronic density of states; rubidium; specific heat.

Density of states and numbers of carriers from the dHvA effect, S. Hornfeldt, J. B. Ketterson, and L. R. Windmiller, *P323*, pp. 785-790 (Dec. 1971).

Key words: Electronic density of states; de Haas van Alphen effect; Fermi surface; Fermi velocity; Fourier series; spherical harmonics; symmetrized techniques.

With the dHvA effect, one can determine the angular dependence of the extremal area and effective mass over all sheets of the Fermi surface. Using recently developed techniques this data can be inverted and the angular dependence of the Fermi radius and Fermi velocity determined. Techniques have been developed to allow the inversion of both open and closed surfaces. For closed surfaces we use an expansion in symmetry adapted spherical harmonics (to order $l=60$) while for open surfaces a three-dimensional Fourier series representation is used. With this information one may determine, for a given sheet of the surface, the number of carriers $n(E_F)$ and density of states $N(E_F)$ by performing the appropriate integrations.

A note on the position of the "gold 5*d* bands" in $AuAl_2$ and $AuGa_2$, P. D. Chan and D. A. Shirley, *SP323*, pp. 791-793 (Dec. 1971).

Key words: Electronic density of states; gold aluminum two ($AuAl_2$); gold gallium two ($AuGa_2$); x-ray photoelectron spectroscopy.

Switendick and Narath recently proposed a solution for the "$AuGa_2$ dilemma" pointed out by Jaccarino et al. This solution was based on the results of band structure calculations. The density of states for $AuAl_2$ derived from these band-structure calculations were presented at this con-

SP324. **The NBS Alloy Data Center: permuted materials index,** G. C. Carter, D. J. Kahan, L. H. Bennett, J. R. Cuthill, and R. C. Dobbyn, Nat. Bur. Stand. (U.S.), Spec. Publ. 324, 683 pages (Mar. 1971).

Key words: Alloy data; bibliography; index; information; Knight shifts; NMR; soft x ray.

This Index contains literature references to ~ 10,000 research papers on physical properties of metals and alloys. The Index contains all NMR Knight shift papers and soft x-ray emission papers. It also contains many soft x-ray absorption papers and a number of papers on generally related topics such as susceptibilities, specific heats, hyperfine fields, and band structures. The papers are annotated in depth and the coded information put onto a magnetic tape. The Permuted Materials Index was created from this tape, listing alloys under each of their constituent components (i.e., CuNi appears under CuNi and under NiCu alloys).

SP325. **Technical highlights of the National Bureau of Standards Annual Report Fiscal Year 1969,** Nat. Bur. Stand. (U.S.), Spec Publ. 325, 243 pages (Mar. 1970).

Key words: Annual report; technical highlights.

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1969. It lists major programs as they were carried out by the three NBS institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology and by the Bureau's Center for Radiation Research and Center for Computer Science and Technology. Summaries are given of typical projects in measurement engineering, applied mathematics, electricity, metrology, mechanics, heat, atomic physics, radio standards, laboratory astrophysics, cryogenics, analytical chemistry, polymers, metallurgy, inorganic materials, physical chemistry, engineering standards, weights and measures, invention and innovation, vehicle systems research, product evaluation, building research, electronic technology, technical analysis, computer sciences, and radiation research. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, and national and international cooperative activities.

SP326. **Accurate characterization of the high-pressure environment.** Proceedings of a Symposium held at the National Bureau of Standards, Gaithersburg, Md., October 14-18, 1968, E. C. Lloyd, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 326, 343 pages (Mar. 1971).

Key words: Accurate measurement; equation-of-state; fixed points; high pressure; high-pressure equipment; instrumentation; pressure scale; shock wave technique; temperature.

The volume contains 38 papers prepared for the Symposium on Accurate Characterization of the High-Pressure Environment held on October 14-18, 1968, at Gaithersburg, Maryland, under the sponsorship of the National Bureau of Standards and the Geophysical Laboratory at the Carnegie Institution of Washington. The papers are presented with the discussions that occurred during the sessions. The book also includes reports of several informal committees of the conferees on choices of reference pressure materials and on other matters relevant to improved measurement and calibration. The Symposium was intended to provide an authoritative survey of problems and techniques presently in use or proposed for precise high-pressure measurement and for temperature measurement at high pressure. *These proceedings include the following papers (indented):*

Hydrostatic pressures of 50 kbar in a piston-cylinder device: measurement of pressure and characterization of the pressure medium, A. Jayaraman and R. G. Maines, *SP326,* pp. 5-8 (Mar. 1971).

A method suited for making resistivity and other electrical measurements to 50 kbar hydrostatic pressure, using a conventional piston-cylinder device, is described. In this method a Teflon cell is used to contain the pressure medium, which is a 1:1 mixture of *n*-pentane and isoamyl alcohol. After the fluid mixture freezes (at about 46 kbar), further advance of the piston results in uniaxial stress. However, this can be readily relaxed by heating the medium to 70 °C. The resultant isotropic pressure distribution stays when the pressure medium is cooled back to room temperature. The technique of probing the pressure distribution inside the cell, as well as pressure calibration procedure, is described.

Ultrasonic and dilatometric measurements at very high pressures, P. L. M. Heydemann and J. C. Houck, *SP326,* pp. 11-22 (Mar. 1971).

Key words: Bulk modulus; density; dilatometric measurements; high pressure; liquids; solids; ultrasonics.

A short-cylinder and piston assembly and its use for dilatometric and ultrasonic measurements on solids and liquids at pressures up to 40 kbar are described. All necessary corrections for the evaluation of measurements are discussed and the systematic uncertainties are given. It is demonstrated that ultrasonic methods can significantly reduce the uncertainties in the determination of density and bulk modulus of both solids and liquids.

Characterization of the bismuth I-II and barium I-II points under hydrostatic pressure, R. J. Zeto, H. B. Vanfleet, E. Hryckowian, and C. D. Bosco, *SP326,* pp. 25-33 (Mar. 1971).

Hydrostatic pressure experiments were made which have new and important relevance to high-pressure calibration in both liquid and solid pressure systems for the bismuth I-II and barium I-II points on the high-pressure scale. The bismuth I-II transformations were characterized and the mechanism of the solid-state reactions was related to pressure calibration. The strain hysteresis commonly associated with the bismuth I-II point was shown to be invalid and was alternatively explained on the basis of a thermally activated nucleation and growth mechanism which was demonstrated to govern these transformations. With hydrostatic pressure, initiation of the bismuth I-II transformation was observed as a function of kinetic times as long as 15 hours while pressure and temperature were maintained constant. The transformation behavior was a function also of the microstructure, purity, and thickness of the sample. The bismuth I-II transformation was not necessarily sharp with respect to kinetic time. As long as 42 hours were observed for completion of the transformation with very thin samples. Under hydrostatic pressure the bismuth I-II equilibrium point was not midway between the initiation of the I-II and II-I transformations but was located appreciably closer to the former transformation. The bismuth I-II calibration point was correlated between liquid and solid pressure systems. For solid systems it was shown that the "apparent" hysteresis was completely one-sided toward the low-pressure side and that the equilibrium point coincided with the initiation of the I-II transformation which should be employed as the pressure calibration point. The bismuth I-II region of indifference was characterized with respect to nature of the sample and manner of measurement. An experimental technique was indicated by which the center of the region of indifference was reproducible within ±5 bars. The barium I-II point was measured at 56.27 kbar on the basis of a manganin gage under hydrostatic pressure.

The upper bismuth pressure calibration point, J. C. Haygarth, H. D. Luedemann, I. C. Getting, and G. C. Kennedy, *SP326,* pp. 35-37 (Mar. 1971).

The Bi III-V and IV-V equilibrium boundaries were studied by monitoring electrical resistance changes. Extrapolation of the III-V data to 25 °C yields an equilibrium transition pressure of 77.5 ± 1.0 kilobar (kbar). The extrapolation also agrees within experimental error with the pressure of 78.2 kbar determined in a separate experiment at 22 °C. The use of the transition as a calibration point is discussed, and a procedure for estimating the compression-stroke transition pressure from the equilibrium transition pressure is proposed.

Optical interferometry at high pressures, K. Vedam, *SP326,* pp. 39-43 (Mar. 1971).

After a brief review of the present status of optical interferometry at high pressures, the experimental technique of measuring the variation of refractive index with pressure to 7 and 14 kbars with one- and two-stage optical pressure vessels respectively, is described along with some typical results obtained. The need for such measurements on liquids and gases which are used as fluid pressure media is emphasized.

Equipment for generating pressures up to 800 kilobars, N. Kawai, *SP326,* pp. 45-47 (Mar. 1971).

A type of high-pressure apparatus has been developed which extends considerably the range of attainable very high static pressure. It consists basically of a sphere segmented into tapering truncated pistons. Hydrostatic pressures in the sample chamber in the centre of the sphere have reached 800,000 bars (11,600,000 psi). Pressures of over one million bars should be possible with the present technology. Some new and interesting results from high-pressure studies are described.

Manganin resistance gages as accurate instruments for high pressure measurements, Yu. A. Atanov and E. M. Ivanova, *SP326,* pp. 49-51 (Mar. 1971).

The rapid development of modern science and technology foretells the wide application of high hydrostatic pressures from 20 to 40 kbar in the near future. The measurement of

pressures in this range is usually carried out by manganin resistance gages. Many authors, however, report different metrological characteristics of individual manganin gages and present widely differing values of pressure coefficient, reproducibility, stability, nonlinearity, etc. There is no common basis for the selection of interpolation and extrapolation equations relating the change of resistance of a manganin gage with the measured pressure.

In this work an attempt is made to investigate the scatter of metrological characteristics of a large group of identical manganin gages by means of an absolute free piston gage, to find the best extrapolation equation and to evaluate possible errors of pressure measurements over 15 kbar.

A critical review of the effect of pressure on thermocouple emf's, R. E. Hanneman, H. M. Strong, and F. P. Bundy, *SP326,* pp. 53-61 (Mar. 1971).

The effects of high pressure on the emf's of thermocouples are critically reviewed and best currently available thermocouple corrections are presented. The important factors affecting these thermocouple corrections are discussed, including pressure-temperature gradients, contamination, and deformation. A novel method for simultaneous and continuous *in situ* measurement of pressure and temperature within a high-pressure cell through use of dual thermocouples is briefly described.

The effect of pressure on the thermal emf of the platinum/platinum 10 percent rhodium thermocouple, P. M. Bell, F. R. Boyd, Jr., and J. L. England, *SP326,* pp. 63-65 (Mar. 1971).

Pressure dependence of the thermoelectric power of thermocouple materials, P. J. Freud and P. N. La Mori, *SP326,* pp. 67-75 (Mar. 1971).

Single-wire measurements of the pressure dependence of the thermoelectric power were made hydrostatically to 8 kbar for chromel, alumel, copper, and constantan and in a piston cylinder apparatus to 40 kbar for chromel, alumel, platinum, and platinum 10 percent rhodium. The temperature interval covered for the hydrostatic measurements was − 195 to 290 °C and for the piston cylinder measurements it was 30 to 380 °C. A detailed discussion is given of the pressure-temperature distribution within the piston cylinder cell. Pressure emf values are presented with an uncertainty of ± 7 percent.

The effect of pressure on the E.M.F. of thermocouples, I. C. Getting and G. C. Kennedy, *SP326,* pp. 77-80 (Mar. 1971).

Temperature measurement by thermal noise at high pressures, R. H. Wentorf, Jr., *SP326,* pp. 81-89 (Mar. 1971).

The temperature of a small carbon resistor (700 to 3,000 Ω) in a high-pressure cell next to a Pt-Pt10 percent Rh thermocouple was measured by thermal noise. Runs were made at 40 and 50 kbar to temperatures of about 1,400 K. The results suggest that at the highest temperatures the thermocouple indicated temperatures from 40 to 60 K too low, in fairly good agreement with estimates made by other methods.

Equations of state for sodium and aluminum, D. J. Pastine and M. J. Carroll, *SP326,* pp. 91-103 (Mar. 1971).

Equations of state are calculated for sodium and aluminum. In each case this is done by first calculating the 0 K isotherm and then adding the thermal contributions to the pressure. The calculations in both cases are theoretical and very few experimental data are used. Comparisons of theoretical prediction and experimental data are very favorable.

An atomistic theory of shock compression of a perfect crystalline solid, D. H. Tsai, *SP326,* pp. 105-122 (Mar. 1971).

Key words: Equation of state of solids; lattice dynamics; shock compression; shock wave; thermal relaxation.

Lattice dynamical calculations have been employed to study the process of compression of a perfect, two-dimensional, fcc lattice by a strong shock wave. The interaction energy between the lattice points is assumed to be the Morse-type potential function, and the interaction is assumed to extend to the fourth nearest neighbors. The formulation of the dynamical problem is described. The details of the computation of the shock wave stress and density profiles, shock velocity, energy density profile, local energy distribution, velocity distribution, and the components of the Grueneisen parameter are discussed. Of special interest is the thermal relaxation process behind the shock front. It is found that the relaxation time is not constant, and that the steady, relaxed region in the shock profile trails farther behind the shock front with increasing time. The implications of these results on the calculation of the high-pressure equation of state of a crystalline solid are examined.

Effect of 2024 aluminum alloy strength on high-pressure shock measurements, M. van Thiel and A. Kusubov, *SP326,* pp. 125-130 (Mar. 1971).

A shock wave technique is described by which wave profiles may be determined in metals. Piezo-resistance manganin gages were used to determine these profiles to 130 kbars in 2024 aluminum alloy. The data are consistent with the assumption that the Hugoniot is the hydrostat. A maximum of 28 kbars is obtained for the maximum yield strength on the release wave following the strongest shock. The derived loading-unloading curves in the pressure volume and pressure mass velocity planes indicate that errors of about 2 percent are produced by use of purely hydrostatic release paths.

Calculation of equation of state from high-pressure sound velocity data, A. C. Holt and R. Grover, *SP326,* pp. 131-135 (Mar. 1971).

We describe a method for calculating the Mie-Grüneisen equation-of-state parameters for simple metals from shock Hugoniot data and a knowledge of the volume variation of longitudinal sound velocity at high pressure. The theory is applied to the calculation of the equation of state of aluminum.

Shock temperature calculations for silicone fluid, M. Cowperthwaite and J. H. Blackburn, *SP326,* pp. 137-145 (Mar. 1971).

The problem of calculating shock temperature indirectly from experimental data without assuming thermodynamic properties is formulated and solved theoretically. In principle, the $(e-p-v)$ and $(T-p-v)$ equations of state can be constructed in an overlapping domain of the $(p-v)$ plane from a family of Hugoniot curves centered at points of known energy and temperature.

Experiments were performed in an attempt to construct these equations of state for silicone fluid 210. Shock and free surface velocities were measured to determine Hugoniot curves in the 300-kbar regime, and energies and densities were measured from − 30 to + 260 °C along the atmospheric isobar to determine the initial states of the shock wave experiments. In practice, it was necessary to assume a form for the $(e-p-v)$ equation of state, since the differences in volumes between states on Hugoniot curves at the same pressure above 40 kbar were found to be comparable with the experimental error in measuring the volumes of

each of these states. The data were fitted to a Mie-Grüneisen type ($e-p-v$) equation of state with variable C_v and $(\partial p/\partial T)_v$, since Hugoniot point indicated a linear dependence of energy on pressure along an isochore, and C_v varied along the atmospheric isobar. Shock temperatures on the 25 °C Hugoniot were calculated at points of intersection with isentropes and by integrating with constant atmospheric pressure values of C_v. The position of the 296 °C isentrope limits the temperature calculation with isentropes to values below 522 °C and 58 kbar, and the values around 50 kbar are 8 percent lower than those calculated with the 25 °C value of C_v, since C_v increases along the Hugoniot curve. Temperature calculations above 58 kbar assumed the 296 °C value of C_v. Considerably more experimental work would be required over the entire pressure range to permit determining equations of state of silicone 210 without making assumptions.

The equation of state of selected materials for high-pressure references, W. J. Carter, S. P. Marsh, J. N. Fritz, and R. G. McQueen, *SP326*, pp. 147-158 (Mar. 1971).

Effect of pressure on the lattice parameters of lead chalcogenides and nickel arsenide-type compounds, S. Minomura, H. Nagasaki, and I. Wakabayashi, *SP326*, pp. 159-165 (Mar. 1971).

The compressibility and thermal expansion of LiF to 60 kbar and 600 °C as determined by x-ray diffraction: report of progress, L. C. Carrison and C. B. Sclar, *SP326*, pp. 167-171 (Mar. 1971).

Measurements were made of the compressibility of LiF to 60 kbars over the temperature range 25 to 600 °C by high-pressure high-temperature x-ray powder diffraction methods. Pressures were determined by using NaCl as an internal calibrant. These results also provide data on the thermal expansion of LiF between 25 and 600 °C at pressures of 38 and 57 kbar. This paper demonstrates the feasibility of determining the unit-cell volume of crystalline solids under concomitant high pressure and high temperature by *in situ* x-ray methods.

Ultrasonic and static equation of state for cesium halides, G. R. Barsch and Z. P. Chang, *SP326*, pp. 173-186 (Mar. 1971).

Calculation of the *P-V* relation for sodium chloride up to 300 kilobars at 25 °C, J. S. Weaver, T. Takahashi, and W. A. Bassett, *SP326*, pp. 189-199 (Mar. 1971).

The *P-V* relation for the B1 phase of NaCl was calculated up to 300 kilobars at 25 °C by means of the Hildebrand and Mie-Grüneisen equations. The effect of (1) the uncertainty in the parameters used, (2) the functional form for the temperature-dependent part of internal energy, (3) the anharmonic contribution, and (4) the second nearest neighbor repulsion on the calculated *P-V* relation is discussed. It was found that the calculated *P-V* relation for NaCl is sensitive to the value chosen for Bt_0, and that the effect of (2), (3), and (4) on the calculated *P-V* relation is small. The precision for the present calculation has been estimated to be ± 2.5 percent. The calculated *P-V* relation is in agreement within experimental uncertainties with the fixed points on the absolute pressure scale, with that determined by Bridgman up to 100 kilobars, and that obtained by Fritz from shock wave data up to 260 kilobars. Simultaneous determinations of the effect of pressure on the volumes of NaCl and MgO were made by x-ray diffraction on an intimate mixture of these two materials. It was found that the pressure values calculated from the volume of NaCl using the calculated *P-V* relation are in agreement with those calculated from the volume of MgO using the *P-V* relation calculated from the values of Bt_0 and Bt_0' with the Murnaghan equation. This agreement verifies not only the calculated *P-V* relation for NaCl, but also establishes the validity of the internal standard method for pressure determination.

The Hugoniot equation of state of sodium chloride in the sodium chloride structure, J. N. Fritz, S. P. Marsh, W. J. Carter, and R. G. McQueen, *SP326*, pp. 201-208 (Mar. 1971).

The Hugoniot equation of state of NaCl has been obtained by measuring the shock velocity through NaCl on copper and 2024 aluminum base plates. Shock velocities through the base plates and standard impedance-matching were used to obtain the Hugoniot curves for both single-crystal (in various orientations) and pressed-powder samples. The smooth behavior of the resulting shock locus up to 230 kbar indicates that NaCl exists in the sodium chloride structure up to this pressure. In the shock-particle velocity plane the best linear fit to the data reported here is $u_s(\text{km/s}) = (3.528 \pm .012) + (1.343 \pm .009)u_p$. A quadratic fit, which gives a large weight to the measured bulk sound speed in NaCl, is $u_s = 3.403 + 1.5422u_p - 0.07345u_p^2$. Isotherms at 293 K, using different forms for the Grüneisen parameter and a simple Debye model for the specific heat, are calculated from the Hugoniots and are presented here. They should prove useful when NaCl is used as an internal standard in high-pressure x-ray devices.

Consistency in the high-temperature equation of state of solids, L. Thomsen and O. L. Anderson, *SP326*, pp. 209-217 (Mar. 1971).

Four equations of state for solids are examined theoretically for mutual consistency in the high-temperature regime. It is found that neither the Birch-Murnaghan nor the Murnaghan equation can be shown to be consistent with either the Mie-Grüneisen or the Hildebrand equation. An expression is derived for the volume dependence of the Grüneisen parameter $\gamma(\rho)$. A recent theoretical treatment of NaCl, proposed for use as a pressure standard, is neither internally consistent, nor is it sufficiently precise for such a purpose.

The solid-liquid phase line in Cu, R. G. McQueen, W. J. Carter, J. N. Fritz, and S. P. Marsh, *SP326*, pp. 219-227 (Mar. 1971).

Shear strength effects on phase transition "pressures" determined from shock-compression experiments, O. E. Jones and R. A. Graham, *SP326*, pp. 229-237 (Mar. 1971).

Plane-wave shock compression experiments provide an independent, and often unique, method for establishing pressures at which phase transitions occur in solids. The transition stress which is measured in a shock experiment consists of two components: a mean isotropic pressure, and a deviatoric shear stress which is related to the yield strength, i.e. the Hugoniot elastic limit (HEL), of the solid when subjected to shock compression. The effects of the nonzero shear strength of a solid on the measured shock transition stress are discussed, and methods outlined for calculating the isotropic pressure component needed for comparison with hydrostatic results. Comparison requires that the compression to initiate the transition be independent of shear distortion. The shock propagation characteristics of a solid which are necessary for establishing a reliable equilibrium transition pressure are considered. Existing HEL data are collected in an Appendix and permit the importance of shear strength to be assessed for various materials. Shock compression data for phase transitions in Bi, Fe, Ge, CdS, and InSb are analyzed and shear strength corrections applied to obtain transition pressures.

Study of phase transitions in insulators by the dielectric constant technique, G. A. Samara and W. L. Chrisman, *SP326,* pp. 243-249 (Mar. 1971).

This paper proposes the measurement of the dielectric constant and dielectric loss as a probe for detecting and studying the properties of pressure-induced phase transformations in insulators. The measurement is very sensitive, relatively simple, and can be adapted for use in many types of high pressure apparatus. To illustrate the general usefulness of the technique, results on a variety of substances (solids and liquids) obtained from measurements in three different pressure apparatus will be presented and discussed. The substances investigated include a number of alkali and thallous halides, strontium titanate, and water.

Experimental determination of Curie points of ferromagnets up to 90 kilobars—possible use for calibration of high pressure, J. M. Leger, C. Susse, and B. Vodar, *SP326,* pp. 251-256 (Mar. 1971).

Second-order phase transformations which occur without volume discontinuity and theoretically without any hysteresis are suggested as secondary pressure gauges and for interpolation under high pressure in different temperature ranges. Results are presented concerning the shifts of Curie temperatures of some ferromagnets up to 90 kbar. The pressure effect is generally small but may be accurately determined.

Fixed points on the high-pressure scale identified by phase transitions in ammonium fluoride, R. Kaneda, S. Yamamoto, and K. Nishibata, *SP326,* pp. 257-262 (Mar. 1971).

The I-II and II-III transitions in NH_4F, as fixed points on the high-pressure scale, have been investigated under purely hydrostatic conditions at the temperatures of 0, 25 and 50 °C. By means of manganin resistance gages, the transition pressures at 25 °C have been determined to be 3605 ± 10 bar for the I-II and 11531 ± 23 bar for the II-III. Their respective dependences on temperature are +2.5 bar/°C and +20.7 bar/°C. The realization of both transition points is easy at and above room temperature, but at low temperatures the II-III transition is very sluggish.

A review of resistance-jump phase changes useful for high-pressure calibration, F. P. Bundy, *SP326,* pp. 263-270 (Mar. 1971).

The coesite-stishovite transition, S. Akimoto and Y. Syono, *SP326,* pp. 273-277 (Mar. 1971).

The coesite-stishovite transition curve has been determined over the temperature range 550 to 1,200 °C in the pressure range 82.0 to 98.0 kbar by means of a tetrahedral-anvil type of high-pressure apparatus. Amorphous anhydrous silica, α-quartz, coesite, and stishovite were used as starting materials. The transition curve was fitted by the linear equation $P(\text{kbar}) = 69 + 0.024\ T(°\text{C})$ using pressure scale proposed by Jeffery et al. This determination was found to be in a reasonable agreement with the previous data, if the common pressure scale is used. Experimental information for the coesite-stishovite transition was also compared with the stability relation derived from enthalpies and entropies of coesite and stishovite. It was suggested that the pressure scale proposed by Jeffery et al. was underestimated considerably around 100 kbar.

The use of solid-solid transitions at high temperatures for high-pressure calibration, P. N. La Mori, *SP326,* pp. 279-282 (Mar. 1971).

Transition pressures have been determined for bismuth I → 2 and bismuth 2 → 3 to the melting point (183 °C). The transitions parameters of thallium 2 → 1, 1 → 3 and 2 → 3 have been measured to 40 kbar and 220 °C. The thallium 1 → 2 → 3 triple point has been determined as 114 ± 1 °C and 37.4 ± 0.4 kbar. The use of the determined transition parameters as high-pressure, high-temperature fixed points is discussed.

The use of iron and gold for calibration of higher pressure and temperature points, H. M. Strong and F. P. Bundy, *SP326,* pp. 283-290 (Mar. 1971).

Transition pressures of Bi 3-5, Sn, and Fe, M. Contré, *SP326,* pp. 291-296 (Mar. 1971).

Making use of "X type anvil," the change in resistance of two reference metals in each run was simultaneously recorded in order to compare their transition pressures. A linear extrapolation through the well-known points below 60 kbar showed inconsistencies in the most commonly used high pressure scales. The recording of the pistons displacements lead to an exponential extrapolation which gave transition pressures of 78 ± 2 kbar for Bi 3—5, of 102 ± 4 kbar for Sn and of 140 ± 15 kbar for Fe.

On application of mercury melting curve for accurate high-pressure measurements, V. S. Bogdanov, Yu. L. Levin, S. S. Sekoyan, and Yu. I. Shmin, *SP326,* pp. 297-301 (Mar. 1971).

High-pressure scale as determined by x-ray diffraction techniques up to approximately 100 kbar, H. T. Hall, *SP326,* pp. 303-305 (Mar. 1971).

Pressure inhomogeneity: a possible source of error in using internal standards for pressure gages, J. C. Jamieson and B. Olinger, *SP326,* pp. 321-323 (Mar. 1971).

Studies have been made on two intimate mechanical mixtures of NaCl and Nb having different composition at high "pressures" using x-ray diffraction. A plot of V_p/V_o for Nb versus V_p/V_o for NaCl showed a different curve for each of the two mixtures. Our analysis and the consequences of this apparent violation of the criteria for an internal pressure gage are discussed.

Comparison of four proposed *P-V* relations for NaCl, J. S. Weaver, *SP326,* pp. 325-329 (Mar. 1971).

Some comparisons among four *P-V* relations for the Bl phase of NaCl discussed at this symposium are presented. The two scales (Models III and V) proposed by Weaver et al. (this volume) and a 1968 revision of Decker's *P-V* relation (D_{68}) are shown to agree closely. The three models yield zero-pressure thermal expansion curves in reasonable agreement with experiment, but give values for B_{to}' smaller than the measured value. This appears to be due, in part, to the form used for the lattice energy. The three models yield pressures about 2.5 percent smaller than those calculated from the pressure scale (F_{68}) based on Hugoniot data proposed by Fritz et al. (this volume). Comparison of Models III, V, and F_{68} in the $u_s - u_p$ plane suggests that part of this difference must result from either the form chosen for the lattice energy in Models III and V or from the Hugoniot data upon which F_{68} is based. Omission of part of the data used in F_{68} improves the agreement of this model with the sonic value of B_{to}' and partially removes the discrepancy between F_{68} and Models III and V. Suggestions for additional studies which may be useful in choosing a *P-V* relation for NaCl for pressure calibration purposes are presented. It is concluded that, since the differences among these scales are comparable to the experimental uncertainties involved in applying them, and since there is no compelling reason to choose one over the others, any of these scales may be used for the present.

SP327. **Equilibrium critical phenomena in fluids and mixtures: A comprehensive bibliography with key-word descriptors,** S. Michaels, M. S. Green, and S. Y. Larsen, Nat. Bur. Stand. (U.S.), Spec. Publ. 327, 235 pages (June 1970).

Key words: Binary liquid mixtures; critical opalescence; critical phenomena; critical point; critical region; equilibrium critical phenomena; gases; liquids; liquid-vapor systems; phase transitions; ternary liquid mixtures; thermodynamics.

This bibliography of 1088 citations comprehensively covers relevant research conducted throughout the world between January 1, 1950 through December 31, 1967. Each entry is characterized by specific key word descriptors, of which there are approximately 1500, and is indexed both by subject and by author. In the case of foreign language publications, effort was made to find translations which are also cited.

SP329. **An index of U.S. voluntary engineering standards,** W. J. Slattery, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 329, 1,000 pages (Mar. 1971).

Key words: Engineering standards, index of; index of standards, recommended practices, specifications, and test methods; Key-Word-In-Context index of voluntary standards; standards, voluntary, index of.

This computer-produced Index contains the permuted titles of more than 19,000 voluntary engineering and related standards, specifications, test methods, and recommended practices, in effect as of December 31, 1969, published by some 360 U.S. technical societies, professional organizations, and trade associations. The title of each standard can be found under all the significant key words which it contains. These key words are arranged alphabetically down the center of each page together with their surrounding context. The date of publication or last revision, the standard number, and an acronym designating the standards-issuing organization appear as part of each entry. A list of these acronyms and the names and addresses of the organizations which they represent are found at the beginning of the Index.

SP329. Supplement 1. **An index of U.S. voluntary engineering standards,** W. J. Slattery, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 329, Suppl. 1, 459 pages (Dec. 1972).

Key words: Engineering Standards, index of; index of standards, recommended practices, specifications, test methods; Key-Word-In-Context index of voluntary standards; standards, voluntary, index of.

This supplement contains the permuted titles of more than 6,300 standards, specifications, test methods, and recommended practices published by 225 U.S. technical societies, professional organizations and trade associations. Each title can be found under all the significant key words which it contains. These key words are arranged alphabetically down the center of each page together with their surrounding context. The date of publication or last revision, the standard number and an acronym designating the standards-issuing organization appear as part of each entry.

SP329. Supplement 2. **An index of U.S. voluntary engineering standards,** W. J. Slattery, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 329, Suppl. 2, 472 pages (May 1975) SD Catalog No. C13.10:329, Suppl. 2.

Key words: engineering standards, index of; index of standards, recommended practices, specifications, test methods; Key-Word-in-Context index of voluntary standards; KWIC index of standards; standards, voluntary, index of.

This supplement contains the permuted titles of more than 5,700 voluntary engineering standards, specifications, test methods, codes and recommended practices published by 164 U.S. technical societies, professional organizations and trade associations. Each title can be found under all the significant key words which it contains. These key words are arranged alphabetically down the center of each page together with their surrounding context. The date of publication or last revision, the standard number and an acronym designating the standards-issuing organization appear as part of each entry.

SP330, 1972 Edition. **The international system of units (SI),** C. H. Page and P. Vigoureux, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 330, 45 pages (Apr. 1972).

Key words: General Conference of Weights and Measures; International Committee of Weights and Measures; International System of Units; SI; Système International des Unités; Units of Measurement.

This translation from the French "Le Système International d'Unités, (SI)" published originally by the International Bureau of Weights and Measures (BIPM) has been prepared jointly by the National Physical Laboratory, UK, and the National Bureau of Standards, USA. Included are Resolutions and Recommendations of the General Conference of Weights and Measures (CGPM) on the International System of Units, together with relevant extracts from the International Organization for Standardization (ISO) for the practical use of the system.

Appendix I gives in chronological order the decisions promulgated since 1889 by CGPM and the International Committee of Weights and Measures (CIPM) on units of measurement and on SI. Appendix II outlines the measurements, consistent with the theoretical definitions given in this document which metrological laboratories can make to realize the units and to calibrate precision material standards. Appendix III describes the laboratory and the committees which come under the Metre Convention. (Supersedes NBS Special Publication 330, 1971 Edition.)

SP331. **Radioactivity calibration standards.** Proceedings of a special session of the International Conference of the American Nuclear Society Meeting on the Constructive Uses of Atomic Energy, Washington, D.C., November 10-15, 1968, W. B. Mann and S. B. Garfinkel, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 331, 120 pages (Aug. 1970).

Key words: Alpha-particle standards; calibration consistency; coincidence counting; decay-scheme effects; efficiency tracing; gamma-ray standards; international comparisons; liquid-scintillation counting; radionuclide half-lives; radionuclide standards.

Experimental procedures and methods used in nine international radioactivity standardization laboratories are described by eight authors. The possibility of attaining accuracies of the order of 0.01% are discussed. The desirability of carrying out consistency checks of gamma-ray standards with time, using a 4π ionization chamber is emphasized. The validity of radioactivity standards is examined. International comparisons organized by the Bureau International des Poids et Mesures are discussed. An analogue method of liquid-scintillation counting is described. Certain types of radioactivity standards are criticized. The fields of interest of the two Canadian laboratories are discussed. Details of the work in progress at the Boris Kidrič Institute and National Bureau of Standards are presented. *These proceedings include the following papers (indented):*

Aspects of radionuclide standardization in the IAEA, H. Houtermans, *SP331,* pp. 5-12 (Aug. 1970).

Some aspects of radioactivity standardization at the CBNM of Euratom, A. Spernol, *SP331,* pp. 13-24 (Aug. 1970).

International comparisons of calibrated radionuclide sources, A. Rytz, *SP331,* pp. 25-36 (Aug. 1970).

Standardization of radionuclides by efficiency-tracing methods using a liquid-scintillation counter, D. G. Jones and A. McNair, *SP331,* pp. 37-52 (Aug. 1970).

Validity of radioactive standards, Y. Le Gallic, *SP331,* pp. 53-68 (Aug. 1970).

Radioactivity standardization in Canada, J. G. V. Taylor and A. P. Baerg, *SP331,* pp. 69-77 (Aug. 1970).

Metrology of radioactive isotopes at the Boris Kidrič Institute of Nuclear Sciences at Vinča-Beograd, Yugoslavia, Dj. N. Bek-Uzarov, *SP331,* pp. 79-103 (Aug. 1970).

Recent activities of the NBS Radioactivity Section, with special reference to the standardization of thallium-208, S. B. Garfinkel and J. M. R. Hutchinson, *SP331,* pp. 105-118 (Aug. 1970).

SP332. **Spectrum formation in stars with steady-state extended atmospheres.** Proceedings of the International Astronomical Union Colloquim No. 2, Commission 36, Munich, Germany, April 16-19, 1969, H. G. Groth and P. Wellmann, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 332, 342 pages (Aug. 1970).

Key words: Chromospheres; coronae; extended atmospheres; non-classical atmospheres; non-LTE.

Commission 36 of the International Astronomical Union sponsored a symposium on Spectrum Formation in Extended Stellar Atmospheres held 16-19 April, 1969. The host was the Observatory of the University of Munich. A major problem is the definition of what is meant by an extended stellar atmosphere. There are intuitive notions in the literature, but the question of specific definitions in various kinds of objects was discussed. Questions of what specifically cause the anomalous extent were largely by-passed. Attention focused mainly on the type spectrum to be expected in various situations. The spectral features to be expected in both static and dynamic atmospheres, including and excluding departures from LTE, were discussed. The symposium was divided into four sections: A. Type of Problems Which Exist; B. Theoretical Methods for Handling Non-LTE Problems; C. Chromospheres and Coronae of Stars; D. Summary. This volume contains the mms of the formal papers that were presented plus an edited and abridged version of the discussions following each paper. *These proceedings include the following papers* (*indented*):

Definition of the types of problems that exist in steady-state extended atmospheres, A. B. Underhill, *SP332,* pp. 3-37 (Aug. 1970).

Key words: Extended atmospheres; interpretation of stellar spectra; line formation.

In section 1 practical details concerning the equivalence of observational and theoretical descriptions of stellar spectra are reviewed, particularly the difficulty of identifying the observed reference level (continuum) with the theoretical continuum in the case when many lines are present. In this connection thought must be given to how integrals over frequency should be normalised and evaluated because the effective continuous absorption coefficient does not remain constant over the range from 0 to ∞. The choice of spectroscopic details by which to determine T_{eff}, log g and abundances requires careful consideration.

In section 2 the factors by which an extended atmosphere are recognized are summarized and the question is posed do all stars have extended atmospheres. Another question requiring an answer is whether the concepts microturbulence and macroturbulence are physically real concepts or whether they are merely fitting parameters to make a simple LTE theory account for the observed spectra of supergiants in which rather wide lines occur and many multiplets show rather steep gradients. In section 3 the types of line sensitive to non-LTE conditions are described. These are resonance lines, lines arising from metastable levels, subordinate lines for which the upper level is sufficiently separated from the continuum and other levels that this upper level is chiefly populated by radiative processes from the ground or other low lying levels and lines which go into emission in low density atmospheres as a result of optical-pumping (fluorescent) processes. Such lines should not be used for abundance determinations by means of LTE theory though this is frequently done.

Theoretical considerations are discussed in Section 4 where first the problem of the two-level atom is sketched and then the problem is generalised to a many-level atom. The parameter λ which gives the probability that a photon is lost from the line by de-excitation processes other than spontaneous emission is defined and it is pointed out that non-LTE physics has the effect of adding a scattering term to the expression for the source function. One example is given of the effect of changing the line source function from the Planck function to a form suitable for isotropic coherent scattering. The line becomes deeper and wider for the same number of atoms. Interpretational problems in stellar spectra are discussed in section 5. It is noted that many lines in main-sequence early type spectra show the effects of departures from LTE. These effects are shown to a conspicuous degree by the spectra of shell stars. The example of He I 5876 in 10 Lacertae, 09V, is discussed and the implication for interpreting the He I lines in all B type main-sequence stars are touched upon. Helium-weak and helium-strong spectra probably indicate variations in density of the outer atmosphere rather than true abundance differences. The spectra of supergiants are also considered and it is pointed out that the Ia supergiants of type B may be hydrogen-poor.

Finally in section 6 the problem of choosing simplified physical representations of line forming when non-LTE physics must be used is discussed. Some relevant points concerning the observed spectral lines used for spectral classification are illustrated by means of partial energy-level diagrams.

Definition of the physical problems connected with extended atmospheres, R. N. Thomas, *SP332,* pp. 38-53 (Aug. 1970).

Key words: Classical atmosphere model; extended stellar atmosphere.

The necessity of carefully defining the phenomenological basis for classification of atmospheres as being "extended" is emphasized, and four alternative bases for such classification are suggested (1) the necessity to include curvature terms; (2) the presence of an ejected shell surrounding a central star; (3) an observational discrepancy between predicted and observed density gradient; (4) an anomaly between predicted and observed phenomena in stars with "dynamic" atmospheres such as cepheids. A number of physical problems connected with the presence of an extended stellar atmosphere are then categorized according to these alternative bases.

Extended atmospheres of planetary nuclei, K. H. Böhm and J. Cassinelli, *SP332,* pp. 54-60 (Aug. 1970).

Key words: Central stars of planetary nebulae; instability limit; nongray; Wolf-Rayet nuclei.

Exploratory calculations on nongray, hydrostatic-equilibrium model envelopes for central stars of planetary nebulae of high temperature and possibly near the instability limit are reported. It is conjectured that these may be related to Wolf-Rayet type nuclei; it appears possible to obtain an OV absorption, and OVI emission, spectrum even in an LTE calculation.

The N IV λ5820 multiplet in WN stars, H. Nussbaumer, *SP332*, pp. 61-64 (Aug. 1970).

Key words: HD 192163 WN6; N IV transition probabilities.

Evaluating transition probabilities of N IV 2p3d $^3P^0$ to 2s4s ^3S and 2p3p ^3P and an emission feature at λ7410 it is shown that a disputed emission at λ5810 in WN stars may not be attributed to N IV.

A self-consistent model atmosphere program with applications to solar OI resonance lines, R. G. Athay and R. C. Canfield, *SP332*, pp. 65-84 (Aug. 1970).

Key words: Non-LTE line formation; resonance lines; solar UV lines.

Profiles and total intensities are computed for solar OI resonance lines at λ1302 and λ1305 using a model atmosphere program that includes non-LTE effects in both hydrogen and oxygen and that includes microturbulence both as a line broadening mechanism and as a contribution to the gas pressure. Good agreement is obtained between computed and observed intensities. The computed profiles appear to have too much self-reversal.

Theoretical methods of treating line formation problems in steady-state extended atmospheres, G. B. Rybicki, *SP332*, pp. 87-118 (Aug. 1970).

Key words: Moving atmospheres; radiative transfer; spectral line formation; spherical geometry; stellar atmospheres.

Theoretical methods applicable to the study of line formation in steady-state extended atmospheres are reviewed. The formal solution of the transfer equation is considered, as well as numerical and analytical methods of determining the source function. Topics discussed include: the local frequency transformation, geometrical effects, and the case of large velocity gradients. A new plane-parallel approximation for spherically symmetric moving atmospheres is given that takes account of transverse velocity gradients.

Application of Monte Carlo methods in transfer problems, C. Magnan, *SP332*, p. 119 (Aug. 1970).

Line formation in moving atmospheres, W. Kalkofen, *SP332*, pp. 120-133 (Aug. 1970).

Key words: Line formation; line-profile computation; moving atmospheres.

We discuss an integral equation method that permits the calculation of the line source functions and of the emergent profiles in finite and semi-infinite atmospheres with macroscopic motion normal to the surface. Solutions are presented for a semi-infinite atmosphere with a temperature rise in the outward direction and with a flow that decays with increasing depth. The computed profiles have the form of P Cygni lines.

Laser action in non-LTE atmospheres, D. H. Menzel, *SP332*, pp. 134-137 (Aug. 1970).

Key words: Laser action; radiative transfer.

The radiative transfer equation is written in microscopic form, and from some simplifications on the ratio of occupation numbers for upper and lower level, a laser action is suggested.

Line formation in multi-dimensional media, H. P. Jones and A. Skumanich, *SP332*, pp. 138-170 (Aug. 1970).

Key words: Line formation in multi-dimensional media; matrix methods for integro-differential operators; numerical methods in transfer; radiative transfer in inhomogeneous media.

The flux divergence technique of Athay and Skumanich (1967) is generalized for application to media whose properties vary in more than one spatial dimension. In this method, the flux divergence is viewed as an integro-differential functional of the source function. The source function is then expanded in terms of basis functions along characteristic paths, and, with the help of various interpolations, the flux divergence is converted to an approximate linear algebraic operator on a discrete spatial grid. A large but finite set of linear, inhomogeneous, simultaneous algebraic equations with known matrix coefficients is thus generated and is solved by direct matrix inversion for the source function at each point of the spatial grid.

Some aspects of the accuracy, stability, and computational convenience of the technique are discussed. Sample solutions for depth dependent, axially symmetric variations of temperature are shown.

The continuous spectrum of hydrogen in a low-density envelope, H. Gerola and N. Panagia, *SP332*, pp. 171-178 (Aug. 1970).

Key words: Collisional excitation; low-density envelope; recombination case.

A progress report on theoretical work on the formation of a continuum in low-density stellar envelopes. Preliminary results are given on a comparison between the recombination case and the case for a semi-empirical approach including the effect of collisions from the ground state.

Bandwidth requirements in spectral line transfer calculations, R. G. Athay, *SP332*, pp. 179-188 (Aug. 1970).

Key words: Bandwidth requirements; line source function.

Accurate evaluation of a line source function, S, requires that the frequency bandwidth be sufficiently large to include properly transfer effects in the line wings. The bandwidth required to achieve a given level of accuracy in the evaluation of S can be specified, in units of the Doppler width, in terms of three parameters: the ratio of continuum to line opacity, r_o, the probability for collisional de-excitation, ϵ, and the Voigt wing parameter a. Bandwidths required to give S to an accuracy of 2 percent are given for values of ϵ and r_o from 10^{-2} to 10^{-8} and for values of a from 10^{-2} to 10^{-5}.

Comparison of discrete space and differential equation methods in non-LTE line transfer problems, P. P. Grant and C. E. Hunt, *SP332*, pp. 189-225 (Aug. 1970).

Key words: Inhomogeneous non-LTE atmospheres; line formation; numerical methods.

Numerical methods are essential to the treatment of line formation in inhomogeneous non-LTE atmospheres. The new methods due to Hummer and Rybicki and to Feautrier now make it possible to make such calculations, although these are often quite time-consuming.

We shall describe an alternative approach using discrete space techniques depending on concepts of invariance. The solution algorithm is closely related to the method of Hummer and Rybicki, whose equations are obtained as a limiting case. The stability and errors of our algorithm are susceptible to mathematical analysis, and make it possible to identify the critical parameters in the calculation with precision. The results for a two-level problem will be compared with those from an implementation of the Rybicki-Hummer equations and a comparison will be made of the performance of the two procedures in respect of speed of computation and storage requirements.

Coherent line formation with depth-dependent parameters, T. L. Carson, *SP332*, pp. 226-238 (Aug. 1970).

Key words: Coherent line formation; numerical methods.

A discrete ordinate method is developed for solving the equation of coherent line formation, for arbitrary given variations with depth in an atmosphere of the temperature (or Planck function, assuming local thermodynamic equilibrium) and the line absorption and scattering coefficients. The direct solution thus obtained can then be used as the starting point of an iterative procedure. Results obtained for an exactly soluble case indicate the utility of the method.

What do we know through spectral information on stellar chromospheres and coronas?, F. Praderie, *SP332*, pp. 241-258 (Aug. 1970).

Key words: Chromosphere; conservation equations; corona; spectral indicators.

Four problems in interpreting spectra to infer chromospheres-coronas are summarized. (1) The *a priori* difficulties in interpreting spectra lie in uncertainty on the range of possible models, coming from uncertainty as to which conservation equations may be applied, and from lack of an exhaustive list of spectral indicators that may be used for uniqueness tests. (2) As spectral indicators we consider: emission lines, self-reversed emission cores, the presence of He I lines in stars not of early type, coronal-type high ionization, excess continuum emission in the rocket UV and the far infrared. (3) To determine what we can infer from observations, we summarize information: inferred by comparison of models to data, on velocity fields, and on spectral variability which might suggest chromospheric activity. (4) We summarize the evidence for chromospheres in A stars, as being those where convection-induced acoustic heating is marginal.

What should we do to know more about chromospheres and coronae of stars?, R. N. Thomas, *SP332*, pp. 259-282 (Aug. 1970).

Key words: Chromospheres; classical atmosphere model; coronas.

Chromospheres-coronas satisfy the last two of the proposed classification schemes: inadequacy of the classical atmosphere (CA) model to represent observations and a priori rejection of the CA model. So we survey the question of what is required for more knowledge from the standpoint of asking what conceptual modifications will increase knowledge and what new observations are required. We stress that continued progress requires a continual interchange of ideas between the solar situation and the range of stellar situations.

Observations of ζ aurigae stars and their interpretation, H. W. Groth, *SP332*, pp. 283-289 (Aug. 1970).

Key words: Chromosphere; chromospheric clouds; Russell-Adams effect; super-excitation.

A summary of information on the extended atmosphere of the K component coming from three eclipsing binaries consisting of a K supergiant and a main sequence B star. Various anomalies exist: (1) Discrepancy between electron density and metallic density inferred from observations, noting that the electrons should come from the metals. This suggests a cloud structure in the atmosphere. (2) Anomalous excitation temperatures and populations of the second quantum level of hydrogen suggests a solar-chromosphere type behavior for these K atmospheres. (3) Significant changes in the profiles of the Ca^+ lines from one eclipse to another. The necessity to distinguish between effects coming from radiation of the B star on the K atmosphere and chromospheric-like effects is emphasized.

Ionization in nova atmospheres, P. Wellmann, *SP332*, pp. 290-294 (Aug. 1970).

Key words: Expansion; ionization; novae shell.

Calculations on the expansion of novae shells are presented, from which the degree of ionization is obtained using a simplified form of a non-LTE ionization equation. From this, estimates of the time of vanishing of the Balmer absorption spectrum can be made.

Circumstellar Ca II K lines in G, K, and M giants and supergiants, A. H. Vaughan, Jr., and A. Skumanich, *SP332*, pp. 295-299 (Aug. 1970).

Key words: Ca^+ emission core; circumstellar absorption lines; late-type giants.

Tentative evidence based on photoelectric observations of the Ca^+ emission core, is presented for the existence of circumstellar envelopes in several G and K type "giants." A significant emission asymmetry in α Tau may imply a chromospheric rather than a circumstellar source.

A physical mechanism for the generation of extended stellar atmospheres, R. W. Hillendahl, *SP332*, pp. 300-319 (Aug. 1970).

Key words: Cepheids; extended atmospheres; hydrodynamics; shock waves.

A physical mechanism that can result in the generation of extended expanding atmospheres is discussed. The process involves the unloading of stellar material following the arrival of a shock wave at the edge of the star. The basic principles are developed from a discussion of a simplified case that has been studied in the laboratory; they are then applied to the atmosphere of a star. A radiation-hydrodynamics computation of a model cepheid is then used to obtain quantitative atmospheric profiles. The computed continuum and spectral lines during the unloading process are then examined. A discussion of the possibility that the unloading process occurs in stars other than cepheids suggests the existence of a shock visibility factor associated with ionization or dissociation in the region behind the shock front and leads to a possible alternate interpretation of the variable star instability strips in the H-R diagram.

SP333. **Research materials developed under the NBS inorganic materials program,** F. E. Brinckman and J. B. Wachtman, Jr., Nat. Bur. Stand. (U.S.), Spec. Publ. 333, 71 pages (September 1970).

Key words: Chemical properties; composition; gases; glasses; liquids; multiphase materials; physical properties; polycrystals; preparation; research.

The National Bureau of Standards develops many specialized materials in the process of carrying out research supporting its measurements, standards, and service activities. These materials include gases, liquids, glasses, single crystals, polycrystals, and various multiphases materials; their compositions (including trace elements in some cases) and physical characteristics are tailored to specific research needs, but the materials are often of use for other research purposes. Production is usually limited to immediate internal needs and samples are not generally available for distribution, but knowledge of production techniques and materials characteristics which may be helpful to other scientists is available. The present listing of research materials developed in the Inorganic Materials Division accordingly gives names of scientific staff members who may be contacted for this type of information as well as giving a brief summary of the nature, method of preparation and properties determined for each material.

SP334. **Industrialized building in the Soviet Union, (a report of the U.S. Delegation to the U.S.S.R.),** J. R. Wright, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 334, 81 pages (Dec. 1970).

Key words: Building economics; building systems; construction industry; housing; precast concrete; production capacity; production management; production methods; standardization; United Soviet Socialist Republics.

The 1969 Exchange delegation to the USSR reports the status of Soviet building industrialization, with emphasis on Soviet housing. The report describes the State management hierarchy, production of precast concrete components and housing construction procedures. The loadbearing panel system, the mainstay of Soviet prefabricated housing, is compared with the newer three-dimensional box system. Detailed analysis is made of the cost of a nine-story panel prefabricated apartment building in the USSR, and the cost of the same building if constructed in the U.S.

SP335. **Innovative metrology—key to progress.** Proceedings of the 1970 Standards Laboratory Conference held at the National Bureau of Standards, June 15-17, 1970, H. L. Mason, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 335, 132 pages (Mar. 1971).

Key words: Metrology management; National Conference of Standards Laboratories; physical measurement; Proceedings NCSL.

The biennial Standards Laboratory Conference of the National Conference of Standards Laboratories convened at the Gaithersburg facilities of the National Bureau of Standards June 15-17, 1970. The theme of the meeting, Innovative Metrology—Key to Progress, was amplified by 23 papers presented at technical sessions devoted to new technologies and applications, laboratory management and operations, new methods of optimizing calibration intervals, new ways of managing, and new international developments. *These proceedings include the following papers (indented):*

The evolution of a radiological mensuration technique, H. Bardach and S. Wisnieff, *SP335*, pp. 11-21 (Mar. 1971).

Key words: Attenuation of betas; beta-transmission phenomenology; counting geometry; mass absorption coefficient derivation; strontium 90 wall-thickness measurement gage; thin-wall mensuration.

A radiological mensuration technique was devised to measure the minimum wall thickness anchoring from interior corner points of small castings invested with internal cavities. The factors involved in the development of the mensuration technique which culminated in the manufacture of a semi-automatic machine tooled with a strontium 90 gage were examined in detail. These factors included the phenomenology of beta transmission through plural media, the subtleties of counting geometry, and the characteristics of the beta spectrum, all of which contributed in some measure to the efficacy and uniqueness of the beta emitter as a mensuration tool.

The technique involved the positioning of an encapsulated strontium 90 point source contiguous with the interior points at which the minimum wall thicknesses were to be measured and determining these thicknesses by referencing the observed beta transmission counting rates to a calibration curve.

An automated time domain instrument test console, L. S. Kreyer, *SP335*, pp. 23-28 (Mar. 1971).

Key words: Automatic measuring devices; automatic performance test; computer control systems; instrument calibration procedures; instrument performance testing; pulse technology; time domain testing.

This paper describes a computer-controlled system which automatically tests the performance of oscilloscopes and other time domain instruments. The system utilizes advances in pulse technology to speed up the calibration process by replacing frequency domain test methods with time domain test methods. Cost effectiveness of this system in terms of reduced man hours to calibrate an instrument, reduction of systematic errors due to operator bias, and consistent reporting of test results are described.

Standards laboratory applications of a computer-automated system, F. B. Seeley, *SP335*, pp. 29-33 (Mar. 1971).

Key words: Computer automation; resistance thermometers; resistor intercomparison; standard cell surveillance.

A computer-automated calibration system whose accuracy and precision make it suitable for standards laboratory applications is described. The system has been applied to electrical, radio-frequency, electro-optical, and electromechanical measurements. Results are summarized that include saturated standard cell, standard resistor, resistance thermometer, micropotentiometer, and attenuator calibrations. Additional topics include the experience in computer programming, reliability, and systems operation.

Cost reduction in calibrating bolometer mounts, W. F. Dentinger and L. dePian, *SP335*, pp. 35-37 (Mar. 1971).

Key words: Automated dc substitution; bolometer calibration; radiofrequency power measurement; self-balancing Wheatstone bridge.

Ordinarily a great deal of time is spent in calibrating bolometer mounts. Manual bridges require considerable care for proper balances, bias adjustments, and calibration procedures. New instruments have been designed to automate many of the manual operations. These instruments are self-balancing and maintain precise power levels with minimum adjustments. Due to the fact that in previous setups a series of measurements had to be made in order to average out errors caused by temperature changes, the new automated system described in this paper can save about 90 percent in measurement time. In addition, a less skilled operator can perform the measurement with the same accuracy.

Measurement comparison programs, H. S. Ingraham, Jr., *SP335*, pp. 39-40 (Mar. 1971).

Key words: Accelerometer round robin; computer program for Youden diagrams; correlation effect; end standard of length.

The measurement comparison program of 1965 circulated unknowns in pairs, allowing use of Youden diagrams to distinguish systematic from random error. In 1969, two pairs were sent out several months apart, allowing check of the correlation effect; a round robin was started on acceleration; a 24-inch end standard was included in the physical package.

Report on the 1968-69 mass measurement agreement comparison round robin, L. B. Macurdy, *SP335,* pp. 41-45 (Mar. 1971).

Key words: Between-group variance; mass comparisons of 1969; systematic and random weighing errors; within-group variance.

Seventeen laboratories took part in the round robin measurements of the NCSL Mass Comparison packages during 1968 and 1969. In order to speed up the measurements the laboratories were divided into two groups. The weights were calibrated by the NBS Mass Laboratory at the beginning and again at the end, and Mettler Instrument Corporation measured all sets near the middle of the series. Two sets of weights were sent to each laboratory at times separated by two months or more in order to provide data on errors made on the same day (within-group variance) and on errors between measurements at longer intervals (between-group variance). Each set of weights consisted of four pairs of one-piece stainless steel weights of 100 g, 25 g, 10 g, and 1 g. Data include weighing errors of the various laboratories and Youden plots of the measurements. Some errors proved to be larger than had been expected. The results illustrate the need for verifying the accuracy of measurement on some rational basis.

NCSL specification presentation, F. J. Dyce, *SP335,* pp. 47-50 (Mar. 1971).

Key words: Calibration records; calibration system specification; intervals; procedures; recall; reliability; traceability.

This paper describes in summary the requirements of the National Conference of Standards Laboratories "Calibration System Specification." It indicates how the specification was written by members of the NCSL Specifications Committee in answer to a DOD request. The specification contains the minimum essential requirements of a calibration system. The paper discusses the steps required to approve the specification as a recommended practice and to obtain Government approval and adoption.

Cost visibility exchange program—a new approach to cooperative savings, R. J. Barra, *SP335,* pp. 51-55 (Mar. 1971).

Key words: Calibration and maintenance manhours; digital counters; digital voltmeters; exchange program on costs; oscilloscopes.

A preliminary survey by the Calibration Systems Management Committee indicates 600,000 manhours per year spent on 9 types of instruments, including oscilloscopes. Member organizations are asked to contribute cost data with the objective of saving one million dollars in calibration and maintenance costs by 1972.

Keys to optimum calibration intervals, R. B. F. Schumacher, *SP335,* pp. 57-64 (Mar. 1971).

Key words: Calibration intervals; economy in adjusting quality level; measurement uncertainty; reliability of working instruments.

The search for optimum calibration intervals or for methods to obtain them can be frustrating. Our theories concerning the behavior of measuring instruments are deficient. and as a result, so are all theoretical models attempting to establish optimum intervals. Nor can we hope to determine empirically what optimum intervals should look like. The many variables in calibration control systems, affecting quality and behavior and performance evaluation of measuring instruments, forbid us to compare the meaning and merit of calibration intervals achieved in one calibration control system with those achieved in another such system. Time does not permit us to experiment in one system until we achieve calibration intervals which are even near optimum. We must be modest and practical. We must lower our sights.

This paper attempts to show the main sources of our ignorance about instrument behavior and about the influence of a calibration control system on instrument behavior and on our evaluation of this behavior. It offers seven keys to the establishment of an efficient method for calibration interval adjustment. Emphasis is on efficiency, practicability, economy. The purpose of adjusting calibration intervals is to maintain a given level of instrument quality level at the lowest cost. Having found a satisfactory calibration interval adjustment method, one should look to other components of the entire calibration control system for opportunities to lower costs.

Intervals by exception, J. Glassman, *SP335,* pp. 65-72 (Mar. 1971).

Key words: Calibration intervals; exponential distribution; reliability, systems effectiveness, tradeoffs.

"Intervals by exception" is a new approach devised at the Navy Metrology Engineering Center to control the evaluation and adjustment of calibration intervals for the Navy Calibration program. It furnishes management with a powerful tool with which to monitor calibration intervals and assure reliability of equipment.

What are some of the interesting features of this new technique?

(1) It enables management to concentrate on problem equipment by pinpointing "dogs" and "gems," i.e., statistically poor and statistically good equipments.

(2) It allows management to select "optimum" intervals based on automatically derived reliability tradeoffs.

(3) It motivates laboratory personnel by providing an information feedback loop for problem instruments.

(4) It lowers operating costs by funneling analysis and engineering effort into the areas of greatest needs and most promising returns.

(5) It lowers costs by lengthening intervals on family types and stabilizing reliability levels.

(6) It provides automatic computer monitoring of all decisions (cause-effect feedback).

This system is presented with charts that illustrate its operation, outputs, and management-oriented controls. The presentation includes data analyses, adjusting of intervals, detection of "dogs" and "gems," resultant changes in system operating characteristics, underlying mathematical assumptions, and mathematical models.

Optimizing calibration intervals, D. J. Greb, *SP335,* pp. 73-79 (Mar. 1971).

Key words: Data support; fixed calibration interval; instrument reliability; statistical validitv; two-method optimization.

This paper describes a two-method system for using simple attributes calibration data to adjust and optimize calibra-

tion intervals. Each method is used only where its superior characteristics predominate; the combination of methods produces a total system which exploits the advantages of each without having to suffer with the disadvantages. The "fixed interval through data" method is employed where there are at least 27 bits of data, the application being unique in that the data is treated as a random sample from an infinite population, sampling variations are accounted for, and all decisions to extend calibration intervals are characterized by statistical validity. When there are only from 5 to 26 bits of data, statistical validity is not possible and the "fixed interval through engineering intuition" method is utilized. However, intuition and judgment are applied only to a set of decision rules, and strong, specific data support is required. The system has not been extended to less than 5 bits of data, although there would seem to be no problem in so doing. Net results in the first 18 months of use are 495 changes involving 34,200 units, with annual savings of 24,100 technician hours, and with no noticeable deterioration in overall instrument reliability.

Optimum cycles determined with confidence, P. A. Seamans, *SP335,* pp. 81-84 (Mar. 1971).

Key words: Calibration histories; equal likelihood; oscilloscopes; RX meters; vacuum-tube voltmeters.

The calibration history of a family of instruments provides data on how often the instruments were recertified and whether each was in calibration when recertified. These data permit the calculation of the optimum calibration interval for a desired level of confidence in the instrument readings. Three case histories (oscilloscope, RX meter, VTVM) show this method is effective. The histories of a family of oscilloscopes over a thirteen-year period show that calibration cost tends to be roughly constant with time and thus does not seem to follow the "bathtub curve." All instruments investigated seem to have equal likelihood of failure in all intervals, and thus the bathtub curve does not seem to hold in general.

Breakthrough techniques for metrology work, L. B. Wilson, *SP335,* pp. 85-88 (Mar. 1971).

Key words: Managerial breakthrough techniques; personnel selection for metrology; steady control versus sudden change.

Metrology work involves the conflicting and diametrically opposed problems of control versus breakthrough. Controls are vital to assure accuracy and reliability. However, breakthroughs are necessary to provide improved accuracies, ranges, and types of measurements. The dichotomy of this situation comes principally from the differences in attitudes involved. Ideally, control and breakthrough should be carried out by two different types of people because of these differences.

Breakthrough techniques, coupled with proper attitudes and a systematic method for establishing objectives and evaluating alternatives, provide a powerful set of new tools for improvement. Examples are given showing the possibilities for applying these tools to reduce costs and provide needed measurement and calibration services.

Data system for improving instrument reliability, F. J. Dyce, *SP335,* pp. 99-104 (Mar. 1971).

Key words: Calibration data system; calibration interval adjustment method; instrument reliability; instrument standardization.

This paper discusses the importance of monitoring and control of instrument reliability. It suggests that a minimum reliability level be set as a goal. It discusses the interval adjustment scheme used at Martin Marietta wherein individual instrument performance determines calibration interval as well as repair and surplus. A thorough explanation is given of the computerized data system used at Martin Marietta to monitor instrument reliability and to isolate repetitive problem areas. Several examples are given of reliability problems which were solved through use of the system.

A unique standardization committee is discussed which justifies the company's sole-source purchase of general-purpose, reliable electronic test equipment.

The paper concludes that striving towards a reliability goal will result in improved reliability and reduced cost.

The importance of visibility and control in laboratory management systems, J. L. King, *SP335,* pp. 95-98 (Mar. 1971).

Key words: Data for decision; standards laboratory management; test equipment records; use, storage, or surplus.

The Test Equipment Control Engineering Section has overall responsibility for 2719 different models of 40,000 items, from purchase to final disposition. Computerized system shows decision-makers the history of costs, locations, and interface with operations; yields savings of $800,000 per year.

The new state standards program, R. Mills, *SP335,* pp. 89-94 (Mar. 1971).

Key words: Length measurements; mass measurements; metrology; standards; state laboratories; volume measurements.

In 1965, Congress appropriated funds for new state standards and instruments in mass, length, and volume. The laboratories receiving this package are, in most cases, under the administration of state offices of weights and measures. These labs not only check the accuracy of field standards used by weights and measures inspectors, but also serve as local measurement centers to perform industrial tests. The equipment and training given to laboratory personnel are described in this paper, as well as some of the administrative details and the utilization we foresee for the state laboratories.

New U.S. Air Force audit program, L. W. Root, *SP335,* pp. 105-109 (Mar. 1971).

Key words: Audit examinations; audit package; Precision Measurement Equipment Laboratories (PMEL); technician skills; U.S. Air Force.

This paper describes a unique quality assurance audit program used for testing worldwide Precision Measurement Equipment Laboratories (PMEL's). Conventional methods utilized during previous audits are examined briefly and disadvantages noted. The advent of highly sophisticated systems and test equipment has placed increased emphasis on the experience and skill level of the technicians who provide calibration support at PMEL's. Specific configuration of a unique package designed to evaluate this skill level is discussed in some detail and results obtained during the past year are presented.

NPL work on the determination of $2e/h$ by the ac Josephson effect, B. W. Petley and K. Morris, *SP335,* pp. 111-115 (May 1971).

Key words: Inductive ratio divider; Josephson effect; NPL of UK; potential-divider resistor; quantum standard of voltage; solder-drop Josephson junctions; superconductivity.

The a-c Josephson effect in superconductivity appears to be an exciting possibility for use as a quantum method of maintaining the volt as an SI unit, through the relations $2\ eV = h\nu$. A potential-divider resistor was devised for precise comparison of a Wesson-cadmium cell with millivolt outputs from various solder-drop junctions excited at 36.8 GHz. The value found for $2\ e/h$ is 483.5941 ± 0.0010 $MHz/\mu V_{69NPL}$.

The impact of advanced electronic technology on measurements, R. F. Clark, *SP335*, pp. 117-119 (Mar. 1971).

Key words: Attenuation measurement; automatic data correction; auxiliary receiver for microwave measurements; dual admittance Woods bridge; Engen microcalorimeter; rf coaxial impedance standards.

Advances in electronic technology have made possible significant improvements in both accuracy and precision of measurements. Some comments will be made on the increase in accuracy through automatic application of data corrections (which were previously too difficult to be practicable) and the elimination of many "human" errors. Better precision coming from increased speed of measurement and improved control of the environment of the measurement will be discussed.

Design and development through metrology, P. Prakash, *P335*, pp. 121-124 (Mar. 1971).

Key words: Designing to specification; fabrication of balances; legal metrology; mass standards; NPL of India.

The National Physical Laboratory of India, in implementing the 1956 Standards of Weights and Measures Act, adjusted and calibrated mass standards of 50 to 10^{-6} kg for 250 State Laboratories. Most of the 5000 balances needed by Inspectors were designed and fabricated by four commercial manufacturers in India, with specifications, technician training, and performance testing supplied by NPL. With this experience, two manufacturers designed and fabricated the higher precision balances for District-level laboratories. The technique is recommended to developing countries faced with similar projects.

Telecommunication measurements for automatic production and maintenance, H. Fleischer, *SP335*, pp. 125-127 (Mar. 971).

Key words: Automatic noise-level recorders; calibration of carrier-frequency filters; microwave transmission lines; Siemens-Halske AEG; Wandel & Goltermann.

Automatic recorders with uncertainties no greater than 0.1 dB up to 18 MHz are used in one channel of a microwave link to measure effective equivalence and noise level to provide production calibration control for filters and attenuators. Details of two German-made systems are described.

Present status of electrical standards and their traceability in Japan, M. Kanno, *SP335*, pp. 129-132 (Mar. 1971).

Key words: Absolute measurements; basic electrical standards; quantum electric standards; radio-frequency standards.

The national electrical standards for Japan described herein are established and maintained in the Electrotechnical Laboratory. Dissemination is by two public agencies. Committees on traceability and on measuring techniques are active in the Institute of Electrical Engineers.

SP336. **Space simulation.** Proceedings of a Conference held at NBS, Gaithersburg, Maryland, September 14-16, 1970, J. E. Richmond, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 336, 985 pages (Oct. 1970).

Key words: Ablation; particulate radiation; re-entry; space simulation; thermal radiation; vacuum; weightlessness.

This volume contains all of the papers presented at the Fifth Space Simulation Conference held at the National Bureau of Standards September 14-16, 1970, that were available for publication. The general scope of the conference was the effect of the space environment on materials, components, structures, and man. The range of topics is too wide to permit a simple classification, but contamination, ablation, degradation of materials by the space environment and predictive testing account for approximately half of the papers presented. Other topics range from purely laboratory problems such as radiometry standards, calibration of vacuum gages, cryopumping and operation of space simulation facilities to gravity simulation, with neutral buoyancy for zero gravity and a man-rated centrifuge for high gravity, use of a drifting submarine to study the psychological aspects of long-duration missions in a space station, and simulation of (1) atmospheric balloon environments, (2) radiation from nuclear power sources, (3) solar wind, (4) micro-meteoroid bombardment, (5) soil friction on the moon, and (6) the Martian atmosphere. *These proceedings include the following papers (indented):*

Molecular contamination in environmental testing at Goddard Space Flight Center, J. C. Goldsmith and E. R. Nelson, *SP336*, pp. 1-24 (Oct. 1970).

Key words: Chemical analysis; contamination; organic residues; outgassing; polymeric materials; residual gas analysis; test facility; vacuum.

A discussion of the various techniques used to detect and analyze materials outgassing from a spacecraft during the environmental test is presented. In addition, a number of compounds that have been detected and their parent outgassing sources are listed. The two major methods for reducing the threat of contamination (i.e., proper choice of spacecraft materials and proper operation of the test facility) are also discussed.

Contamination measurement in space environment simulation chambers, C. M. Wolff and M. L. Ritter, *SP336*, pp. 25-49 (Oct. 1970).

Key words: Contamination collection units; gas-liquid chromatography; infrared spectrometry; mass spectrometry; quartz crystal oscillator mass monitors; radiometry; reflectometry; space environment simulation chambers.

Contamination measurement is classified according to the requirements; i.e., the identity, sources, and effects of contamination by active and passive sampling. The chemical nature of the most common contaminants found in space environment simulation is discussed. Qualitative and quantitative techniques for contaminants analyses are described and evaluated. These techniques include mass spectrometry, quartz crystal oscillator mass monitors, infrared spectrometry, and gas-liquid chromatography. Also, the uses of optical surfaces and thermal control coatings as contaminants effects monitors are described.

Contamination studies in a space simulated environment, D. L. Enlow, *SP336*, pp. 51-77 (Oct. 1970).

Key words: Absorption; condensation; contamination control; evaluation; far infrared; fluid dynamic force; microorganisms; optical properties; planetary quarantine; polymers; shock force; space simulation; testing; volatile products.

Biological and optical contamination problems can be best investigated experimentally. Studying the dynamics of microorganisms in a vacuum environment showed that shock forces in the order of a 1000 g's will liberate 20 percent of the previously bound particles and the effect of simulated attitude control gas jet firing will remove more than 50 percent of the bound particles.

A potential source for optical degradation to infrared systems is identified as the absorption phenomena of condensed volatile products from certain polymeric materials. The effects of this condensation were analyzed by a combination of surface photography and IR spectroscopy. These preliminary investigations point out the need for proper materials selection for far infrared space-borne optical systems.

External spacecraft contamination modeling and countermeasures, T. Baurer, M. H. Bortner, I. M. Pikus, and A. M. Cooper, *SP336,* pp. 79-103 (Oct. 1970).

Key words: Contamination; mass transfer; spacecraft.

The problem of spacecraft external contamination is a function of both the spacecraft and the receptors, in relation to the natures and quantities of contaminants involved, i.e., the problem depends on both design and mission. The relevant phenomenology may be conceptualized in a model which assumes that a mass-transfer mechanism is operative, including sources, transport modes, and sinks. Typical sources include engine debris, jettisoned wastes, outgassing, and cabin leakage. Gaseous contaminant transport is based on the complex interaction of gas-surface interaction potentials and hydrodynamic, electrostatic, and magnetic fields. Condensed-phase materials are subject to hydrodynamic coupling, induced polarization, and electrostatic field effects. The sink or deposition mechanism assumes differential charge development on conducting (e.g., vehicle skin) and dielectric (e.g., windows, lenses) external surfaces, such as to cause preferential attraction to the latter. The net electrostatic potentials at the dielectric surfaces cause charge neutralization of impinging ions, followed by bonding, scattering, and desorption. Impacting particulates adhere or scatter at the dielectric surface depending on the relative magnitudes *of local surface potential,* strength of induced dipoles, and particle velocity vectors normal to the surface. Flowing and adhering contaminants continually cover the surface, preserving its dielectric nature. This model suggests the applicability of at least three complementary approaches to the problem of counteracting contamination, viz., passive prevention of the appearance of contaminants, active removal measures during the transport of contaminants which do appear, and means of counteracting or discounting the effects of contaminants which complete their transit to sensitive surfaces.

Particulate contaminant measurement by quartz crystal microbalance, R. L. Chuan, *SP336,* pp. 105-111 (Oct. 1970).

Key words: Particulate sampling; quartz crystal microbalance; spacecraft contamination.

A piezo-electric crystal executing vibrations in a shear mode can be used as a mass balance with very high sensitivity. Various methods have been used by investigators in diverse fields to bring the mass to be measured to such a balance. Some of these are: absorption of a gas into the surface of the crystal; condensation of a gas onto a cooled crystal; chemical reaction with material bonded to the crystal surface; and impaction of particulate matter onto the crystal surface. The present paper deals with this last mass-accretion mechanism as applied to the measurement of contamination in the form of particulate matter present in space environment (actual and simulated).

The QCM (quartz crystal microbalance) responds to a mass change on its surface typically in the following manner: $\Delta f = -Cf^2\Delta m$, where Δf is the change in the crystal resonant frequency f due to the addition of mass Δm, and C is a constant whose magnitude is about 10^6. For a nominal frequency of 10^7 Hz the sensitivity, $\Delta f/\Delta m$, is of the order of 10^8 Hz/gm, from which it is seen that the mass resolution of the QCM depends directly on frequency resolution. Frequency resolution, in any given oscillator, depends on the characteristic time within which measurements are taken—the resolution generally degrading as the time increases. Thus for small mass change occurring in a long time (by which we mean seconds or tens of seconds) the frequency resolution is commonly not better than about 0.1 to 1 Hz for a 10^7 Hz oscillator. However, if the characteristic measurement time is less than, say, 10^{-2} sec, the frequency resolution can be quite good—being of the order of 10^{-2} Hz or better. This consideration lends itself to the sensitive and accurate measurement of discrete particulate mass, because when such a mass is deposited on the crystal there is an almost instantaneous, though small, frequency shift. By utilizing this very high rate of frequency shift it is possible to measure particulate mass down to the order of 10^{-11} gm. This is equivalent to a single particulate of 2 micron diameter with mass density 2 gm cm^{-3}.

In addition to measuring the mass of particulate matter, the technique also provides information on whether the material is volatile. If subsequent to its impaction onto the crystal surface, with an accompanying frequency shift, the particulate material evaporates, there will not only be a loss of mass but, more importantly, there will be cooling of the crystal. The crystal can be chosen so as to exhibit a frequency change of a sign opposite to that caused by mass addition. Then the instantaneous frequency change caused by the impaction of particulate will be followed closely by an opposite frequency change due to evaporation.

Experimental data will be presented showing the response of the QCM to nonvolatile and volatile particulate matters.

Space measurements of the contamination of surfaces by OGO-6 outgassing and their cleaning by sputtering and desorption, D. McKeown and W. E. Corbin, Jr., *SP336,* pp. 113-127 (Oct. 1970).

Key words: Cleaning; desorption; ions; outgassing; quartz crystal microbalance; solar panels; space; sputtering; surface contamination.

Results of the contamination of surfaces by outgassing of the OGO-6 satellite and the rates at which these surfaces are now being cleaned by sputtering and desorption after being in space for five months are given. The contamination measurements are being made with a quartz crystal microbalance to define the conditions of Al and Au surfaces used in an experiment to measure gas-surface energy transfer. It was found that the primary source of outgassing on the satellite was its two solar panels baking out in the sun. The time constant for the exponential decay of the outgassing is 1,000 hours. The maximum amount of contamination adsorbed by the surfaces exposed to the outgassing was reached after five months in orbit and is 96 mg/m^2 for the Al surface and 52 mg/m^2 for the Au surface. The contamination has a desorption activation energy of 26 kcal/g mol which falls into the energy range of materials, such as, epoxies and vacuum oils. The surfaces are now undergoing cleaning by desorption at 1.2×10^{-9} g/m^2s and sputtering by upper atmospheric neutral impacts at 2.3×10^{-9} g/m^2s. A method to greatly increase the cleaning rate by removal of the contamination by sputtering with upper atmospheric ions is discussed.

Simulation of radiation from RTG power sources, P. A. Newman, Jr., *SP336*, pp. 129-140 (Oct. 1970).

Key words: Evaluation; MOSFETS, neutrons; Pu^{239}-Be; radiation simulation; RTG; test.

The recent interest in Radioisotope Thermoelectric Generator (RTG) power systems for deep space missions, and the ever increasing use of the radiation sensitive MOSFET in spacecraft electronics has made it essential that an assessment of the radiation effects for this combined application be determined. An RTG with its continuous flux of neutrons and gamma photons provides a long term hostile environment for electronic components. This paper deals with a radiation source (Pu^{239}-Be) selected to simulate, for the most part, the neutron effects of the RTG. Preliminary experiments with this source have indicated that for most electronic applications the neutron contributions of the RTG over a five year mission in present spacecraft configurations will not be a major problem. An analysis of the data from several experiments indicate that predictions of the radiation effects can be made for "hotter" configurations with a reasonable degree of confidence.

In situ vacuum gauge calibration by the reference transfer method, L. D. Blado and R. H. Lilienkamp, *SP336*, pp. 141-150 (Oct. 1970).

Key words: Reference transfer method; vacuum gauge calibration.

Application of the Reference Transfer Method to in situ calibration of ionization gauges was evaluated in order to ascertain the effectiveness of the method when applied in a manner determined both by the commercial availability of equipment and by the restraints of an operating space environment simulation facility. A prototype Reference Transfer Calibrator (RTC) was assembled from standard vacuum components. Transfer ratio determinations were made in the range 10^{-4} to 10^{-8} torr. These experimental measurements were then compared with theoretical calculations, thereby verifying the feasibility of the technique.

Methods of determining residual gas composition from residual gas analyzer data, R. H. Lilienkamp, *SP336*, pp. 151-164 (Oct. 1970).

Key words: Mass spectrometry; residual gas analysis computer simulation; residual gas analysis data reduction; space vacuum system gas.

Three methods of determining residual gas composition from Residual Gas Analyzer (RGA) data are compared using a computer simulation of an RGA to generate the data for analysis. Typical vacuum system gas mixtures and errors from shot noise were simulated. Errors were also introduced into the calibration data used to interpret the RGA data. The first method is an iteration technique which proved to be inferior to the other methods. The second is a matrix inversion method which worked well for the gases used in this study but which must be evaluated for each gas mixture. The third method is a multiple regression analysis giving least squares fit to the data. This method uses all of the data from the RGA and is usable with any mixture of gases. The effect of the calculation of the residual gas composition is also shown.

Spectral absolute reflectance measurements of CO_2 frosts in the 0.5 to 12.0 micron region, B. E. Wood, A. M. Smith, B. A. Seiber, and J. A. Roux, *SP336*, pp. 165-183 (Oct. 1970).

Key words: Absorbing; anomalous dispersion; carbon dioxide; cryodeposit; cryogenics; frost; infrared; integrating sphere; Mars; reflectance; scattering; simulation; spectral.

In situ absolute reflectance measurements have been made for carbon dioxide frosts formed on liquid-nitrogen cooled substrates. Data were obtained spectrally in the wavelength range from 0.5 to 12.0μ using an infrared integrating sphere. CO_2 frosts were found to exhibit an anomalous dispersion reflectance peak at 4.3 microns which was shown to be a very sensitive indication of the presence of solid CO_2. Also CO_2 frosts scatter short wavelength radiation ($\Lambda < 1.0\mu$) significantly and is semi-transparent for much of the wavelength range between 2.0 and 12.0. The application of these results to problems associated with cryogenically cooled surfaces is discussed.

NBS radiometric standards—present and future, H. J. Kostkowski, *SP336*, pp. 185-187 (Oct. 1970).

Key words: Irradiance; radiometric standards; radiometry; spectral irradiance; spectral radiance.

One of the primary functions of the National Bureau of Standards is to realize, maintain and disseminate national standards of measurement. In radiometry, the currently available standards consist of various types of tungsten lamps or blackbodies that have been calibrated in terms of spectral irradiance, or total irradiance.

The standards of spectral radiance are either tungsten strip lamps or blackbodies, have temperatures from 500 to 3000 K, and are calibrated, depending on the temperature and source, from 0.2 to 15 μm. Their uncertainty varies from about 0.1 to 5% depending on the temperature and wavelength. Two additional, useful standards that do not require calibration and are available commercially are the graphite arc and the copper-point blackbody.

At present, there are two standards of spectral irradiance. The first is a 1000-watt coiled coil tungsten filament quartz-halogen lamp and the second consists of this lamp mounted in a ceramic reflector. Their spectral irradiances at a wavelength of 0.9 μm and working distances of 50 and 40 cm are about 25 and 105 $\mu w\ cm^{-2}\ nm^{-1}$ respectively, and they both vary with wavelength roughly as a 3200 K blackbody. These standards are uncertain by values ranging from 3% at 2.5 μm to 8% at 0.25 μm. However, a research effort is now under way which is expected to reduce these uncertainties within a year by a factor of about 3.

The standards of total irradiance consist of the same lamps used for spectral irradiance standards and in addition 100, 500, and 1000 watt projection lamps. They have irradiances varying from about 0.5 to 135 mw cm^{-2} at working distances from 100 to 40 cm. The uncertainty of these sources has been estimated to be about 1%.

Radiometric detectors that can be calibrated electrically are becoming commercially available and appear useful in replacing irradiance source standards for some applications, particularly at the upper levels of approximately 100 mw cm^{-2}. Such absolute or calorimetric detectors, as they are sometimes referred to, are being developed and extensively evaluated at NBS. An uncertainty and reproducibility of a few tenths of a percent is anticipated for some models of these detectors.

A description of the standards, of how they are realized, of current attempts and limitations in extending their range or reducing their uncertainties, and the present NBS policy for their dissemination will be included in the verbal presentation.

Apparatus for laboratory simulation of ionospheric flow over on-board instruments of an AES, E. N. Evlanov, V. B. Leonas, and S. V. Umansky, *SP336*, pp. 189-196 (Oct. 1970).

Key words: Apparatus; beam diagnostic; ion source; ion transportation; laboratory space simulation; vacuum system.

An apparatus for a simulation of ionospheric plasma flow over on-board instruments of an artificial earth satellite (AES) is described. The simulated fluxes of nitrogen, hydrogen, and other ions have energies in the range of 5 -10^2 eV, current density of $1 \cdot 10^{-8}$ A/cm and provide good simulation of the natural working conditions of on-board instruments. A description of diagnostic means which are used for analysis of the flow parameters is given.

Thermal conductivity measurements of a candidate Viking heat-shield material after sterilization, and during exposure to vacuum, and to a simulated Martian atmosphere, L. R. Greenwood and R. M. Fleming, *SP336*, pp. 197-208 (Oct. 1970).

Key words: Ablation material; thermal conductivity; vacuum effect.

An experimental program has been conducted to measure the thermal conductivity of the proposed Viking heat-shield material, Martin SLA-561, after sterilization (60 hours at 276 °F) and during exposure to vacuum and to a simulated Martian atmosphere (74.4 percent CO_2, 12.8 percent N_2, 12.8 percent Ar). In situ thermal conductivity measurements were made at 75 °F using the line-source technique. The thermal conductivity of SLA-561 was measured to be 0.0298 Btu/ft-hr-°F at atmospheric pressure. In the first environmental sequence consisting of atmosphere, vacuum, and simulated Martian atmosphere exposure, a 60-percent reduction in thermal conductivity was measured in vacuum. After a 4-hour exposure to a 7-torr pressure in the simulated Martian atmosphere, the thermal conductivity increased 67 percent from the value measured in vacuum. The second environmental sequence consisted of measurements in the atmosphere, after sterilization and during exposure to vacuum and the simulated Martian atmosphere. The results of these measurements showed that sterilization had no effect on the thermal conductivity measured at atmospheric pressure nor on the changes measured in vacuum and in the simulated Martian atmosphere. Thermal conductivity was measured at varying pressures during both environmental sequences and the results showed the thermal conductivity to be essentially independent of pressure below 10^{-4} torr with the transition from molecular to continuum flow occurring in the 10^{-2} to 10 torr pressure range.

Method for rock property determination in ultrahigh vacuum, E. R. Podnieks and P. G. Chamberlain, *SP336*, pp. 209-223 (Oct. 1970).

Key words: Anisotropy; compression tests; mass spectroscopy; mechanical properties; outgassing; pressure measurements; rock mechanics; space environment simulation; ultrahigh vacuum.

A special ultrahigh vacuum system was designed for determining deformational and strength properties of simulated lunar rocks. The system provides a vacuum of 10^{-9} to 10^{-10} torr (10^{-7} to 10^{-9} N/m^2) depending on the specimen size and rock type. The vacuum was measured by various types of gages and also by ion pump current measurements. The partial pressure measurements of the various gas components were obtained by a quadrupole residual gas analyzer. The vacuum chamber has two stainless steel bellow-type feedthroughs for loading and a spring mechanism to compensate for the atmospheric pressure effect on the rock specimen. The uniaxial load was applied to the specimen by a servo-controlled hydraulic testing machine. Specimens of tholeiitic basalt, dacite, and semiwelded tuff were used. Special procedures in specimen preparation and preconditioning were developed. During the pumpdown period, prolonged roughing and an initial bakeout produced significantly low final pressures in the chamber. Test data presented include a typical load-deformation curve from rock specimen in ultrahigh vacuum, outgassing characteristics during loading in terms of pressure variation, and changes in the composition of gases being released by the specimen.

Friction between solids and simulated lunar soils in ultrahigh vacuum and its significance for the design of lunar roving vehicles, L. L. Karafiath, *SP336*, pp. 225-244 (Oct. 1970).

Key words: Adhesion; basalt; fiberglass; friction; steel; titanium; ultrahigh vacuum.

The initial and kinetic friction between various solids and ground basalt, simulating the lunar soil, was measured in ultrahigh vacuum with a rotating disk-type apparatus designed for this purpose. Pressures below $p = 10^{-9}$ torr have been routinely reached with the vacuum system consisting of a turbomolecular, a getter-ion and a liquid-N_2-cooled titanium sublimation pump. The testing program included tests with steel, titanium, and fiber-glass disks and ground basalt in two particle size ranges, coarse (250-500μ) and fine (38-62μ). The experimental results show that both the initial and kinetic friction invariably increase in ultrahigh vacuum. For the range of normal stresses applied in the experiments, the total kinetic friction was highest for fiberglass followed by titanium and steel; the total initial friction was highest for fiberglass followed by steel and titanium.

Real time simulation of atmospheric balloon environment, A. J. Paillous and M. Roussel, *SP336*, pp. 245-259 (Oct. 1970).

Key words: Atmospheric environment; balloon; computer; ozone; plastic material; simulation; solar ultraviolet radiation.

A simulation chamber was designed in order to study the behaviour of several balloon materials during long time flights. Solar ultraviolet radiation, pressure, temperature and atmospheric composition are the simulated constituents of the atmospheric balloon environment. Samples are irradiated without mechanical strain. A computer program, taking the values of different parameters (of the environment and of the material) against wavelength into account, gives the information for conducting the simulation. Experiments are performed in real-time. Exact ultraviolet energy doses, in each spectral wavelength interval, between 300 and 410 nm, are delivered every day to samples. A night-day cycle is simultaneously achieved with a thermal cycle.

Analysis of the simulation of the solar wind, D. E. Zuccaro, *SP336*, pp. 261-277 (Oct. 1970).

Key words: Charge exchange; charge neutralization; ion optics; mass separators; proton sources; solar wind; sputtering; ultrahigh vacuum systems.

This analysis surveys the properties of the solar wind, establishes a set of requirements for solar wind simulation, and develops a conceptual design of a simulator system. The significant features of the design are the following. The protons are formed in an r-f excited plasma discharge ion source. A 20° deflection magnetic mass separator is used to purify the proton beam of other ions, energetic charge exchange neutrals, and Lyman alpha photons. The use of a small diameter beam permits differential pumping of the ion source and the sample chamber. The proton beam either can be expanded to flood the sample, or it can be scanned over the sample.

Solar wind simulator, H. J. King, *SP336*, pp. 279-296 (Oct. 1970).

Key words: Ion beam deflection; ion optics; mass separator; proton source; solar wind simulator.

It is necessary to expose samples of thermal control coating materials to a proton flux in the laboratory in order to

estimate the stability of their reflective and absorptive properties when exposed to the solar wind. The choice of the ion source, mass separator, and beam transport system which make up an experimental apparatus to perform these tests is discussed. A final system design is presented which is capable of irradiating 10 standard samples 2 cm in diameter with a proton beam ranging in energy from 0.5 to 3.0 KeV and in intensity from 1 to 1000 times that of the nominal solar wind.

Laboratory experiment on solar wind interaction with eomagnetic field, E. M. Dubinin, G. G. Managadze, and I. M. odgorny, *SP336,* p. 297 (Oct. 1970).

Key words: Earth magnetic field; earth tail; magnetosphere; plasma theory; shock wave; solar wind.

It is impossible to reproduce in a laboratory all phenomena which exist at the interaction of the solar wind and the Earth magnetic field. In previous works it was shown that choice of experimental conditions permits one to simulate some of the most interesting effects, for example, the collisionless shock near the Earth magnetosphere. According to the principle of limited simulation, to reproduce the magnetosphere and the collisionless shock the parameters of the artificial solar wind should be: plasma density—$n = 10^{13}$ cm^{-3}, electron temperature—$T_e = 15-20$ eV, embedded magnetic field—$B \sim 40$ Oe, ion temperature—$T_i \sim 5$ eV, stream velocity—$V = 3 \cdot 10^7$ cm/sec.

At these conditions the plasma flux compressed the dipole magnetic field on the day side and formed a configuration of the magnetic field similar to the magnetic field of the Earth tail. Between the artificial magnetosphere and the plasma flow the collisionless shock is displayed. The thickness of the shock is in agreement with plasma theory and has the same order of magnitude in dimensionless expression as in space measurements. In the shock high level magnetic field microfluctuation was discovered. The dimension of the fluctuations is about that of the Larmour radium of ions. The microfluctuations were predicted in plasma theory as a result of Alfven and magnetosound instability.

In addition to the shock investigations, measurements of the plasma density, velocity and magnetic field strength were carried out before and behind the shock.

Effect of photodegradation on organic coatings, P. J. Hearst, *SP336,* pp. 299-312 (Oct. 1970).

Key words: Atmospheric exposure; ATR spectroscopy; clear and pigmented films; infrared analysis; internal reflection spectroscopy; mercury-arc irradiation; organic coatings; photodegradation; surface degradation; volatile degradation products; xenon-arc irradiation.

Clear and pigmented coating films were irradiated with a mercury arc, a xenon arc, and sunlight. Strips of the free films, consisting chiefly of alkyd, vinyl, and epoxy coatings, were exposed in a quartz chamber. The major volatile product, as determined by infrared spectroscopy, was carbon dioxide, but the products varied depending on the irradiation, the pigmentation, and the type of coating. Internal reflection spectra indicated primarily the formation of carbonyl groups, and the greatest changes were obtained for coatings that did not have high initial carbonyl absorption.

Relation between dose rate effects and laboratory simulation of space radiation damage, A. Roizès and R. Schuttler, *SP336,* pp. 313-321 (Oct. 1970).

Key words: Defect annealing; impurities; silicon; space simulation.

The experimental simulation of space radiation damage is usually done on a much shorter time scale than the satellite lifetime. The defect annealing in the semiconductor may lead to an overestimation of the real space degradation; indeed the irradiation time may be of the same magnitude order than the annealing time constant. Cleland's experiments on germanium show that for a sufficient dose the defect number electron induced may be half as much in the long irradiation case than in the shorter one.

The higher density of punctual defects introduced by a greater flux rate enhances the production of multiple defects as reducing the production of vacancy-impurity complexes.

Different factors that can influence the defect center distribution are analysed in the range -100 to $+100$ °C.

It is shown that to improve the device hardness against radiation, we must study the production rate of defects in the bulk material coming from different growing methods and makers, as we know that the damage depends on impurity constant.

Moreover a second improvement can be reached by annealing enhancement. Thus we must choose a material whose defect annealing temperature is as near as possible than the device temperature operation. A combination of these two requirements can help to select an optimal crystal for devices in space environment.

It is shown that with a better knowledge of the recovery process it will be possible to simulate long irradiation time with reasonable operation time of a particle accelerator by irradiating devices at a controlled temperature higher than the usual temperature operation.

For example, calculations made on the E center defect (vacancy—phosphorous association) show that one year irradiation at 300 K can be simulated with the same dose, in one hour irradiation at 400 K.

We deduced that in a room temperature simulation the number of defects, in this case, is overestimated by about 50% approximately.

Some problems concerning the simulation of plastic films degradations by ionizing radiations, A. J. Paillous and Ph. Fayet, *SP336,* pp. 323-344 (Oct. 1970).

Key words: Electron damage; electron energy; electron spin resonance; evaluation; gel; mechanical properties; optical properties; plastic films; poly(ethylene terephtalate); proton damage; proton energy; radiation effect; radiation intensity; recovery; solubility; space simulation; temperature effect; tests; viscosity.

Simulation in the laboratory, of the action of polyenergetic proton- and electron-fluxes encountered in Space is necessary for a convenient estimate of polymeric film materials. In order to select the best simulation conditions, the following points were experimentally investigated on poly(ethylene terephtalate) films, irradiated in vacuum by 1.5 MeV-protons and by 0.35-, 0.6-, 2.0 MeV-electrons: a) dose rate effects; b) effects of interruptions during irradiation (samples being kept in vacuum); c) recovery during post-irradiation exposures to air or to vacuum; d) effect of the sample temperature during irradiation; e) effect of particles' energy; and f) effect of the particles' nature.

It appears that accelerated tests in a vacuum can be used to predict the damage created during missions in Space which are of a longer duration than that of the tests themselves. Electron damage in Space can be simulated by a monoenergetic electron irradiation which introduces into the sample the same absorbed energy dose than the computed dose which would be absorbed in Space. For plastic films there is no practical equivalence in the effects of proton- and electron-irradiation, except for the optical trans-

mission properties. The need for an in situ testing of mechanical and optical properties is outlined.

Ultraviolet and charged particle degradation of aluminum and silver coated FEP teflon second surface mirrors, F. G. Cunningham, B. L. Bean, and S. G. Park, *SP336,* pp. 345-358 (Oct. 1970).

Key words: Aluminum coated teflon; electron degradation; proton degradation; silver coated teflon; teflon film; ultraviolet degradation.

An experimental program has been undertaken in which bare FEP Teflon films were subjected to ultraviolet irradiation and charged particle bombardment, and in which five mil aluminum and silver coated FEP Teflon films were: i) ultraviolet irradiation in vacuum and oxygen; ii) irradiated with 5, 10 and 25 or 30 KeV electrons and protons; and iii) exposed to simultaneous ultraviolet-proton and ultraviolet-electron bombardment.

The charged particle irradiations indicate that a measurable change occurs in the spectral reflectance of both silver and aluminum backed material at a dose of about 1×10^{15} particles/cm^2, and that this degradation increases as the total dose is increased. This spectral reflectance change appears first and is the most pronounced in the ultraviolet for a given total dose. At a total dose of 1×10^{16} particles/cm^2 the surfaces generally look cloudy and oftimes mottled. Upon closer examination this mottling is found to be due to the presence of Litchenberg figures within the teflon—especially in the case of electron irradiation—which are caused by charge storage and subsequent electric discharge. The calculated changes in integrated solar absorptance generally agree with those reported by other observers. The ultraviolet results confirm that silver coated teflon is stable when irradiated in vacuum and indicate that aluminum coated material undergoes a small decrease in integrated solar absorptance (i.e., an improvement) when so irradiated.

The interaction of low energy electrons with polymeric perfluorinated ethylenepropylene (FEP), J. B. Schutt, *SP336,* pp. 359-382 (Oct. 1970).

Key words: Degradation mechanising; electron bombardment; electron degradation; polymeric perfluorinated ethylenepropylene; proton bombardment; thermal control coatings.

Photomicrographs are presented showing the effects of 30 KeV electrons on FEP. Depicted are Lichtenberg patterns, bubbles and a buckling effect. The attempt to explain these observations is derived from a theoretical analysis based on a diffusion mechanism for charge flow using beam current as a source term. The solution is used to demonstrate that charge is stored centrosymmetrically with respect to ground. These effects are discussed in terms of an "electrolysis" mechanism resulting from charge storage and beam energy thermalization. Explicit expressions are given for surface charge storage and voltage across the sample resulting from such charge accumulation. Buckling is treated from a thermodynamic basis using the Helmholtz free energy and assuming the distortion develops isothermally. "Electrolysis" is postulated via a mechanism selecting the tertiary carbon as the active site for mobile moiety generation.

The usefulness of optical data for purposes of thermal design taken from samples irradiated with low energy electrons in the laboratory is questioned. Because FEP is an electrical insulator, these experiments must, therefore, be carried out in a neutral laboratory environment, or be characterized in the space environment from carefully designed electrical experiments.

The degradation of Alzak by short wavelength ultraviolet radiation, M. J. Donohoe, R. McIntosh, Jr., and J. H. Henniger, *SP336,* pp. 383-392 (Oct. 1970).

Key words: Alzak; thermal control coatings; ultraviolet degradation; vacuum UV.

Experimental evidence is presented to further support earlier findings on the UV induced degradation of Alzak, which was found to be inversely proportional to wavelength between 220 and 300nm. UV and vacuum UV exposures at selected wavelengths between 123.6 and 300nm indicate degradation to be inversely proportional to wavelength down to 185nm. Equivalent exposure to 123.6nm radiation however, produced less degradation indicating a change in the damage dependency below 185nm. Degradation of up to 12% change in reflectance at 295nm is reported for Alzak exposed to less than 50 equivalent sun hours of vacuum UV radiation.

The photo-response at an alkaline paint interface with aluminum, W. A. Wappaus, *SP336,* pp. 373-402 (Oct. 1970).

Key words: Alkaline paint; conduction of paints during ultraviolet exposure; electrode potential of paints; photo degradation; thermal control coatings; ultraviolet degradation.

When a spacecraft coating comprised of aluminum oxide and potassium silicate is applied to an aluminum alloy (6061) substrate and subsequently partially coated with evaporated gold electrodes, a measurable potential is developed between the substrate and the gold electrodes. This effect is observed when the coating is in darkness and in vacuum. A dark current is also observed. Prior to observation, the specimen is heated in vacuum to 150 °C for 24 hours.

When the coating is irradiated in situ with UV shorter in wavelength than 3600 Angstroms, the current and voltage is found to increase. Upon exposure to prolonged irradiation this current level decays exponentially with time. The voltage similarly decays with time in an exponential manner indicating that photo-degradation of the electronic transport properties is occurring.

The transport mechanism proposed to account for this behavior is a migration of protons toward the aluminum substrate and negative hydroxyl ions toward the gold electrodes resulting in the electrolysis of water in the coating! In the presence of UV this process is accelerated resulting in an increased current flow of three orders of magnitude. Since the current flow during UV radiation decays exponentially, this suggests a diffusion limited process.

Plans and status of NMAB ad hoc committee on testing for prediction of material performance in structures and components, R. S. Shane, *SP336,* pp. 403-404 (Oct. 1970).

Key words: Combined environments; components; material performance; predictive testing; structures.

National Materials Advisory Board—National Research Council—National Academy of Sciences—*ad hoc* Committee on "Testing for Prediction of Material Performance in Structures and Components"—Interim Report.

At the request of the Office of the Director of Defense Research and Engineering, the National Materials Advisory Board of the National Academy of Sciences has undertaken to review "Testing for Prediction of Material Performance in Structures and Components."

The basic purposes of the study have been identified as: (a) make a selective survey of the needs for new and/or improved predictive (including accelerated) testing techniques, (b) consider predictive methods for forecasting the per-

formance of materials in structures and components under combined stresses in service; (c) identify the factors of predictive testing and explore approaches for development of methods and techniques of predictive testing; (d) appraise the benefits of predictive testing as well as the risks of predictive testing; (e) provide guidance in establishing a policy for Government and/or Industry interaction; (f) recommend mechanisms for implementing this policy.

An *ad hoc* Committee has been appointed and convened. The principal problem areas appear to be (a) interaction phenomena, (b) design of multi-factor tests which forecast definitively the behavior of structures and components in the presence of known or foreseeable failure modes, involving materials (c) lack of systematic accumulation of existing information so that gaps in needed knowledge become apparent and remedial action can be taken before design choices are irrevocably made, (d) peripheral failure modes are frequently overlooked.

NMAB plans to co-sponsor the ASTM National Symposium on Predictive Testing, Anaheim, California, April 21-23, 1971.

Monitoring service testing by nondestructive testing, R. W. McClung, *SP336,* p. 405 (Oct. 1970).

Key words: Compaction density; eddy current measurements; fuel rods; impregnation density; monitor tests; neutron radiography; ultrasonics; x rays.

Applications of nondestructive testing techniques to monitor tests include the use of x rays with both film and television detection to monitor thermal cycling of fuel rods, neutron radiography on irradiation experiments, eddy-current measurement of space interval between components, and interim monitoring by ultrasonics of the wall thickness of a vessel in a reactor experiment. Studies during fabrication development include multiple interim measurements of compaction density of fuel rods and impregnation density of graphite using quantitative gamma and x-ray attenuation as well as use of eddy-currents to monitor changes in quality of sodium bonding in a fuel rod. Recommended approaches include the use of eddy-current methods to monitor changes in electrical properties, dimensions or flaw character, ultrasonics to measure changes in elastic properties, dimensions of flaw character, penetrating radiation to observe or measure changes in density, or dimensions and other forms of energy for similar applications.

Signature analysis—nonintrusive techniques for incipient failure identification application to bearings and gears, B. Weichbrodt and K. A. Smith, *SP336,* pp. 407-448 (Oct. 1970).

Key words: Bearings; diagnostics; gears; reliability; signature analysis; vibration.

This paper describes how acoustic and vibration signals generated by operating machinery can be used to diagnose its internal condition without using internal sensors which might perturb the system of interest.

It is shown how characteristic "signatures" can be electronically extracted from the overall noise and vibration signals. By interpreting these signatures in the light of engineering knowledge of the machinery under study, it is often possible to identify incipient failure modes long before final failure. This technology opens up many new possibilities to avoid unscheduled maintenance, improve product quality and reduce testing time.

The paper discusses in detail specific applications to bearing and gear diagnostics and shows how the diagnostic process can be electronically implemented and automated. Several other application areas are briefly discussed.

A major part of the work which is reported in this paper was sponsored by the Condition Monitoring Engineering Operation of General Electric's Aircraft Engine Group, for development of jet engine diagnostic systems.

Measurement methods for microcircuits, W. M. Bullis, *SP336,* pp. 449-455 (Oct. 1970).

Key words: Device fabrication; environmental testing; integrated circuits; measurement methods; microcircuits; silicon.

One of the problems encountered with testing in either simulated or real environments is associated with the necessity of demonstrating that the failures observed are, in fact, due to the environment rather than random effects which would occur even in the absence of the environmental stimulus. This problem is particularly acute in the case of high-reliability electronic components such as silicon monolithic integrated circuits. For these parts, desired levels of reliability can be achieved only if all process steps in their manufacture can be carried out in a controlled and reproducible fashion. This paper surveys the status and availability of standard test methods suitable for making the measurements which are necessary to achieve such control. Consideration is given to standard measurement methods appropriate for thin film integrated circuits and hybrid microcircuits as well as those for silicon monolithic integrated circuits fabricated by the epitaxial, planar process.

Life testing using continuous acceleration, E. Rabinowicz and B. Shiralkar, *SP336,* pp. 457-471 (Oct. 1970).

Key words: Accelerated testing; cumulative damage; failure; life testing; mechanical reliability.

One method of carrying out accelerated tests consists of increasing the stress at a uniform rate with time until failure. It is shown that from such tests the life under normal stress conditions can be predicted by plotting the results on a stress-time curve on which the stress axis has been modified so that area represents amount of damage. Tests with electric light bulbs, whose failure obeys a cumulative damage criterion, give good agreement between predicted and measured life. The danger of the continuous acceleration procedure is that the stress may become so high that new failure modes are introduced.

Establishment of an optimum duration for spacecraft component thermal vacuum tests, W. L. Harvey, *SP336,* pp. 473-485 (Oct. 1970).

Key words: Absorption; adsorption; "bake out"; components; decomposition; degassing; environment; evaporation; outgassing; simulation; sublimation; thermal conduction; thermal vacuum tests; volatile constituents; volatilization.

The duration of planetary space missions precludes performing component thermal vacuum tests which simulate the mission time period. Many arbitrary approaches have been taken to establish adequate durations for these tests. This paper outlines an approach which considers the probable effects of the thermal vacuum environment on the components and their constituent materials. In general these effects are found to be related to outgassing rate which is time and temperature dependent. A test cycle is proposed which considers this situation and utilizes any prior "bake out" heat exposure to reduce the test duration to a reasonable period.

Equipment to study high velocity dislocations in materials, V. R. Parameswaran and J. Weertman, *SP336,* pp. 487-508 (Oct. 1970).

Key words: Dislocation velocity; high speed dislocations; impact stress pulse; piezoelectric stress gauge; quartz; slip bands.

The microstructural and physical properties of a material deformed under high strain rates are quite different from those of the slowly deformed material. This is attributed to the motion of a shock front consisting of an array of high speed dislocations through the shock loaded material. An equipment was constructed to shock load single crystals of metals by shooting small steel pellets using a gas gun. The slip bands generated on the surface of the crystals by the stress pulses give a measure of the dislocation mobility in the material. In this paper the equipment used to produce the stress pulses and that used to measure and record the stress pulses are described.

Some effects of equalization on acceleration response and fatigue life expectancy, R. M. Mains, *SP336,* pp. 509-524 (Oct. 1970).

Key words: Acceleration response; evaluation; fatigue life; lumped parameter system; mechanical impedance; random vibration; test; transfer impedance; transmissivity equalization; vibration.

A set of calculations is reported for various transmissibilities of a 10-mass system, intended to be representative of an exciter, fixture, test article arrangement. The difficulties of achieving equalization at some coordinate when it has a transmissibility range of 10^6 or more are noted. By comparison of r.m.s. responses to a level power spectral density input, it is shown that factors of 5 to 10 or more difference in acceleration response result from equalization at different coordinate locations. These differences in r.m.s. response would produce corresponding differences in predicted real-time behavior. The differences in r.m.s. spring stress responses were smaller for various equalization locations, but still large enough that predictions of fatigue life expectancy (for the system used) would be much affected by the choice of equalization location.

Charged particle track implications for accelerated testing, T. M. Flanagan and V. A. J. van Lint, *SP336,* pp. 525-534 (Oct. 1970).

Key words: Radiation damage; radiation testing.

This work considers the ionization effects produced by the passage of energetic particles through material, emphasizing the fact that the ionization is formed along particle tracks rather than being uniformly distributed throughout the material. Thus, the particle track through a material can be visualized as a cylinder centered on the particle path disturbed by ionization and carrier trapping. The dimension of the disturbed region is related to the range of the electron ejected by the ionization event, while the density of carriers within the disturbance depends on the ejected electron range and on the ionization efficiency of the energetic particle. The disturbed regions then relax with characteristic times ranging from the very short to the very long. The dose-rate dependence arises from the relationship of the characteristic relaxation times and the average time for two particles to disturb the same volume. At low doses, each particle track traverses primarily unirradiated material, and the effects are additive. At higher doses, nonlinearities are expected, since particles penetrating a previously disturbed region may find the carrier traps in a different charge state than in virgin material. Another source of nonlinearities is the density of ionization which will vary with particle type and energy. The size of the disturbance around a track varies from 100 to about 2000 Å, depending on the material. This quantity can be used to calculate the average overlap time for a given dose rate. The dose which must accumulate before nonlinearities are apparent can be estimated from the trap density of the material. Each of these factors must be taken into account when planning on assessing simulation of radiation effects.

A simulation to validate future space missions, T. P. Foley, A. W. Metz, and A. W. Yonda, *SP336,* pp. 535-547 (Oct. 1970).

Key words: Simulation; space systems; system test bed.

A simulation tailored to be responsive to the needs of aerospace systems analysts has been developed. The simulation is written in FORTRAN so that it can easily be transferred between different computers. The simulation is modularly structured so that new functions can be simulated and easily added. The level of detail of the simulation of model elements can vary widely. When macroscopic system aspects have been studied and optimal configurations established, then sub-systems of interest can be modeled in greater detail and embedded in the macroscopic simulation for more detailed study. Thus, design engineers can study the performance of their design in a total system environment before hardware is fabricated.

The parameters of the simulation permit the configuration of models rapidly. These can be run against a scenario of input parameters which when varied provide information on system performance. Thus, many different projected system configurations can be quickly exercised and discarded until only a few feasible system configurations remain. These then can be exercised with model elements being more detailed enabling a more comprehensive analysis. Provision is made for entry of errors into the system so that performance characteristics of the system in a degraded state can be studied. The exercising of Executive Program strategies is provided for. Thus, a tool which is oriented toward supporting the systems analysis requirements for studying dynamic system performance has been developed.

General purpose centralized automatic testing for improvement of shipboard system performance, F. J. Zupan, *SP336,* pp. 549-568 (Oct. 1970).

Key words: Data acquisition; data dissemination; data processing; maintenance; operational readiness; performance monitoring; testing.

Increased operational effectiveness of Navy shipboard systems is the primary goal of the Navy automatic testing program. This paper discusses the rationale and techniques utilized in developing an experimental model which will help update and modernize traditional methods and approaches to systems monitoring and maintenance. Developments in acquisition, processing and dissemination of information are related to a centralized on-line performance monitoring system are covered. Both laboratory and shipboard functional tests were performed, with a laboratory model system monitoring typical Navy electronic and non-electronic systems. Test results, a discussion of problem areas, and prediction of the impact of centralized testing on the shipboard maintenance and operating organization are included.

Explosive oxidations initiated by simulated meteoroid penetration into spacecraft atmospheres, W. H. Carden, *SP336,* pp. 569-585 (Oct. 1970).

Key words: Blast over-pressure; combustion front; hypervelocity impact; meteoroid penetration; oxidative detonation; oxidative flash; oxygen atmosphere; spacecraft.

Hypervelocity impact tests were conducted in an evacuated range on target samples which simulated a NASA S

IVB wall configuration since this stage is planned as the primary structure in the NASA Orbiting Workshop program. The samples formed part of the wall of a large tank which contained an oxygen-rich atmosphere. The explosive oxidations which occurred inside the tank as a result of perforation were observed and the results were analyzed. The bare thermal insulation on the inside of the wall further enhanced the otherwise severe reaction which occurs with a metallic wall in the presence of enriched oxygen.

The dynamic environment simulator—a multienvironmental an-rated centrifuge, D. B. Rogers, M. McCally, and K. L. appel, *SP336,* pp. 587-598 (Oct. 1970).

Key words: Combined environmental stress; dynamic environment simulator; man-machine system; man-rated centrifuge; simulation research.

The U.S. Air Force Dynamic Environment Simulator is a man-rated centrifuge with multiple environment simulation capabilities. This facility can generate combinations, either simultaneous or sequential, of acceleration, vibration, temperature, barometric pressure, gas composition, noise and related environmental stresses. Simulation of a broad variety of aerospace flight mission environments is now possible using this facility. The man rating of this facility was carried out in the last six months of 1969 and resulted in the first manned run in December of that year. Although presently programmed to meet Air Force data requirements for the design of planned and proposed aircraft systems, the Dynamic Environment Simulator represents a national research capability capable of supporting the requirements of many R & D programs including manned space flight, high speed surface transportation and other systems or functions where man is exposed to physical environmental stresses in combination.

Use of the BEN FRANKLIN submersible as a space station mulator, M. J. Ferguson and C. B. May, *SP336,* pp. 599-621 Oct. 1970).

Key words: Closed ecological system; habitability; maintainability prediction; microbiology; microflora shift; physiology; psychology; space station simulator; submersible.

This paper presents the NASA-sponsored effort using the Ben Franklin submersible as a space station analog during the 30-day drift mission in the Gulf Stream, starting 14 July and ending 14 August 1969. The areas of investigation include: (1) Psychological and physiological measurements during the pre-mission, mission, and post-mission phases were related to observed crew behavior. The results reveal that detailed consideration must be given early in the design to those aspects which could cause crew annoyance and frustration, and which could be further aggravated by long confinement. Selection of crew pairs for compatibility of personality will help reduce stress in small closed systems. (2) Habitability in a closed ecosystem was investigated. The objective was to determine the suitability of BEN FRANKLIN submersible habitability data for providing guidelines for future spacecraft design. These include provision for privacy, control of temperature and humidity, and adequate facilities for personal hygiene. (3) Microbiological investigation as a study of the effect of total biological isolation upon the flora of the crew, environmental and life support subsystems. The continuing shift and simplification of microbial flora on the 30-day mission indicates a need for investigation of the problem in association with longer space missions. (4) The maintainability experiment objective was to obtain detailed information on the frequency, duration, type, and complications of onboard maintenance during the mission.

Development of an open circuit cryogenic life support system for use in neutral buoyancy space simulation, C. M. McClure and C. W. Williams, *SP336,* pp. 623-649 (Oct. 1970).

Key words: Cryogenics; liquid air; liquid nitrogen; liquid oxygen; neutral buoyancy; space simulation.

Marshall Space Flight Center has a need for a self contained underwater life support system which can supply a breathing mixture to the neutral buoyancy test subject, without the need for a surface tethered supply line. A prototype system has been developed which utilizes a mixture of liquid oxygen and liquid nitrogen contained in a single supply tank. Development and testing has shown that this system will supply the quantity and quality of gas required under completely controlled and predictable conditions to depths of at least 60 feet.

Advanced diving techniques applicable to extended mission neutral buoyancy space simulation. J. B. MacInnis and C. M. McClure, *SP336,* pp. 651-659 (Oct. 1970).

Key words: Diving; hyperbaric; neutral buoyancy; simulation; space.

Diving methodology is reviewed. Nonsaturated diving is recognized as the basis for almost all neutral buoyancy testing to date. Saturated diving methodology is reviewed and its possible special adaptation for extended duration mission neutral buoyancy simulation is proposed. The advantages of using the new closed circuit rebreather SCUBA gear is also reviewed and proposed as an aid to extended mission simulation.

A method to obtain an ultraclean environment, M. S. Cridlin and J. W. O'Connor, *SP336,* pp. 661-668 (Oct. 1970).

Key words: Anti-migration traps; cold shrouding; contamination; environment; ion pumping; low pressure; low temperature; pumping; ultraclean; vacuum.

The Goddard Space Flight Center has designed and fabricated a system which offers an effective approach toward solving the problems usually encountered in creating an ultra high vacuum. The vacuum techniques described find application in an Auger Spectrometry System.

This ionization pumped system is unconventional in that: (1) Interior chamber cryogenic shrouding is eliminated. In lieu of the internal shrouds the method is to submerge the entire chamber exterior in a dewar of liquid nitrogen. Eliminating the shrouds within the chamber eliminates sources of contamination and the exposing of the wall exterior to the cryogenics eliminates the typical ambient temperatures that chamber walls normally experience, (2) The ionization pump is located within the ultrahigh vacuum chamber, rather than outside. This eliminates the gate valve typically associated with an externally mounted pump and permits greatly increased realization of the conductance pump capacity. The pump is protected by use of gas purging when pressures are increased to atmospheric.

The method of precleaning, prior to bakeout, involving high temperature gas purging is described as well as the entire systems operation. Pressures in the order of 7×10^{-13} torr have been observed.

This paper describes a Micrometeoroid Impact Simulation System (MIMS) at NASA Langley Research Center and outlines current research efforts. The MIMS electrostatically accelerates electrically charged, micrometer-size

particles to velocities in excess of 30 km/s. Particles can be accelerated one at a time or at various rates to above 10/s. The major components of the MIMS are a microparticle charger-injector, a horizontal 4-million-volt Van de Graaff accelerator, an assemblage of particle detectors, a particle deflection system, a data system, and a series of target chambers. The data system is a computer-controlled, real-time system which records information to determine the velocity, mass, and diameter of each particle which enters the target area. The system also controls and selects particles, and rejects particles which do not have the desired velocities. The system is used to study damage to sensitive surfaces, develop micrometeoroid detectors, and obtain data about meteoroid entry physics.

Properties of optical materials in space, F. W. Paul, *SP336,* pp. 949-959 (Oct. 1970).

Key words: Information center; interferometric measurements; optical materials; physical property changes; space environment.

A program has been established to provide a central clearinghouse for information about the effects of space environment on the optical and other physical properties of optical materials. Information is being collected and organized on the effects of space environment on refractive index, dispersion, transmittance, reflectance, thermal expansion coefficient, Young's modulus, birefringence, and yield and breaking points of all materials of interest for the transmission or reflection of optical radiation in space.

In technical areas where information about the behavior of materials does not exist a program of laboratory investigations will provide the required information. In preparation for some in-house studies of materials at very low temperatures and also during exposure to a charged particle flux an experiment has been devised and instrumented to provide measurement of dimensional changes and refractive index changes at several wavelengths. The essence of the method is the use of Fabry-Perot interferometry to measure independently the dimensions of the sample of material and the optical path length through the material.

A space radiation environment simulator for the evaluation of solar cells, P. A. Newman, J. J. Hirshfield, H. E. Wannemacher, and M. Eck, *SP336,* pp. 935-947 (Oct. 1970).

Key words: High vacuum; solar cells; space radiation; space simulation; thermal control.

A facility for studying the properties of solar cells and other optically sensitive devices under a wide range of environmental conditions such as could be found on extra-terrestrial space missions has been developed at the NASA Goddard Space Flight Center. The system includes control of temperature, vacuum and solar irradiation while irradiating a 23 cm by 23 cm array of samples with 4 MeV protons or electrons. Typically the samples can be controlled in temperature between − 170 and 150 °C, while a shroud, used to control radiative coupling, can be independently controlled between − 196 and 150 °C. The vacuum system, which is virtually free of hydrocarbon contamination, will evacuate the chamber to less than 1×10^{-8} torr in less than 4 hours. A 400 l/s Noble Vac-Ion pump backed by a titanium bulk sublimator and a titanium filament evaporator has been designed to accommodate the large gas loads possible during irradiation. A 4.2 KW compact Xenon arc solar simulator provides a close match to the solar spectrum from low irradiances to an irradiance of four solar constants. An automatic data acquisition system modified to generate digital solar cell I-V characteristics is used to collect data in a form suitable for computer processing.

A programmable dynamic thermal vacuum system for solar array component testing, J. W. Fairbanks and M. B. Eck, *SP336,* pp. 669-682 (Oct. 1970).

Key words: Gaseous nitrogen heater; gas stream blower; GN temperature conditioning; solar array; solar cell; thermal cycle vacuum testing; thermal shroud.

The Programmable Dynamic Thermal Vacuum System (PDTVS) was designed to provide long-term laboratory evaluation of solar array components undergoing thermal cyclic effects anticipated for specific missions. This system is capable of duplicating the temperature excursions, including rate-of-change of temperature, for practically all missions currently under consideration at NASA. The equipment can obtain test specimen temperatures between + 150 °C to − 120 °C with a rate-of-change of at least 6 °C/min. The PDTVS can accommodate thirty-six 6 in × 6 in test specimen holders and position each one in front of a illumination port for periodic in situ electrical measurement with a solar simulator.

Basically, the facility consists of an ion-pump vacuum system with 2 bell jars, thermal conditioning equipment, a stage blower, a programmable control unit and an LN storage tank. The novel developments in this system include a high-energy low-mass heater which employs radiative convective coupling of a gas stream to an IR source. The test carrousel shaft is used for specimen positioning and an instrumentation penetration. Initial difficulties required modification of the blower bearings, shaft and housing to accommodate the wide range of gas stream temperature without affecting performance.

The cryopumping system for the space simulation chamber, H. Nakagawa and R. Tsunoda, *SP336,* pp. 683-698 (Oct. 1970).

Key words: Cryopumping; ion pump; pumping speed; space simulation chamber; vacuum.

Recently, the space simulation facility which has distinctive feature was completed in Japan. This facility consists of main- and sub-chamber and other necessary equipment. The main-chamber, having 1.8 m dia. and 6 m length, is accompanied by the pumping system of very high pumping speed. The pumping system consists of cryopump, diffusion pump, mechanical Roots booster pump and rotary vacuum pump. The ultimate pressure of the order of 10^{-9} torr was achieved by this system. The sub-chamber, having 60 cm dia. and 120 cm length, is accompanied by the pumping system which is completely oil free. The pumping system consists of cryopump, sputter-ion pump and cryosorption pumps. The ultimate pressure of the order of 10^{-10} torr was achieved by this system. Determination of the pumping speed of the cryopump is a very complicated procedure and in this study we propose the new factor: "Arrival Probability" which is computed by Monte Carlo method. The dynamic performance of oil free pumping system, especially the usual order of cryosorption pump was investigated, and the residual gases were analyzed by mass-filter. The concept of "Self-contamination Factor" proposed by Dr. R. Chuan is adopted to this study to determine the performance of the system, and the factors of 0.006 and 0.0012 were obtained under the actual operating condition.

Simulation of surface-atmosphere interaction processes for Mars, K. M. Foreman, *SP336,* pp. 699-723 (Oct. 1970).

Key words: Convective processes; Mars atmosphere exploration; planetary atmosphere-surface interaction; planetary meteorology; research facility; simulation technique; space research.

Landings of unmanned spacecraft on Mars can be affected by the dynamics of the lower planetary atmosphere. In an effort to understand the convective motion and effect of surface topography and soil on local atmospheric motion, a laboratory-scale simulator has been designed and built to examine parameters of significance systematically. Scaling law relationships were used in sizing the facility and appropriate test conditions within the terrestrial gravitational environment. This facility is a 4-foot diameter by 8-foot high stainless steel chamber capable of maintaining test conditions to about 10 microns absolute pressure and gas temperatures between -85 °C[b] and $+65$ °C[b]. The planetary surface is simulated by an electrically heated aluminum surface controlled to within $\sim\pm 0.7$ °C[b] of the initial set conditions.

Measurements of test gas temperature above the simulated planetary surface are made with a specially designed traversing mechanism carrying thin film and thermistor sensors. Temperature profiles above the surface are similar to theoretical calculations for equatorial Mars regions at midmorning, if the lower Martian atmosphere is assumed to have an eddy viscosity of about 5×10^5 cm²/s. Additional data show that temperature gradients increase near the surface as the gas pressure is decreased below atmospheric level, and that the degree of turbulence (as evidenced by temperature fluctuations) appears to diminish with lower pressure.

Exploratory tests of thin film sensors as wind speed indicators at simulated Mars surface pressure of 5mb show possible difficulty in differentiating velocity from temperature at wind speeds less than several m/s magnitude. However, thin films appear quite responsive as temperature sensors to pressures on the order of less than 1 mm Hg A.

Operation of a large thermal vacuum chamber at Martian ressure levels, T. Buna and J. R. Ratliff, *SP336*, pp. 725-748)ct. 1970).

Key words: Evacuating; heat transmission; infrared scanning; Mars environmental simulation; outgassing; thermal insulation; thermal-vacuum chambers.

A test program was conducted to evaluate techniques of insulating the cold shroud of a large thermal-vacuum chamber from its outer shell, in order to prevent excessive cooling of the latter during Mars environmental simulation tests. A fluidized insulation concept using polystyrene flakes in the shroud/shell interspaces was found to best meet both thermal and operational requirements. With 140 R (77.8 K) shroud, convective transport through the insulation was negligible up to 20 mm Hg chamber pressure, and did not exceed permissible levels up to 50 mm Hg. At the higher pressure levels local heat transfer through the insulation was found to be of a cyclic nature. Thermal data are presented in the form of Nusselt-Rayleigh type correlations. Unique techniques devised for rapid installation and removal of the insulation are described; chamber shell temperature monitoring techniques (including infrared scanning) are evaluated; and the pumpdown characteristics of the insulated chamber are established.

A cryopump for steady-state testing of rocket engines under titude conditions, M. J. Triplett and W. E. Riggs, *SP336*, p. 49 (Oct. 1970).

Ablative heat shields for planetary entries—a technology view, G. D. Walberg and E. M. Sullivan, *SP336*, pp. 751-2 (Oct. 1970).

Key words: Ablation; evaluation; heat shields; heat transfer; planetary entry; radiation.

A review of ablation technology is carried out to assess the present state of the art and point out areas in which further research is required for planetary entry heat shields. Analyses and test techniques which have been developed to treat heat shields for Earth entry with combined radiative and convective heating are reviewed. With the lessons learned from Earth-entry research in mind, the work carried out to date for entry into various planetary atmospheres is reviewed and technological problem areas are discussed. In defining significant phenomena, various mechanisms and processes are discussed and their relative importance is illustrated by describing the analysis of a manned planetary-return Earth entry. In discussing the work to date on planetary entry, two broad categories of research are considered: (1) entry into tenuous atmospheres and (2) entry into the dense atmospheres of Venus and the giant planets. In each of these categories, atmospheric characteristics, entry velocities and modes, vehicle geometries, heating levels and candidate ablation materials are discussed. Present ground and flight-test capabilities are summarized and compared with planetary entry conditions. Particular attention is paid to coupled ablative-radiative phenomena which require the radiation spectrum of the facility to essentially duplicate that of the planetary atmosphere under study.

Ablation phenomena in supersonic laminar and turbulent flows, E. M. Winkler, M. T. Madden, R. L. Humphrey, and J. A. Koenig, *SP336*, pp. 813-835 (Oct. 1970).

Key words: Ablation; ablation-induced transition; cross-hatched striations; Teflon.

Arc tunnel experiments using pipe specimens of TFE-7 examine the ablation of Teflon under a supersonic laminar and turbulent boundary layer. Test conditions include Mach numbers of 2.3 and 3.0, supply pressures of 2×10^6 N/m² to 3×10^6 N/m² and supply temperatures of 2200 to 5000 °K. Experimental results are compared with computer predictions. In two laminar boundary-layer tests, parallel striations appear; in all turbulent boundary-layer tests, criss-cross striations appear.

Prediction of mechanical erosion of charring ablators, L. H. Hillberg, *SP336*, pp. 837-851 (Oct. 1970).

Key words: Ablation; aerodynamic shear; carbon; char; cork; epoxy-novolac; erosion; phenolic carbon; silicone rubber.

A simple method has been developed for predicting the mechanical erosion of charring ablators exposed to an aerodynamic environment. The method requires the knowledge of two variables: the aerodynamic shear stress at the ablating surface and the surface temperature. Test data are used to obtain two empirical constants necessary for correlating the erosion recession rate in terms of these two variables. The empirical constants have been determined for phenolic cork, phenolic carbon, epoxy-novolac, and high density silicone rubber.

Heating in cracks on ablative heat shields, E. M. Winkler, R. L. Humphrey, M. T. Madden, and J. A. Koenig, *SP336*, pp. 853-877 (Oct. 1970).

Key words: Ablation; catastrophic ablation; substructure heating; surface cracks.

An experimental program has been carried out in the U.S. Naval Ordnance Laboratory (NOL) 3 Megawatt Arc Tunnel to study the effect of cracks in an ablative heat shield on the substructure heating. The tests used a supersonic contoured nozzle with a Teflon duct attached to it. The ducts had transverse and longitudinal cracks machined into the surface. They were instrumented for pressure, temperature,

heat transfer and skin-friction measurements. The cracks were found to have pronounced effects on the ablative behavior. The heating is moderate under a laminar boundary layer, but can be catastrophic when the boundary layer is turbulent, depending upon the size and direction of the crack. The results for the transverse cracks were compared with an available analytical prediction. The heat-transfer measurements tend to support the concept of vortex cells existing within the cracks. Cracks that are deep as compared with their width result in very little substructure heating.

Apparent operating limits of arc heaters with respect to total enthalpy and stagnation pressure, R. Richter, *SP336,* pp. 879-892 (Oct. 1970).

Key words: Arc currents; arc heaters; constricted arc; enthalpy; operational limits; stagnation pressure.

For many years arc heaters have been operated over a wide range of operating conditions. An apparent upper limit with respect to stagnation pressure and total enthalpy was found which could not be exceeded. It is attempted to show that this limit is not imposed by the enthalpy-pressure combination but is caused by the limit in total power input that can be achieved with the non-segmented constricted arc heater. The failure or fast deterioration of arc heater components is found to be primarily due to high arc currents which are employed to heat the gas to maximum temperature. It is concluded that the enthalpy-stagnation limit of nonsegmented constricted arc heaters operating under similar constraints can be exceeded.

Operating characteristics on the Air Force flight dynamics laboratory reentry nose tip (RENT) facility, J. C. Beachler, *SP336,* pp. 893-904 (Oct. 1970).

Key words: Ballistic missiles; heat protection; reentry; test facility.

Reentry missile nose tip development requires ground test facilities capable of simultaneously producing extreme pressures and heat transfer rates. The Reentry Nose Tip (RENT) Facility was developed by the Air Force Flight Dynamics Laboratory to produce this high pressure hyperthermal environment. The present and planned capability of this facility is described and typical pressure and heat transfer profiles of the test jet are shown.

Investigation of the characteristics of fluids vented into a vacuum, R. Steddum, D. Maples, and F. M. Donovan, *SP336,* pp. 905-914 (Oct. 1970).

Key words: Flow rate tests; high speed movies; particle velocities; vacuum tests; water jet.

For manned space stations planned for the future, it becomes necessary to eject fluids into the space environment. These ejected fluids form ice clouds which remain in the vicinity of the spacecraft and could interfere with optical instrumentation. In order to study the dynamics of fluid jets in a space environment, a high vacuum system was modified to allow the injection of fluids into a vacuum region while maintaining a pressure below 0.1 N/m². The cone angles, individual particle velocities, and mass flow rates of water sprays under vacuum conditions were measured. The individual particle velocities of sprays produced by outgassed water were lower than the particle velocities of sprays produced by water with a definite amount of dissolved gas.

Micrometeoroid impact simulation system, R. A. Golub and J. R. Davidson, *SP336,* pp. 915-933 (Oct. 1970).

Key words: Hypervelocity; impact damage; micrometeoroid; particle detectors.

SP337. Silicon device processing. Proceedings of a symposium held at Gaithersburg, Maryland, June 2-3, 1970. C. P. Marsden, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 337, 46[7] pages (Nov. 1970).

Key words: Analysis; device processing; diffusion; epitaxy; junctions; resistivity; surface preparation.

This Proceedings contains the information presented at th Symposium on Silicon Device Processing held at the Nationa Bureau of Standards on June 2-3, 1970.

This Symposium covered the measurement field and was pur posefully restricted to the generic topics of diffusion, epitaxy surface preparation and interdependence of unit processin operations. This emphasis on measurement during th processing operation or on the characteristics of the processe material, showed the necessity and more important, the ambigu ties of current methods of measurement. The application of som new techniques to measurement were also discussed. *Thes proceedings include the following papers (indented):*

Some thoughts on how we might improve our materials an process work, D. G. Thomas, *SP337,* pp. 3-10 (Nov. 1970).

Crystallographic imperfections as related to silicon cryst growth, J. A. Lenard, *SP337,* pp. 11-18 (Nov. 1970).

Epitaxial growth of silicon, B. A. Joyce, *SP337,* pp. 19-2 (Nov. 1970).

Diffusion in silicon: properties and techniques, C. F. Gibbo *SP337,* pp. 21-35 (Nov. 1970).

Measurement and control of dielectric film properties durin semiconductor device processing, B. E. Deal, *SP337,* pp. 36-5 (Nov. 1970).

Equipment considerations for silicon epitaxial reactors, M. Hammond and W. P. Cox, *SP337,* pp. 51-59 (Nov. 1970).

A comparison of a resistance-heated reactor for silicon epita ial growth with other epitaxial systems, W. A. Kohler, *SP33* pp. 60-65 (Nov. 1970).

Techniques for depositing highly uniform and defect-fr epitaxial silicon, D. C. Gupta, *SP337,* pp. 66-78 (Nov. 1970

Control of thin silicon films grown from silane, D. J. Dumi *SP337,* pp. 79-86 (Nov. 1970).

The growth of submicron single and multilayer silicon epitax J. Simpson, A. C. Adams, and M. H. Hanes, *SP337,* pp. 87-9 (Nov. 1970).

Techniques for determining surface concentration of di fusants, J. C. Irvin, *SP337,* pp. 99-110 (Nov. 1970).

Current status of the spreading resistance probe and its appl cation, T. H. Yeh, *SP337,* pp. 111-122 (Nov. 1970).

Incremental sheet resistivity technique for determining diff sion profiles, R. P. Donovan and R. A. Evans, *SP337,* pp. 12 131 (Nov. 1970).

Nuclear methods for the determination of diffusion profile B. J. Masters, *SP337,* pp. 132-140 (Nov. 1970).

Use of high-energy ion beams for the analysis of doped surfa layers, S. Chou, L. A. Davidson, and J. F. Gibbons, *SP33* pp. 141-155 (Nov. 1970).

Determination of diffusion coefficients in silicon and accept values, M. F. Millea, *SP337,* pp. 156-167 (Nov. 1970).

Diffusion technology for advanced microelectronic processin W. Greig, K. Cunniff, H. Hyman, and S. Muller, *SP337,* pp 168-174 (Nov. 1970).

Diffusion from doped-oxide sources, M. L. Barry, *SP337,* pp. 75-181 (Nov. 1970).

Capacitance—a device parameter and tool for measuring doping profiles, B. R. Chawla, *SP337,* pp. 182-183 (Nov. 1970).

Concentration dependent diffusion phenomena, P. E. Lakeman, Jr. and J. M. Borrego, *SP337,* pp. 184-191 (Nov. 1970).

Orientation dependent diffusion phenomena, L. E. Katz, *SP337,* pp. 192-201 (Nov. 1970).

Diffusion-induced defects and diffusion kinetics in silicon, S. Prabash and M. L. Joshi, *SP337,* pp. 202-222 (Nov. 1970).

Limitations of current epitaxial evaluations, R. N. Tucker, *SP337,* p. 223 (Nov. 1970).

On the interpretation of some measurement methods for epitaxially grown layers, P. J. Severin, *SP337,* pp. 224-233 (Nov. 1970).

Thickness measurement of very thin epitaxial layers by infrared reflectance, P. A. Schumann, Jr., *SP337,* pp. 234-243 (Nov. 1970).

Spreading resistance measurements on buried layers in silicon structures, R. G. Mazur, *SP337,* pp. 244-255 (Nov. 1970).

Variations of a basic capacitance-voltage technique for determination of impurity profiles in semiconductors, W. C. Liehaus, W. van Gelder, T. D. Jones, and P. Langer, *SP337,* p. 256-272 (Nov. 1970).

A new impurity profile plotter for epitaxy and device, B. J. Gordon and H. L. Stover, *SP337,* pp. 273-284 (Nov. 1970).

Structural faults in epitaxial and buried layers in silicon device fabrication, P. Wang, F. X. Pink, and D. C. Gupta, *SP337,* pp. 285-301 (Nov. 1970).

An instrument for automatic measurement of epitaxial layer thickness, A. Roddan and V. Vizir, *SP337,* pp. 302-312 (Nov. 1970).

Defects induced in silicon through device-processing, M. L. Joshi and J. K. Howard, *SP337,* pp. 313-364 (Nov. 1970).

A study relating MOS processes to a model of the Al-SiO_2-Si system, M. H. White, F. C. Blaha, and D. S. Herman, *SP337,* p. 365-374 (Nov. 1970).

Activation analysis in silicon device processing, G. B. Larrabee and H. G. Carlson, *SP337,* pp. 375-383 (Nov. 1970).

The use of the scanning electron microscope as a semiconductor production line quality control tool, J. W. Adolphsen and R. Anstead, *SP337,* pp. 384-397 (Nov. 1970).

Metallization deposition parameters and their effect on device performance, J. R. Black, *SP337,* pp. 398-408 (Nov. 1970).

Methods for determination of the characteristics of hyperpure semiconductor silicon and their information content for the device production, F. G. Vieweg-Gutberlet, *SP337,* pp. 409-411 (Nov. 1970).

Mechanical damage—its role in silicon surface preparation, J. B. Soper, *SP337,* pp. 412-418 (Nov. 1970).

Crystallographic damage to silicon by typical slicing, lapping, and polishing operations, T. M. Buck and R. L. Meek, *SP337,* p. 419-430 (Nov. 1970).

The preparation of practical, stabilized surfaces for silicon device fabrication, A. Mayer and D. A. Puotinen, *SP337,* pp. 431-435 (Nov. 1970).

Surface contamination, J. W. Faust, Jr., *SP337,* pp. 436-441 (Nov. 1970).

The precipitation of oxygen in silicon, and its effect on surface perfection, W. J. Patrick, *SP337,* pp. 442-449 (Nov. 1970).

Auger spectroscopy and silicon surfaces, J. H. Affleck, *SP337,* pp. 450-456 (Nov. 1970).

Characterization of semiconductor surfaces and interfaces by ellipsometry, N. M. Bashara, *SP337,* p. 457 (Nov. 1970).

SP338. **Status of thermal analysis.** Proceedings of a Symposium on the Current Status of Thermal Analysis held at Gaithersburg, Maryland, April 21-22, 1970, O. Menis, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 338, 189 pages (Oct. 1970).

Key words: Atherosclerotic plaque; DSC; elastomers and vulcanizates; explosives; high temperature DTA; kinetics by TGA; selection of DTA parameters; temperature standards; TGA; theory of isoperibol and adiabatic shield calorimeters.

The symposium papers offer contributions in differential thermal analysis (DTA), differential scanning calorimetry (DSC), development of standards for DTA temperature scales, and applications in high temperature biochemical, polymer and explosive materials. The selection and the effect of experimental parameters on the types of information on thermal curves is described. The measurement theory of isoperibol and adiabatic shield calorimeters by the method of intermittent heating is described and the magnitude of calorimetric instrumental errors is outlined. In an analysis of a differential scanning calorimeter, three instrumental time constants are described and the necessary corrections for the various instrumental and thermal time constants are recommended. The need for and the status of temperature scale standards for DTA is discussed. An evaluation of 12 materials for use as standards by cooperating laboratories is presented. High temperature (> 1900 K) DTA, problems of high temperature calorimetry to 1300 K are discussed. The implications concerning the nature of biological membranes and decomposition of atherosclerotic plaques are derived from differential scanning calorimetry of three-component systems of phospholipid, cholesterol or one of its esters and water.

A description is given of an apparatus developed for measuring the rate at which vapors are evolved during the thermal degradation of material in a modified thermogravimetric apparatus. The modifications of a DTA cell to minimize explosions is described. Data derived from the use of lead azide was used to evaluate the technique. Thermogravimetric analysis for establishing basic composition of elastomer compounds and vulcanizates were reviewed. A careful study of oxidation characteristics of carbon black in the formulation is also included. *These proceedings include the following papers (indented):*

Standardization of differential thermal analysis test methods, P. D. Garn, *SP338,* pp. 1-22 (Oct. 1970).

Key words: DTA atmosphere effects; DTA experimental design; DTA peak structure; DTA sample shapes; DTA standardization.

The appearance of a differential thermal analysis curve depends greatly, for many materials, upon the method of experimentation. This is because the physical properties of the specimen will have differing effects upon the actual events taking place. The experimental parameters, mainly the sample holder and atmosphere, should be selected to learn as much as possible about the properties of most interest. The use of a single set of conditions as a general practice will be ineffective.

Macrocalorimetry—how accurate?, K. L. Churney, G. T. Armstrong, E. D. West, *SP338*, pp. 23-59 (Oct. 1970).

Key words: Adiabatic shield; calorimetric errors; calorimetry; isoperibol; measurement theory.

The measurement theory of isoperibol and adiabatic shield calorimeters operated by the method of intermittent heating is reviewed and recent developments indicated. Implications of the theory in terms of calorimeter design and tests for systematic errors are discussed. Some idea of the magnitude of calorimetric errors (as compared to errors arising from uncertainties in the change of state of the system under study) is outlined.

Status of thermal analysis temperature scale standards, O. Menis and J. T. Sterling, *SP338*, pp. 61-86 (Oct. 1970).

Key words: ASTM Committee; differential thermal analysis; International Committee on Thermal Analysis; temperature scale region of 40 to 900 °C; temperature scale standards.

Current status in the development of suitable temperature scale standards for differential thermal analysis is described. It involved the cooperative effort at NBS in the collection and evaluation of data on 12 materials studied by the Standards Committee of the International Committee on Thermal Analysis. In addition the results of the study group of an ASTM Committee with the cooperation of NBS are presented. The selected temperature values depend on the transition temperature of a number of compounds as well as two low temperature melting metals. The temperature scale region of 40 to 900 °C can be covered effectively with the ten materials, which will serve as calibration standards.

High temperature differential thermal analysis, R. D. Freeman, *SP338*, pp. 87-98 (Oct. 1970).

Key words: Differential thermal analysis; dynamic calorimetry; high temperature chemistry.

Three areas are discussed: (1) high temperature (> 1900 K) differential thermal analysis (DTA); (2) some problems in conventional high temperature calorimetry, which may be relevant to high temperature dynamic calorimetry; and (3) a brief description of our efforts to achieve dynamic calorimetry to at least 1300 K.

Thermal studies on lipid-water systems by differential scanning calorimetry with reference to atherosclerosis, G. J. Davis and R. S. Porter, *SP338*, pp. 99-117 (Oct. 1970).

Key words: Atherosclerosis; cholesterol and its fatty acid esters; differential scanning calorimetry; lecithin; lipid-water systems; phospholipids; sphingomyelin; thermal studies.

Studies have been performed on lipid-water systems by differential scanning calorimetry. Three-component systems were investigated. The components consisted of a phospholipid, cholesterol or one of its esters, and water. The phospholipids studied included lecithin and sphingomyelin. The cholesteryl derivatives used in the ternary systems included cholesterol and its oleate, linoleate, and stearate esters. The temperatures and heats of transition for these systems were investigated. The results reveal considerable differences in the stability of complexes formed in these ternary systems with the unsaturated esters generally leading to the least stable structures. The morphologies likely represent compositions and order similar to the layered structures observed for the same and related phospholipid-cholesteryl derivative molecular organization. The results have implications concerning the nature of biological membranes and the deposition of atherosclerotic plaques.

An analytical evaluation of differential scanning calorimetry (DSC), J. H. Flynn, *SP338*, pp. 119-136 (Oct. 1970).

Key words: Analyses of thermal apparatus; differential scanning calorimetry; evaluation of heats and temperatures of transition; instrumental time constants; interfacial thermal conductivity; thermal analyses.

Three instrumental time constants were found in an analysis of the (Perkin-Elmer DSC-1B) Differential Scanning Calorimeter: an energy pulse response (1.5 s), a temperature-averaging network response (≈ 15 s) and a temperature programming response (8.0 s). The first constant may be determined from the decay of the response to infrared light pulses. It affects the shape of a transition curve but not the heat of transition calculated from the area. The second constant affects only the base line and the third, the temperature calibration.

Application of elementary heat flow theory to a wide range of experimental variations in the interfacial thermal resistance demonstrated that interfacial time constants are a negligible factor in determining the melting transitions of many substances.

It was concluded that corrections for the various instrumental and thermal time constants are necessary if meaningful parameters are to be deduced, especially at fast heating rates.

Apparatus for rate studies of vapor producing reactions, R. J. McCarter, *SP338*, pp. 137-150 (Oct. 1970).

Key words: Differential thermal analysis; DTA; kinetics; pyrolysis; TGA; thermal analysis; thermal degradation; thermogravimetric analysis.

An apparatus was developed for measuring the rate at which vapors are evolved during the thermal degradation of materials and thereby deriving the kinetics of such reactions. Requisite to the operating scheme of the apparatus is the provision of a high-temperature zone to convert condensable or tarry vapors into noncondensable form.

The apparatus yields a direct measure of reaction velocity, rather than the integrated indication obtained with thermogravimetric analysis. This simplifies the identification and calculation of kinetic parameters. Increases in sensitivity and operating range are also achieved. Flexibility in operation is obtained that permits the separate recording of reactions that tend to overlap.

Although the apparatus has been operated principally with a combustible gas indicator serving to meter the evolved product vapors, a number of options are available for the latter function, including flow meters and various continuous gas analyzers. The applicability of the method appears promising.

Differential thermal analysis of primary explosives—modified technique, R. J. Graybush, F. G. May, A. C. Forsyth, *SP338*, pp. 151-164 (Oct. 1970).

Key words: Differential thermal analysis; Dupont 900 DTA remote cell; lead azide; lead styphnate; mercury fulminate; metastable materials; potassium dinitrobenzfuroxan; primary explosives.

The usefulness of differential thermal analysis (DTA) in the study of metastable materials has been hindered by the tendency of samples to explode during the experiment. A description is given of modifications which have been made to the remote cell used in conjunction with a Dupont 900 DTA such that the possibility of explosion is minimized. Using lead azide to evaluate the technique it is shown that complete curves for the exothermic decomposition

$$PbN_6 \rightarrow Pb + 3N_2$$

are reproducibly obtained. The endotherm in the curve corresponding to the fusion of the product lead serves as a confirmation of the reaction. Illustrations are given to show extensions of the system to other sensitive compounds, namely lead styphnate, mercury fulminate, and potassium dinitrobenzfuroxan.

Thermogravimetry of vulcanizates, J. J. Maurer, *SP338,* pp. 65-185 (Oct. 1970).

Key words: Carbon black; curatives; elastomer compounds and vulcanizates; oxidation; thermogravimetric analysis.

Thermogravimetric analysis provides an important advance in the analysis of elastomer compounds and vulcanizates. This paper reviews the current state of such investigations including a consideration of key experimental variables, precision and accuracy for estimating basic composition of different types of practical formulations. Additional information can be obtained by careful study of the oxidation characteristics of the carbon black in the formulation. The latter is influenced by both physical (e.g., surface area) and chemical (type of cure system or polymer) effects. Finally, an isothermal oxidation procedure is discussed for demonstrating differences in carbon black(s) and/or curatives in routine comparisons of samples.

339. **Source listing of OMNITAB II program,** S. T. Peavy, R. N. Varner, and D. Hogben, Nat. Bur. Stand. (U.S.), Spec. Publ. 339, 371 pages (Dec. 1970).

Key words: Accuracy; algorithms; ANSI FORTRAN; documentation; error checking; machine independent; OMNITAB II operating system subprograms; OMNITAB II source listing; programming techniques; transportable; user-oriented computing system.

OMNITAB II is a general-purpose interpretive computing stem designed to allow a nonprogrammer to use a high-speed mputer easily, accurately and effectively. The system permits user to perform arithmetic operations including complex thmetic, trigonometric calculations, miscellaneous function culations, statistical analysis, Bessel function calculations, d operations on matrices and arrays.

The OMNITAB II system contains 177 subprograms written the ANSI FORTRAN language. Every effort has been made make the system transportable. This publication contains a mplete listing of all these subprograms. The listing is preceded a brief introduction which describes the programming hniques used; the use of system library functions; and the programs used to control the flow of operations in the OMTAB system.

340. **Technical highlights of the National Bureau of Standards, Annual Report Fiscal Year 1970,** Nat. Bur. Stand. (U.S.), Spec. Publ. 340, 258 pages (Feb. 1971).

Key words: Annual report; technical highlights.

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1970. It lists major programs as they were carried out by the three NBS institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology and by the Bureau's Center for Radiation Research and Center for Computer Science and Technology. Summaries are given of typical projects in measurement engineering, applied mathematics, electricity, metrology, mechanics, heat, atomic physics, radio standards, laboratory astrophysics, cryogenics, analytical chemistry, polymers, metallurgy, inorganic materials, physical chemistry, engineering standards, weights and measures, invention and innovation, vehicle systems research, product evaluation, building research, electronic technology, technical analysis, computer sciences, and radiation research. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, and national and international cooperative activities. A special section is devoted to NBS and the Consumer, Metric Study, Flammable Fabrics Program, Measurements for Air Quality and Building Technology.

SP341. **Damage in laser materials.** Proceedings of a symposium sponsored by the American Society for Testing and Materials and by the National Bureau of Standards June 24-25, 1970, NBS, Boulder, Colorado, A. J. Glass and A. H. Guenther, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 341, 126 pages (Dec. 1970).

Key words: Ferroelectric materials; glass; laser damage; lasers.

The second ASTM Symposium on Damage in Laser Materials was held at the National Bureau of Standards at Boulder, Colorado on June 24th and 25th, 1970. About 150 attendees heard papers by fourteen speakers, representing the major manufacturers of laser glass, government, industrial and university laboratories. Although the primary emphasis was on Nd:glass as a laser material, damage mechanisms and morphology in ruby, sapphire, and nonlinear optic materials were also considered. It was clear that substantial advances have been made in the last year in the production of damage-resistant laser glass for use in conventional Q-switched lasers. New diagnostic techniques have been developed, and in some cases, adopted as quality control procedures by the glass manufacturers. Theoretical understanding of the fundamental damage mechanisms is beginning to emerge, and material properties relevant to these damage mechanisms are beginning to be measured. It was equally clear that a great deal of effort remains to be expended to develop techniques suitable for nondestructive testing of laser materials, and that many properties of laser materials at high energy density are presently poorly understood.

SP342. **Report of the 55th National Conference on Weights and Measures 1970,** F. C. Bell and H. F. Wollin, Report Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 342, 315 pages (Apr. 1971).

Key words: Conference; weights and measures; weights and measures—history; weights and measures—law; weights and measures—regulations; weights and measures—technical requirements.

This is a report of the proceedings (edited) of the Fifty-fifth National Conference on Weights and Measures, sponsored by the National Bureau of Standards, held in Salt Lake City, Utah, July 13-17, 1970, and attended by state, county, and city weights and measures officials and representatives of the Federal Government, business, industry, railroads, and associations.

SP343. **Precision measurement and fundamental constants.** Proceedings of the international conference held at the NBS, Gaithersburg, Maryland, August 3-7, 1970, D. N. Langenberg and B. N. Taylor, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 343, 543 pages (Aug. 1971).

Key words: Fundamental constants; least squares adjustments; precision measurements.

This volume presents the Proceedings of the International Conference on Precision Measurement and Fundamental Constants, held at the National Bureau of Standards in Gaithersburg, Maryland, from August 3 through August 7, 1970. The conference brought together theoretical, experimental, and applied scientists for the purpose of discussing modern techniques of precision physical measurement and their application, along with modern theoretical developments, to the determination of the fundamental constants. The topics covered were: frequency and time standards; length standards; the velocity of light; the Rydberg constant; electrical standards; the proton gyromagnetic ratio; the Faraday constant; atomic masses; the proton magnetic moment; Josephson effects; x rays; fine and hyperfine structure in simple atoms; lepton g-factor anomalies; the gravitational constants; least squares adjustments of the constants. These Proceedings contain the invited tutorial talks as well as the contributed papers presented at the Conference. Also included are the post-paper discussions and a panel discussion entitled "Should Least Squares Adjustments of the Fundamental Constants be Abolished?"

SP344. Superseded by Special Publication 398.

SP345. **A metric America. A decision whose time has come,** D. V. De Simone, Nat. Bur. Stand. (U.S.), Spec. Publ. 345, 189 pages (July 1971).

Key words: Metrication; metric conversion; metric system; metric usage; Public Law 90-472; U.S. Metric Study.

This publication is the comprehensive report on the U.S. Metric Study undertaken by the National Bureau of Standards pursuant to Public Law 90-472. The report evaluates and distills the information contained in the twelve interim reports of the study series and also covers what has been learned from Great Britain and other countries that are now in or have been involved in a metric changeover. Data in the report show that America is already metric in some respects and that the great majority of businessmen, educators and other informed participants in the study reported that increased use of the metric system is in the best interests of America. Included in the publication are the recommendations of the Secretary of Commerce to Congress that the United States change to the metric system through a coordinated national program over a ten-year period.

SP345-1. **International Standards. U.S. Metric Study Report,** Nat. Bur. Stand. (U.S.), Spec. Publ. 345-1, 157 pages (Dec. 1970).

Key words: Engineering standards; IEC; ISO; International standardization; metric study; PL 90-472; product certification; standards; U.S. Metric Study.

This report discusses developments on the international scene that have occurred since the passage in 1968 of the Metric Study Act, PL 90-472. Australia, Canada and other countries of the British Commonwealth have recently taken steps toward the adoption of the metric system for their customary weights and measures. European countries are harmonizing their national standards and are developing international agreements for quality assurance and product certification. These harmonized standards are being based on recommendations issued by the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO).

The issue of international standardization is separate and distinct from those of the Metric Study, but the two subjects overlap somewhat, particularly in the case of dimensional standards. The extent to which U.S. standards are adopted by IEC and ISO depends mostly on U.S. participation in committees or groups drafting the international standards and only secondarily on the measurement units. The report recommends the development of a firm U.S. policy on participation in international standardization and product certification, without awaiting the outcome of the U.S. Metric Study.

SP345-2. **U.S. metric study interim report. Federal Government: civilian agencies,** R. E. Clark and J. M. Tascher, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-2, 328 pages (July 1971).

Key words: Federal Government; International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; SI; U.S. Metric Study.

This publication reports the findings of a survey to ascertain the views of the civilian agencies of the Federal Government on the issues raised by the U.S. Metric Study Act. With regard to internal operations of the Federal agencies, the report covers present metric (International System of Units, or SI) usage and its advantages and disadvantages, expectations of future changes in measurement usage if the U.S. continues its laissez faire policy toward the SI, and attitudes toward a possible nationally coordinated metrication program. In the latter connection, the report contains estimates of added cost or savings impacts on agency internal operating budgets to be expected from a nominally 10-year planned metrication program, both during the transition and thereafter. The survey also assessed the impacts of metric usage and of its increase on the areas of responsibility of the Federal agencies in the society at large (e.g., communications, science and technology, health, labor affairs, international affairs and trade), and on the agencies' interfaces therewith.

SP345-3. **U.S. metric study interim report. Commercial weights and measures,** S. L. Hatos, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-3, 116 pages (July 1971).

Key words: Commercial weights and measures; International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; SI; U.S. Metric Study.

This publication, one of a series prepared pursuant to the U.S. Metric Study Act, explores the impacts metrication would have on commercial weights and measures activities. More specifically, the report concerns: (1) the cost of adapting or changing commercial weighing and measuring devices to record and/or indicate in metric units, and (2) the effects of metrication on state and local weights and measures jurisdictions.

SP345-4. **U.S. metric study interim report. The manufacturing industry,** L. E. Barbrow, Coordinator, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-4, 172 pages (July 1971).

Key words: International System of Units; manufacturing industry; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; SI; U.S. Metric Study.

This publication reports the results of a study to assess the impacts of increasing metric usage—past, present and future—on U.S. manufacturing industry. The study, conducted pursuant to the U.S. Metric Study Act, is based on responses from more than 2,000 manufacturing companies. Information was obtained on: past and present experience with use of the metric system, including advantages and disadvantages thereof, and the views of the firms with regard to future U.S. policy—whether the

country should continue its laissez faire approach to metric usage, or should undertake some sort of national program to encourage more widespread use of metric weights and measures. A separate survey of a smaller number of selected firms obtained detailed information as to estimated cost impact of a national metrication effort.

SP345-5. **U.S. metric study interim report. Nonmanufacturing businesses,** J. R. Cornog and E. D. Bunten, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-5, 200 pages (July 1971).

Key words: International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; nonmanufacturing businesses; SI; U.S. metric Study.

This publication, prepared pursuant to the U.S. Metric Study Act, reports on the experiences and views of nonmanufacturing businesses with regard to metric usage and its increase. The study is based on a survey of more than 2500 companies and firms primarily involved in: agriculture, forestry, fisheries, mining, construction, transportation, communications, utilities, wholesale/retail trade (including exporters/importers), finance, insurance, real estate or services. Information was obtained on: past or present experience with use of the metric system (including perceived advantages and disadvantages thereof), attitudes toward future metrication in a world of increasing metric usage (including preferred U.S. policy regarding), and estimated cost impacts and benefits which would be attendant to a national metrication program.

SP345-6. **U.S. metric study interim report. Education,** B. D. Robinson, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-6, 216 pages (July 1971).

Key words: Education; International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; SI; U.S. Metric Study.

This publication concerns the effects of increasing worldwide use of the metric system on education in the United States. The study was carried out and the report prepared for the U.S. Metric Study by the Education Development Center in Newton, Massachusetts. The aims of this education study were fourfold: (1) to assess the educational advantages and disadvantages of both the metric and the customary systems of units, (2) to determine the current usage of metric measures in U.S. schools and trends in that usage, (3) to find the ways in which education would have to change as the U.S. accommodates to increased worldwide use of the metric system, under a laissez faire or a planned approach, and estimate the costs of the changes, and (4) to make recommendations of ways in which to take best advantage of said changes. The report also discusses and suggests ways of achieving curriculum changes needed in view of increasing metric usage. The publication includes the program of the Education Conference, held in October 1970, as one of a series of National Metric Study Conferences, and the texts of the key papers presented at that conference by the National Education Association and the National Science Teachers Association.

SP345-7. **U.S. metric study interim report. The consumer,** B. D. Rothrock, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-7, 152 pages (July 1971).

Key words: Consumers; International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; National Metric Study Conferences; SI; U.S. Metric Study.

This report, one of a series prepared pursuant to the U.S. Metric Study Act, presents information on U.S. consumers' knowledge of the metric system and attitudes and opinions regarding metrication in the U.S., and discusses the effects of increasing worldwide metric usage on selected areas of consumer concern. This study is based on (1) an extensive survey conducted by the Survey Research Center of the University of Michigan and (2) prepared expert papers on selected areas of consumer interest. The survey data permitted an analysis of the receptivity of consumers to metrication, and of the need and possible effectiveness of a program to educate citizens should planned metrication be undertaken.

SP345-8. **U.S. metric study interim report. International trade,** G. F. Gordon, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-8, 188 pages (July 1971).

Key words: Foreign trade; International System of Units; metrication; metrication, impact of on foreign trade; metric conversion; metric conversion, effect on foreign trade; metric system; metric usage; metric usage, effect on foreign trade; SI; U.S. Metric Study.

This publication, one of a series prepared pursuant to the U.S. Metric Study Act, evaluates the potential effects that a U.S. conversion to the metric system may have on the Nation's foreign trade. The report is based on a survey of exporters and importers trading in measurement-sensitive products, which was conducted by the Bureau of Domestic Commerce of the Department of Commerce.

SP345-9. **U.S. metric study interim report. Department of Defense,** L. E. Barbrow, Coordinator, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-9, 132 pages (June 1971).

Key words: Department of Defense; International System of Units; metrication; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; SI; U.S. Metric Study.

This publication reports the results of a Department of Defense study, conducted pursuant to the U.S. Metric Study Act, to determine and evaluate the advantages and disadvantages, including impact on operational capability, that would attend adoption of the International System of units of weights and measures (otherwise known as the Modernized Metric System) for use in the Department (DoD). The report includes estimates for each of the major components of the DoD of the costs of a transition to metric system usage. In addition to discussing the specific advantages and disadvantages that would be expected within the Department, the report describes the dependence of the DoD on the National Industrial Base, and discusses how this interaction would be involved in a national metrication effort.

SP345-10. **U.S. metric study interim report. A history of the metric system controversy in the United States,** C. F. Treat, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-10, 312 pages (Aug. 1971).

Key words: Metric system; weights and measures.

A review of the debate between 1790 and 1968 on the question of whether or not the United States should adopt the metric system of weights and measures. Legislative activities with respect to weights and measures and campaigns for and against adoption of the metric system are reviewed. Significant investigations of the question by both public and private bodies are highlighted. An extensive bibliography is included.

SP345-11. **U.S. metric study interim report. Engineering standards,** R. D. Stiehler, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-11, 264 pages (July 1971).

Key words: Engineering standards; international standards; International System of Units; metrication; metrication

and engineering standards; metric conversion; metric system; SI; standards; U.S. Metric Study.

This report, one of a series prepared pursuant to the U.S. Metric Study Act, is concerned with (1) the relationship between measurement language and engineering standards, and (2) the compatibility of U.S. Standards with corresponding international standards. Incompatibilities between corresponding standards result from differences of engineering practice. Measurement units contribute to the incompatibilities among many dimensional specifications which comprise about 25% of engineering standards. In the remaining standards, measurement units are either not involved or serve merely as a language. The study compares U.S. standards with other national and international standards.

SP345-12. **U.S. metric study interim report. Testimony of nationally representative groups,** J. V. Odom, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 345-12, 180 pages (July 1971).

Key words: International System of Units; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; metric conversion; metric system; metric usage; National Metric Study Conferences; SI; U.S. Metric Study.

This publication, a part of the U.S. Metric Study series, summarizes the inputs received from the more than 700 associations, societies, unions and other groups which were invited to submit their opinions and viewpoints on the issues raised by the U.S. Metric Study Act. Most of these submissions were publicly presented at hearings held during the course of the Study.

SP346. **Hydraulic research in the United States 1970. Including contributions from Canadian Laboratories,** G. Kulin and P. H. Gurewitz, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 346, 354 pages (Mar. 1971).

Key words: Fluid mechanics; hydraulic engineering; hydraulic research; hydraulics; hydrodynamics; model studies; research summaries.

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1969-1970 are summarized. Projects from more than 250 university, industrial, state and federal government laboratories in the United States and Canada are reported.

SP347. **Proceedings of joint meeting of government operations research users and producers, held at the National Bureau of Standards, Gaithersburg, Maryland, June 5-6, 1969,** E. H. Hustvedt, Conference Coordinator and M. L. Friend, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 347, 164 pages (May 1971).

Key words: Conference proceedings; contract research; federal government; information exchange; NBS; operations research/systems analysis studies; OR users and producers; planning.

Frequently government agencies are unsure as to whom to contact when they want Operations Research/Systems Analysis studies made, and many agencies know very little about what other agencies might be doing in the field of operations research. Many public and private agencies have little knowledge as to which government agencies might derive the most benefit from their kinds of expertise and experience.

The Joint Meeting of Government Operations Research Users and Producers was organized to improve the communications among Users of operations research within the government, and Producers of operations research in public and private organizations.

Government agencies were invited to report on exactly what they expect of their OR producers, what they expect to have done with the results, what the purposes and their uses of systems analysis are, and to give a general profile of their in-house work.

Universities were invited to report on their capabilities and their desires and to discuss the OR projects currently in progress on their campuses.

This meeting was the second in a planned series of meetings. It had for its purpose the longer range goal of providing more responsive and more adequate studies for improving government agency management and productivity.

SP348. **The science of ceramic machining and surface finishing.** Proceedings of a symposium sponsored by the American Ceramic Society, the Office of Naval Research, and the National Bureau of Standards, Nov. 2-4, 1970, held at NBS, Gaithersburg, Md., S. J. Schneider, Jr., and R. W. Rice, Editors, and C. F. Bersch, A. M. Diness, and J. B. Wachtman, Jr., Associate Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 348, 431 pages (May 1972).

Key words: Ceramic machining; ceramics; mechanical effects of machining; removal and shaping of ceramics; surface treatment.

This volume presents the proceedings of the Symposium on the Science of Ceramic Machining and Surface Finishing held at the National Bureau of Standards in Gaithersburg, Md., on Nov. 2-4, 1970. The symposium was jointly sponsored by the Baltimore-Washington Section of the American Ceramic Society, the Office of Naval Research, and the National Bureau of Standards. The purpose of the conference was to survey the developing science of ceramic machining and to stimulate further progress by discussion of current problems and research programs. In addition to a panel discussion, 37 review and original research papers were presented with attention focused on four main areas: (1) Techniques and Mechanisms of Removal and Shaping (2) Surface Treatment (3) Analysis and Characterization of Machining Effects and (4) Mechanical and Other Effects of Finishing. An edited version of the floor discussion following each paper is given. *These proceedings include the following papers (indented):*

Science and the machining and surface finishing of ceramics, R. W. Rice, C. F. Bersch, and A. M. Diness, *SP348,* pp. 1-3 (May 1972).

Key words: Machining; machining costs; methods of machining and finishing; surface-dependent properties; surface finishing.

Historically, the technology of machining and surface finishing of ceramics has advanced by empirical methods. Further advances appear limited without gaining basic knowledge of the mechanisms of removing or redistributing material from or on ceramic surfaces. Because of the diversity of ceramic behavior, this is a challenging scientific problem. However, meeting this challenge can result not only in improved or new machining and finishing processes but also in greater understanding of the character of the resultant surface and sub-surface, and hence of the surface dependent properties.

Mechanical methods of ceramic finishing, P. J. Gielisse and J. Stanislao, *SP348,* pp. 5-35 (May 1972).

Key words: Abrasive; ceramics; diamond; fracture; grinding; grinding forces; grinding temperatures; machining; polishing; residual stresses; stock removal; surface analysis; theory of grinding.

Mechanical methods of finishing ceramics have been reviewed based on current practice as well as past and present research results. A total systems evaluation is

volves technical process and economic parameters. State of the art information indicates a need for scientific evaluation of the basic stock removal process.

Experiments simulating grinding with single point diamond tools have generated quantitative and qualitative data on mechanical, dynamic, and thermal aspects of the stock removal process. Generation of the data involved specially designed techniques.

Analysis of the results have been made in terms of mechanical, geometric, and material parameters. A mechanical and thermodynamic model is presented.

Direct observation of material removal process during grinding of ceramics by micro-flash technique, O. Imanaka, S. Fujino, and S. Mineta, *SP348*, pp. 37-43 (May 1972).

Key words: Alumina; brittle fracture; chip removal process; forsterite; glass-ceramics; grinding of ceramics; micro-flash technique; observation of chips during grinding; steatite.

In order to make the mechanism of grinding ceramics clear, chip removal processes have been observed during grinding with a specially-built setup which consists of a flash lamp, synchronizer, microscope, and motor-driven camera. Duration time of the flash is about 0.8 μs in half-value width, and a storage capacitor in the flash lamp circuit can store an energy of about 10 W · s. By choosing the flashing point, grinding phenomena at different positions on the contact arc can be photographed at certain time intervals.

The experiments were done mainly by using one grain of diamond attached to a disk which was mounted on a shaft of a surface grinding machine. Workpiece materials examined were glass-ceramics and several types of oxide ceramics, e.g., alumina, forsterite, and steatite ceramics. The main results obtained are as follows: Under moderately large depth of cut, the chips generated from ceramics are generally of a fragment type and are distinguished from those of ductile materials. Part of these chips were observed to be removed, of course, directly by the grain, but a considerable part of them were found to splinter out of the workpiece surface in a short time after the grain has passed over. Possible explanations are proposed for those phenomena. The above-mentioned facts suggest that a damaged layer may remain under the ground surface of ceramic materials. It is also demonstrated that chips of continuous type are occasionally observed at high grinding speed and under moderately small depth of cut. The chip formation of this type depends delicately on the materials to be ground.

Grinding—A means of shaping and sizing ceramics, J. A. Mueller, *SP348*, pp. 45-52 (May 1972).

Key words: Capability; ceramics; grinding wheels; selection; shaping; sizing.

The shaping and sizing of ceramic bodies can be done with abrasive grinding wheels. From a grinding wheel point of view, ceramic bodies may be classified into two groups. One group that is harder than 800 Knoop and the other group that is softer than 800 Knoop.

The materials that are harder than 800 Knoop generally require the use of diamond wheels. Diamond wheels have the capability to remove stock, to generate precise geometry, and to produce finishes as fine as those that are measured in light bands.

The selection of the diamond grinding wheel is critical because improper selection can cause excessive grinding costs, poor quality, and low productivity. The selection of the diamond grinding wheel includes not only the selection of the specification of the wheel formulation but also the selection of the geometry of the wheel.

Case histories of finishing and shaping ceramic bodies illustrate the capability of the grinding wheel in these areas. Suggestions for starting speeds, feeds, and wheels together with a list of practical everyday "Rules of Thumb" for efficient grinding are documented.

Aspects of machining glass-ceramic materials, G. H. Allgeyer and L. V. Colwell, *SP348*, pp. 53-57 (May 1972).

Key words: Abrasive machining; brittle chip formation; brittle fracture; chip accommodation; glass; glass-ceramics; machining and grinding technical ceramics; material removal rate; specific energy; wheel structure.

The manufacture of optical and mechanical parts from glass-ceramic materials usually requires the removal of unwanted stock resulting from casting, hot forming, or the cutting of blocks from large ingots or blanks. Desired surface finishes at specified dimensions are the usual requirements. Conventional metalworking cutting tools did not produce satisfactory results. Scratching, splintering, and brittle fracture were responsible for the material removal action in the sawing, drilling, turning, and milling operations attempted. Very rough unsatisfactory surfaces resulted.

The physical and mechanical properties of CER-VIT® material classify it as a brittle, crystalline material in the usual machining state. The best controllable means of material removal was found to be abrasive machining. The high hardness (550 Knoop) and abrasive character of these materials conclusively recommend diamond as the most satisfactory cutting medium. Machinability studies were conducted on CER-VIT® glass-ceramic material using diamond abrasive tooling while adjusting the controllable machining variables. The results and relationships of these techniques as applied to CER-VIT® glass-ceramic are discussed.

Significance of the experimental results is explored with particular emphasis being placed upon the predictable performance of diamond tools and the feasibility of programming of machining variables for utilization of numerically controlled machining processes.

The principles of grinding, R. S. Hahn and R. P. Lindsay, *SP348*, pp. 59-71 (May 1972).

Key words: Abrasive wear parameter; grinding; material removal parameter; principles of grinding; surface finish in grinding; surface integrity in ground surfaces; wheel dressing.

Three distinct actions are shown to take place in the grinding process, namely rubbing, ploughing, and cutting. A clue to the relative importance of each of these can be obtained by plotting the volumetric rate of stock removal against the wheelwork interface force for unit width (force intensity). Such plots show for some materials a threshold force intensity below which no stock removal occurs. Equations relating the stock removal rate and the interface force intensity are developed and a "material removal parameter" is defined. Similar equations for the wheel wear and a "wheel-wear parameter" are also developed. It is found for many materials that the stock removal rate is a linear function of the interface force intensity. However, the abrasive removal rate or dimensional wheel wear is found to vary approximately as the square of the interface force intensity. Increasing wheel surface speed is generally found to raise the material removal parameter.

The essential parameters in dressing with single pointed

diamonds are introduced and their effect on controlling the sharpness of a grinding wheel is discussed. Semi-empirical equations for predicting wheel wear are given in terms of force intensity, wheel hardness, and wheel-workpiece conformity. The factors influencing surface finish are described, including the dressing lead, the depth of cut of the dresser diamond, and the interface force intensity. Thermal damage and surface integrity are discussed. The existence of a threshold force intensity (or feed rate) below which no thermal cracking takes place is shown. Raising the workspeed tends to raise this threshold. Wheel sharpness is also found to be an important variable, and means for quantitatively measuring wheel sharpness are given.

A basic study of the diamond grinding of alumina, D. M. Busch and J. F. Prins, *SP348*, pp. 73-87 (May 1972).

Key words: Abrasion; chatter vibrations; forces in grinding; fracture of alumina grains; grinding noise; grinding of alumina; scratching of glass; single diamond cutting of alumina.

Experiments were performed using single diamond points to cut Coors AD96 alumina under conditions simulating the grinding of this material. These studies involved different diamond particles and the forces were recorded during the cutting action.

Parallel to the single diamond experiments, grinding tests were performed on the same ceramic material using the same types of diamonds with which the single point studies were done. The grinding experiments and the single diamond experiments were then compared to get a better understanding of the actual cutting mechanism involved when grinding aluminium oxide.

The wear of the diamond particles and the damage inflicted on the ceramic material were studied with the aid of electron microscopy. A relationship was found between the forces measured, the deterioration of the bonding material, and the wear of the diamonds.

Special attention was given to diamonds of the MDA-S type, a blocky, sharp-edged diamond grit, and diamond spheres. These two types of diamonds were compared in grinding and showed similar results due to the production of flat areas on the spheres and the movement and wear of the blocky particles in the bonding material to present flat faces to the workpieces.

The grinding experiments also entailed a study of machine vibrations, especially chatter vibrations and the grinding noise associated with it.

On the strength of ceramics as a function of microstructure, grinding parameters, surface finish, and environmental conditions, R. Sedlacek, F. A. Halden, and P. J. Jorgensen, *SP348*, pp. 89-96 (May 1972).

Key words: Alumina; delayed fracture; grinding of ceramics; microstructure; stress corrosion; vacuum strength.

The tensile strength of four aluminas is described in terms of their microstructure and composition. The effect of microstructure on the attainable surface finish is discussed, and the results of profilometric evaluation of ground surfaces are presented. Various postgrind treatments are shown to have differing effects on microstructure. Griffith's flaw theory is applied to aluminas of different grain sizes, and calculated strengths are found to agree with experimental data. The phenomena of delayed fracture and stress corrosion are discussed; the strength of alumina is found to be higher under vacuum than in air and is independent of stress rate.

Grinding alumina with diamond abrasives, R. J. Caveney and N. W. Thiel, *SP348*, pp. 99-112 (May 1972).

Key words: Alumina; cylindrical grinding; diamond grinding wheel; electron microscopy; removal mechanism; surface damage; surface finish; surface grinding; wear mechanism.

This paper is the result of a preliminary investigation into the grinding of high density alumina with diamond abrasive grinding wheels.

Following extensive work on the application of diamond for tungsten carbide and steel grinding, the De Beers Diamond Research Laboratory recently embarked on a research programme to study the various aspects of ceramic grinding. In the Diamond Abrasive Technology Centre's Grinding Section, ceramics with three different alumina contents were ground with a variety of diamond types both natural and synthetic to establish what effect changes in wheel speed have when surface grinding these materials. The mode and extent of damage of the ground surfaces of the specimens were investigated using conventional electron microscopy. In addition to these investigations, measurements were made of the quality of the surface finishes that can be obtained under different grinding conditions. Variations in grinding efficiency, machining costs, and surface damage are discussed for the three alumina grades tested. The mechanism of wear of the different diamond types was studied and is demonstrated by means of scanning electron micrographs.

Also reported in this paper are the initial results obtained from tests on cylinders of the same three alumina grades mentioned above. These initial tests were aimed at finding the most suitable combination from the point of view of wheel life, of wheel and workpiece speeds, and incorporated tests with both natural and synthetic grits.

Ceramic substrate and specimen fabrication, H. C. Leistner and W. A. Wilson, *SP348*, pp. 113-117 (May 1972).

Key words: Ceramics; finishing; grinding; specimens; substrates; ultrasonic machining.

Procedures have been developed to fabricate ceramic materials used as substrates for precision, coaxial, thin film resistors. Excellent radio frequency characteristics have been obtained from this procedure in developing radio frequency standards at the National Bureau of Standards at power levels of 10 milliwatts to 100 watts and frequencies from direct current to 4.0 gigahertz. Substrates fabricated for this purpose require precise tolerances and surface finish to insure uniformity of thin films deposited on a ceramic substrate.

In addition, procedures have been developed to fabricate specimens used in determining the dielectric and magnetic properties of ferrites, insulating ceramics, glass, fused silica, and single crystal materials. A variety of shapes are required including spheres, rods, disks, and ellipsoids. Precise tolerances are required to obtain qualitative property measurements of the materials involved.

In both procedures, special techniques are used with existing equipment in grinding ultrasonic machining, lapping, and polishing to obtain the required end product. This paper deals with both the application of the required products and the methods used to fabricate these products.

On the shaping of brittle solids by erosion and ultrasonic cutting, H. L. Oh, K. P. L. Oh, S. Vaidyanathan, and I. Finnie, *SP348*, pp. 119-131 (May 1972).

Key words: Abrasion; brittle-ductile transition; erosion; fracture location; ring cracking; shaping; size-effect; statistical nature of strength; ultrasonic cutting; Weibull distribution.

In mechanical shaping processes for brittle solids, materials are removed by the propagation and intersection of cracks. To control the resulting surface finish, the extent of cracking is localized by loading the surface in very small regions, usually with small abrasive grains. Thus, in analyzing such processes as erosion and ultrasonic cutting, we have to examine the fracture patterns produced by small hard indenters.

As a starting point, it is shown that fracture loads for indenters subjected to normal force may be predicted from conventional strength tests by using Weibull's statistical treatment of brittle strength. It is then shown that Weibull's procedures may be extended to predict the distribution of fracture location in brittle solids. For the case of a spherical indenter under normal and tangential forces, many cracks may form as the load is increased. It is shown that the location of the outermost of these cracks may be predicted. Estimates may also be made of the depth of cracking and thus the extent of the cracking produced by a single contracting particle may be described.

These results may be applied directly to study the process of erosive shaping. The influence on volume removal of changes in the velocity and size of the impacting particles is predicted and shown to be in accord with experiment. Many other features of the erosion process may be described including a transition to "ductile" behavior in the case of glass when the impacting particles are small enough. The analysis of ultrasonic cutting presents greater difficulty because the distribution in size of the abrasive grains is of great importance. However, predictions may be made for the influence of load, grain size, and material properties on the rate of volume removal and these are shown to be in general accord with experiment.

Sonic machining of ceramics, W. B. Campbell, *SP348,* pp. 33-139 (May 1972).

Key words: Abrasive; ceramic machining; sonic machining; vibrational machining; wheel machining.

The effect of 10 kHz sonic vibrations on the shaping and finishing of fired ceramic shapes was investigated to identify optimum machining conditions commensurate with product and surface quality. Sonic motors, developed at The Ohio State University and with outputs up to 15 horsepower, were used to activate the machine tool. Significant improvements in tool wear were observed in impact-tuned systems that produced removal rates greater than 45 cu in per min. Template and profile tooling were successfully used to obtain open cutting surfaces. Over 3,000 test cuts provided the data necessary to identify optimal parameters of operation.

Environment-sensitive machining behavior of nonmetals, A. R. C. Westwood and R. M. Latanision, *SP348,* pp. 141-153 (May 1972).

Key words: Adsorption; ceramics; drilling; environmental effects; fracture; glasses; machining; mechanical behavior.

Liquid environments can influence the efficiency of machining nonmetallic solids in a variety of ways, e.g., by serving as lubricants, coolants, or particle dispersants. More importantly, however, certain environments can markedly increase or decrease the hardness of the near-surface regions of such solids, and thereby exert a profound influence both on the rate of material removal and on tool life. Because of its technological potential, the characteristics and possible mechanisms of this latter phenomenon—the Rebinder effect—receive primary consideration in this paper.

For crystalline ceramics, Rebinder effects in machining arise because of the influence of the environment on near-surface dislocation behavior. Effects resulting from adsorption-induced changes in the surface free energy of the solid are of minor importance. Rebinder effects can also occur in noncrystalline solids, however, and recent observations on such effects in various glasses are described. The possibility that these effects are caused by a stress-plus-chemisorption-induced redistribution of sodium ions in the near-surface region is discussed.

The importance of considering the total cutting system, environment-solid-tool, in any account of environment-sensitive machining is stressed, for environments which facilitate material removal when one type of tool is used can be detrimental to the effectiveness of another tool with a different cutting action.

Shaping or figuring ceramic surfaces by ion-beam bombardment, P. W. Levy, *SP348,* pp. 155-168 (May 1972).

Key words: Figuring; ion-beams; optical surfaces; polishing; radiation damage; sputtering.

The shaping or figuring of glass and ceramic surfaces by ion-beam erosion is a relatively new technique. All operations are carried out in a vacuum. Usually the optic is bombarded by a collimated beam of rare gas ions whose energy is between 1-100 keV. Selected areas can be eroded by electrostatically deflecting the beam or, less conveniently, by moving the optic. The erosion area can be controlled by focusing the beam with electrostatic or magnetic lenses. The basis of the erosion process is the physical phenomenon known as sputtering. This occurs when the incident ions scatter elastically with atoms near the surface of the target and some of the displaced atoms, after participating in one or more collisions, acquire sufficient velocity to escape from the solid. Other dislodged atoms become interstitials and, together with vacancies created in the recoil process, create a radiation-damaged layer just below the eroding surface, whose thickness is roughly the range of the bombarding ions. For ceramic materials, typical erosion rates are on the order of angstroms/μamp/cm^2/min and increase with increasing angle of incidence. Ion-beam currents up to 100 μamp/cm^2 are practical. Under these conditions, the material struck by the beam may reach temperatures between 300 and 700 °C. The maximum lattice disruption occurs at a depth of one incident ion range from the original surface just as the eroding surface reaches this point. Additional bombardment does not increase the damage beyond this maximum. Furthermore, the damage is minimized by using bombardment conditions which maximize the temperature in the target. It is not known if there are any radiation damage effects which reduce the usefulness of ion-beam figured optics. At the moment, it would appear that ion-beam figuring is a practical technique for "touching up" conventional optics and, more importantly, for fabricating nonspherical or nonaxially symmetrical optics. Also, the ion-beam erosion process is particularly amenable to computer control.

The effect of sputtering on surface topography and strength of ceramics, R. W. Rice, *SP348,* pp. 171-187 (May 1972).

Key words: Carbides; glass, ion beam sputtering; nitrides; oxides; RF sputtering; strength; surface finish; twins.

The topography developed as a result of RF sputtering on a variety of ceramic surfaces is described showing that sur-

face cracks, scratches, pits, etc., are fairly rapidly rounded out. Generally, this occurs without differential grain boundary sputtering. However, some bodies develop a rough finish due to nonuniform microstructural removal. Limited trials with ion beam sputtering show it also rounds cracks, etc., but does not develop a rough finish on bodies that will with RF sputtering.

Because of the rounding of stress concentrating features and generally similar effects on single and polycrystalline bodies, sputtering was investigated as a substitute for flame polishing, but with much wider applicability. Flame polished strengths were not obtained. However, some materials (e.g., $MgAl_2O_4$) do show greater improvements in strengths than others (e.g., Al_2O_4) as a result of sputtering. These differences will be discussed and results compared with other methods of surface finish.

Both the detailed nature of the sputtered surface as well as enhancement of grain boundaries and other microstructural features under certain conditions indicate that sputtering may also be useful as an etching technique.

Computer controlled ionic polishing of optical surfaces, J. W. Douglass, *SP348*, pp. 189-192 (May 1972).

Key words: Computer controlled process; ion beam technology; ionic polishing; optical fabrication; optical scatter; sputtering.

Results of the development of an ionic polishing investigation are described. During this investigation many controlled polishing experiments were performed. The results of two of these experiments are presented. In the first of these, a 0.203 m diameter optical flat of fused silica was polished to a diffraction limited surface quality of 95A (9.5 nm) rms. The second experiment described was the conversion of a 0.203 m diameter Cervit sphere into an f/5 paraboloid of diffraction limited quality by using analytical expressions to generate the removal distribution. The ionic polishing process was computer controlled for this experiment. The temporal stability and optical scatter performance of ionically polished surfaces has been determined to be as good as or better than conventional surfaces.

Arc, laser, and electron beam machining of ceramics, R. W. Rice, *SP348*, pp. 193-195 (May 1972).

Key words: Arc machining; cutting; drilling; electron beam machining; laser machining; shaping; thermal shock control.

The various types of arc, laser, and electron beam machining, the considerations that are required in their operations, and some of the applications for which they have been tried or used, are briefly reviewed. The most general consideration is whether thermal shock and stress cracking will be a problem. The environmental and material parameters, which vary substantially with the types of these different machining processes, can also be quite important. Meeting the requirements of all these considerations does limit the versatility and applicability of these techniques. Nevertheless, they deserve consideration for a variety of applications.

The techniques and mechanisms of chemical, electrochemical, and electrical discharge machining of ceramic materials, D. W. Lee and G. Feick, *SP348*, pp. 197-210 (May 1972).

Key words: Ceramic materials; chemical machining (CHM); electrical discharge machining (EDM); electrochemical machining (ECM); intermetallic compounds.

Electrochemical Machining (ECM), Electrical Discharge Machining (EDM), and Chemical Machining (CHM) techniques have not been extensively used as a material removal process for ceramics. The fact that these processes are not dependent upon the hardness of the workpiece should make them attractive for the shaping of ceramics. However, ECM and EDM techniques are limited to material with reasonably good electrical conductivity while CHM may be limited by the availability of effective etchants and the nature of the ceramic itself.

The theory and techniques of chemical, electrochemical, and electrical discharge processes will be reviewed. The variables and important parameters of the material removal processes will be discussed, including etchants and mask techniques for chemical milling; current-voltage characteristics, dielectric fluids, electrode materials, etc., for EDM; electrolytes, gap effects, current density, etc., for ECM. The available information and experiences developed on metals and alloys will be used to examine the applications and limitations of these processes to ceramic materials. Where possible, the effects of the material removal process on the surface condition, microstructure, and subsequent material properties will be pointed out. Finally, comments will be made on the technical and economic feasibility of ECM, EDM, and CHM processes for the shaping, cutting, and finishing of crystalline ceramics.

Improvements in the surface finish of ceramics by flame polishing and annealing techniques, M. J. Noone and A. H. Heuer, *SP348*, pp. 213-232 (May 1972).

Key words: α-Al_2O_3; annealing; flame-polishing; reinforcements; ruby; sapphire; strength; surface perfection.

Improvements in the surface perfection (i.e., "smoothness") of ceramics can be achieved by thermal treatments at temperatures where material transport may be induced at the surface. Such treatments include annealing in controlled environments, where surface diffusion, vapor transport mechanisms, etc., may be active, and flame polishing, where a thin layer at the surface of the material is melted, allowed to flow freely, and then resolidified.

The effects of these treatments on the surface of single crystals of α-Al_2O_3 are reviewed in this paper. The most sensitive assessment of the degree to which surface perfection is attained is the measurement of the strength of the treated crystals; for this reason, strength data are used extensively to characterize the thermal treatments described. In the case of flame polishing, it found that a sufficient degree of surface perfection can be attained so that the strength is no longer limited by surface defects (the usual experience with ceramics) but by defects within the material. The technological significance of high strength Al_2O_3 filaments for reinforcement of metals and the unfortunate deterioration of the surface in these applications is briefly described.

Healing of surface cracks in ceramics, F. F. Lange, *SP348*, pp. 233-236 (May 1972).

Key words: Abrasive machining; ceramics; crack healing; sintering; surface damage.

Grinding, cutting, thermal shocking, impacting, and roug handling all introduce surface cracks that degrade th strength of ceramics. Within the last year, it has been show that, once introduced, these cracks can be eliminated b either resintering the damaged ceramic component for th case of oxides or oxidizing the component for the case c materials such as SiC.

Results of crack healing experiments, performed o Al_2O_3, ZnO, and SiC will be reviewed. The technical impl

cations of these results will be discussed as related to abrasive machining.

Flame polishing of flat oxide bars, P. F. Becher and R. W. Rice, *SP348*, pp. 237-244 (May 1972).

Key words: Flame polishing; glass; rutile; sapphire; spinel; strength; surface characterization; twinning.

Some of the problems and limitations of flame polishing flat bars are discussed. Results are presented for single crystal, α-Al_2O_3, as well as for more limited trials of $MgAl_2O_3$, TiO_2, and soda lime glass. The wide variability of strength is partially related to variations in surface, but twinning also appears to be important in sapphire and TiO_2. Preliminary results on twin sources and their effect on strength of sapphire are discussed.

Continuous flame polishing of sapphire filament, J. T. A. Pollock, *SP348*, pp. 247-256 (May 1972).

Key words: Characterization; continuous flame polishing; sapphire filament; strength enhancements.

Continuous flame polishing of nominal 2.5×10^{-4} m diameter single crystal sapphire filament oriented with the c-direction parallel to the filament axis has resulted in considerable enhancement of the tensile fracture strength. Optimum increases of approximately 1.1×10^9 N/m² (1.6×10^5 psi) have been obtained on flame polishing many lengths of filament exhibiting as-grown tensile strength of $2.2 - 2.8 \times 10^9$ N/m² ($3.2 - 4.0 \times 10^5$ psi). Flame polishing was carried out in a continuous manner at 6.3×10^{-4} m/sec using an oxygen/hydrogen flame. Data are presented which suggest that the enhancement is not entirely dependent on the production of a more perfect Al_2O_3 surface. Increases in strength of approximately 5.5×10^8 N/m² (8×10^4 psi) are reported for filament which has passed through flames not sufficiently hot for surface melting to occur. Maximum strength enhancement is obtained when the oxygen/hydrogen flame temperature is such that an axial molten zone two to three times the filament diameter is produced at the filament surface. When the flame temperature is too high, the geometric integrity of the filament is lost and an apparent fall in tensile strength from the peak value is observed.

Metallographic evidence is presented indicating that the molten zone has a radial depth of less than 6.5×10^{-6} m. Scanning electron microscopy and related surface analysis studies are reported which confirm that optimum polishing results in a smoother filament surface. Experiments to determine the state of stress in the filament before and after polishing are described.

The relative contributions to the reported tensile strength enhancement of thermal strain relieving, thermally activated atomic diffusion leading to blunting of possible fracture sources, and the creation of a more perfect Al_2O_3 surface are discussed.

Preparation of smooth crystalline, damage free, sapphire surfaces by gaseous etching, W. A. Schmidt and J. E. Davey, *SP348*, pp. 259-265 (May 1972).

Key words: Crystalline sapphire surfaces; fluorinated-hydrocarbon etch; fluorotrichloromethane; freon etching; hydrogen annealing; sapphire; sapphire substrates; sapphire surface preparation.

Sapphire has a combination of properties such as relative chemical inertness, exceedingly high resistivity, optical transparency, and crystalline structure that suggests its use as a substrate material for various semiconductor devices. Its successful use for silicon vapor phase epitaxy substrates indicates that similar results might be possible with other semiconductors. Previous epitaxial studies have shown that surface crystalline disorder and topographic imperfections inhibit epitaxial growth; therefore, highly polished, well ordered sapphire surfaces were needed. Mechanical polishing alone is insufficient as it results in cold flow and work damage.

Initial experiments in removing surface damage were performed with hot phosphoric acid and with hydroxide etches. Undesirable preferential etching was observed for both processes and the processes did not seem amenable to the routine production of high quality surfaces. Two other surface treatments for which successful results have recently been reported were investigated.

The first was a hydrogen firing technique in which the substrates were heated in hydrogen in an Mo wound resistance furnace at 1500 °C. The second was a simple laboratory process in which the sample is heated by means of RF heating of a carbon susceptor to 1350 °C in an atmosphere of helium and fluorotrichloromethane (Freon-11). Commercial reagents were used throughout and a fused quartz tube was used for the reaction chamber for the second technique.

Reflection electron diffraction (RED) was used to determine the surface crystalline order, and electron microscopy (EM), using high resolution replication techniques, was used to examine the topography structure of the surfaces. A number of different substrates from various industrial sources, with different surface topographies and different orientations, were used.

Hydrogen firing at 1500 °C results in an etch rate of 0.1 10^{-6} m/min. Firing for times up to 45 min did not produce consistent surfaces on the 0, 60 or 90° orientations. While hydrogen firing did produce high quality, well ordered crystallograph surfaces by RED, their topographic condition was poor. Resolvable surface structures could be detected on some with standard optical microscopy (200x, dark field) and for all high resolution EM measurements. The final surface finish quality was related to the quality of the prefired surface, indicating that complete damage removal was not accomplished.

Freon firing at 1350 °C resulted in an etch rate of 1.5 10^{-5} m/min. This technique consistently produced well ordered, high quality surfaces for the 60 and 90° oriented surfaces. EM viewed 60 and 90° freon-fired surfaces had no resolvable surface structure after a 5 min etch and were well ordered crystallographically as measured by RED. The same etch produced strongly etched surfaces on 0° oriented material.

The strength of gas polished sapphire and rutile, R. W. Rice, P. F. Becher, and W. A. Schmidt, *SP348*, pp. 267-269 (May 1972).

Key words: Chemical polishing; rutile; sapphire; spinel; strength; twinning.

Surface polishing of α-Al_2O_3 using a helium-freon gas mixture at elevated temperatures is shown to yield bend strengths comparable to flame polished sapphire. However, the gas polishing process proved to be more versatile as evidenced by the success with flat bar surfaces. Further, the process can be readily applied to some other materials as demonstrated by the substantial improvements in the strength of TiO_2 after gas polishing. Limited attempts at polishing other ceramic materials are also discussed, as well as observations on strength variations and fracture behavior.

Analysis and characterization of ceramic surfaces for electronic applications, R. C. Sundahl and L. Berrin, *SP348*, pp. 271-290 (May 1972).

Key words: Aluminum oxide; Auger electron spectroscopy; crystallographic texture; ion microprobe; scanning electron microscopy; substrates; surface defects; surface segregation; thin film adhesion; thin film circuit imperfections.

The criteria which are used to evaluate the surfaces of ceramic substrates for use in the electronics industry must be related to the specific application of the surface. This article emphasizes one such application— the use of a ceramic surface as a support for complex thin film conductor patterns which serve to interconnect silicon integrated circuit chips. Those ceramic surface parameters which are found to be critical to this application are (1) topographical properties, (2) chemical properties, and (3) crystallographic properties.

These properties are characterized using such tools and techniques as optical, transmission electron and scanning electron microscopy, profilometry, electron microprobe analysis, ion microscope analysis, Auger electron spectroscopy, and electron diffraction. Special emphasis is placed on the relationship between the results of such analyses and the performance of the surface as part of the SIC interconnect system.

Surface characteristics of ceramic substrates for hybrid and microwave electronic circuits, J. K. Emery, *SP348*, pp. 293-300 (May 1972).

Key words: Camber; ceramic; fired; flatness; ground; lapped; microwave; polished; roughness; substrate; surface; thick film; thin film; waviness.

Several methods currently used for finishing ceramic substrates in ready-for-deposition state are discussed, including firing, glazing, burnishing, grinding, lapping, and polishing. Each method tends to exhibit a different and typical combination of surface characteristics, such as variations in thickness, parallelism, camber, waviness, roughness, and localized defects; each of these in turn may influence the deposition process, performance, and reliability. Analysis of some typical surface details, particularly roughness and waviness, as significant surface factors capable of affecting process or function, is presented with comments on instrumentation and measurement procedures.

Significant differences exist in the use of terms relating to substrate surfaces and their characteristics; a need is indicated for more particularized use of such terms and for recognition of uniform definitions. Clarification of terminology may facilitate improved communications and measurements, which in turn may correlate with current and future requirements in circuit production. Several existing applicable standards are referenced, and definitions of terms are suggested. A number of choices of surface characteristics are presented which may be related with process controls and function, but no recommendations for particular values of surface details are intended.

Ceramic surface texture by reflective replica technique, W. C. Lo, *SP348*, pp. 301-307 (May 1972).

Key words: Alumina substrates; surface replica; surface texture.

Surface texture is a parameter of general concern in the study of thin film metallizing adherence on ceramic substrates. It refers to the geometrical character of the surface irregularities recurring many times across the ceramic surface tending to form a pattern. In this context, surface texture is determined by the size, shape, arrangement, and distribution of the surface constituents.

This note presents a convenient method by which the surface texture of ceramic substrates can be visually assessed and recorded photographically using a simple metallographic microscope.

Examples in applying this technique for distinguishing and differentiating surface textures of different types of ceramic substrates are given. Use of the technique for identifying surface defects is also shown.

The simplicity of the method should warrant its use for monitoring the physical surface quality of ceramic substrates.

Quantitative surface finish characterization by CESEMI, E. W. White, H. A. McKinstry, and A. Diness, *SP348*, pp. 309-316 (May 1972).

Key words: Ceramic materials; CESEMI (Computer evaluation of scanning electron microscope images); digital magnetic tape recordings; profilometer; profilometer rasters; quantitative characterization; scanning electron microscope; surface finish analysis; surface morphology; surface roughness; surface topography; three-dimensional images.

A feasibility for quantitative characterization of surface finishes based on the computer evaluation of scanning electron microscope images (CESEMI) has been established. Measurement of the number, size, shape, and orientation of isointensity (or selected intensity interval) regions constitute the basic analysis. Brightness in SEM images varies as a function of the steepness of slope of the surface at a given point. In their analysis, the characteristics of grooves, pits, ridges, etc., can be studied separately. Detailed interpretation of the results is not attempted in this preliminary study.

A feasibility for recording and analyzing profilometer rasters has also been demonstrated. Such recordings are, in essence, true three-dimensional images of surface topography insofar as the profilometer stylus faithfully follows the surface morphology. Analysis of these profilometer recordings by the basic CESEMI computer programs yields direct descriptions of the topography. The SEM image and profilometer "image" analyses appear to be complementary techniques. One obvious advantage of the SEM image analysis is that it is a no-contact technique; hence, there are no problems introduced by stylus damage.

An assessment of surface and subsurface damage introduced in ceramics by semifinish grinding operations, B. G. Koepke, *SP348*, pp. 317-332 (May 1972).

Key words: Ceramics; etch pits; fracture; grinding damage; plastic deformation; surface condition; surface grinding.

The nature and extent of grinding damage introduced by surface grinding a number of ceramics having widely varying mechanical properties have been studied. Surface damage has been characterized by optical and electron microscopy, and subsurface damage has been observed using etch pit techniques. Grinding damage was found to depend strongly on wheel type and rate of material removal as well as on the mechanical behavior and microstructure of the workpiece. The results indicate that grinding damage is mainly composed of mixtures of three types depending on the mechanism of material removal.

When material is removed efficiently from low impact resistance ceramics (e.g., magnesium oxide and ferrite), the surfaces are generated by brittle fracture and are composed of regions of transgranular and intergranular fracture. When grinding is inefficient, i.e., when the grinding wheel loads up material is removed by plastic flow. The resultant surface on deformable ceramics (e.g., magnesium oxide, ferrite, and silicon) are smooth and burnished but may contain thermal cracks due to the heat generated. In this instance, subsurface damage consists of a discrete, highly deformed layer containing cracks in most cases.

When material is removed efficiently from high impact resistance, nondeformable ceramics (e.g., alumina and boron carbide) material is removed by plastic flow and by transgranular and intergranular fracture. The presence of extensive plastically flowed regions on the ground surfaces of extremely hard ceramics is surprising and points out the extremes of stress and temperature existing under the wheel-workpiece interface during a grinding pass.

Observations on mechanically abraded aluminum oxide crystals by transmission electron microscopy, B. J. Hockey, *SP348,* pp. 333-339 (May 1972).

Key words: Abrasion; aluminum oxide; dislocations; ion-bombardment; microtwins; scanning electron microscopy; subsurface damage; transmission electron microscopy.

Use of the argon ion-bombardment thinning technique has made possible the examination of the near surface regions of mechanically abraded aluminum oxide by transmission electron microscopy. Observations on diamond-polished (0.25 μm), alumina-polished (0.3 μm), and diamond-ground specimens have shown that subsurface damage as well as surface damage is typically produced.

Specifically, mechanical polishing introduces relatively high densities of dislocations to a depth of approximately 1 μm from the original surface. The dislocations are generally in the form of half-loops and are clearly associated with surface scratches produced by individual abrasive particles.

The magnitude of residual surface stresses and the irregular surface topography produced by grinding necessitated the removal of at least 2–4 μm from the original surfaces. At this depth, both the nature and extent of subsurface damage in polycrystals varied from grain to grain. Most grains contained either tangled dislocation arrays or microtwins (either basal or rhombohedral). A number of grains, however, were found to be completely free of damage and may correspond to regions below fracture surfaces which are apparent in observations of ground surfaces by scanning electron microscopy.

Acoustic emission monitoring of surface-damaged ceramic materials, L. R. Bunnell, J. C. Crowe, and P. E. Hart, *SP348,* pp. 341-342 (May 1972).

Key words: Acoustic emission; glass; Lucalox; Pyroceram; surface damage.

The acoustic emission response of Lucalox, fused silica, single crystal alumina, Pyroceram, and soda-lime-silica glass to surface damage is reported. Low temperature annealing at 200 °C reduces the response levels; annealing at 400 °C removes all of the induced acoustic activity.

Effects of surface finishing on mechanical and other physical properties of ceramics, R. J. Stokes, *SP348,* pp. 343-352 (May 1972).

Key words: Ceramics; cracks; dislocations; electrical properties; electro-optical; ferrite; machining; magnetic properties; mechanical properties; optical properties; residual stress.

This paper reviews the effects of mechanical finishing operations on the physical properties of ceramics. Ceramic machining results in a defective surface containing cracks, dislocations, point defects, and residual stresses. The relative significance of these defects depends on the physical property of interest. The mechanical properties of single crystals are sensitive to dislocations (semibrittle) and surface cracks (brittle); the mechanical properties of polycrystals are sensitive to surface cracks; the electrical properties of semiconductors are sensitive to surface trapping sites; magnetic, piezoelectric, and optical properties are particularly sensitive to residual stresses. To optimize physical properties, these defects must be eliminated by mechanical lapping, chemical etching, or thermal annealing.

Strength effects resulting from simple surface treatments, H. P. Kirchner, R. M. Gruver, and R. E. Walker, *SP348,* pp. 353-363 (May 1972).

Key words: Abrasive machining; alumina ceramic; chemical polishing; crack healing; delayed fracture; glazing; humidity; refiring; strength; surface flaws; surface treatments; thermal shock.

In well made polycrystalline alumina ceramics subjected to external loads, fracture originates, in almost every case, at surface flaws rather than at volume flaws. This susceptibility to surface flaw failure has been reliably established in experiments in which compressive surface layers were used to obtain substantial improvements in strength. Knowing that the failures occur at surface flaws, the artificial introduction of surface flaws can be used to obtain an understanding of the ways in which surface flaws affect the strength. Additional information can be gained by using simple treatments to change these artificial surface flaws and by observing the effect of these treatments on the strength.

In the present investigation, artificial flaws were introduced by single point tools, abrading, thermal shock, and abrasive machining. The flaws were treated by refiring, chemical and flame polishing, chemical etching, glazing, and prolonged storage in various environments.

The changes in the flaws were characterized by microscopy and to a limited extent by profilometry. Both flexural and tensile strengths were measured. The effects of the treatments are discussed in terms of changes in the average strength and variations in the distributions of the individual strengths.

The effect of grinding direction on the strength of ceramics, R. W. Rice, *SP348,* pp. 365-375 (May 1972).

Key words: Carbides ceramics; fracture; grain size; grinding; hardness; mechanical testing; nitrides; oxides; strengths.

It is shown that grinding bars in a direction parallel with the tensile axis has limited effects on their strength while grinding perpendicular to the tensile axis may have no effect or can reduce strengths as much as 50 percent. In single crystals, the reduction in strength generally increases with the hardness of the material but can also depend on crystallographic orientation. In polycrystalline bodies, the reduction also depends a great deal on grain size, with the effect generally increasing with decreasing grain size. Also the effect tends to be greater in polycrystalline bodies that are weaker than normal. The effect of grinding direction on strength is attributed to stress concentrations due to grinding stria, whose continuity and depth generally increase with hardness. The severity of these stria tends to increase as the amount of plastic deformation in the machined surface decreases. The amount of plastic deformation is shown to vary approximately inversely with hardness. The effect of varying strength with grinding direction on the interpretation of various tests is discussed.

The influences of material removal on the strength and surface of an alumina, H. S. Starrett, *SP348,* pp. 377-388 (May 1972).

Key words: Alumina; surface finish; surface treatments; Weibull.

Southern Research is conducting a quantitative investigation of test methods used to evaluate brittle materials. The material for this study is a high purity, high density alumina manufactured by Coors Porcelain Co. of Golden, Colo. The primary scope of the total program is a study of test methods, scaling laws, and surface finish effects. The scope has been broadened to include the effects of property interactions on strength and the relationships between micro and macro characterization and the mechanical properties.

Initial tensile and flexural data indicated that surface finish had no effect on the tensile strength of this particular alumina. Since this was contrary to generally accepted results, considerable effort has been expended in investigating this phenomenon. It has been postulated that the lack of an effect may have been due to subsurface damage that occurred during the grinding operations.

The investigations into surface/subsurface damage have focused into four principal areas. Microstructural characterization has been used to characterize the surfaces of interest, to look for evidence of damage, and to look for microstructural events which may be normalizing the data. A study of fracture source distribution has been made in order to determine the depth of damage which would have a significant effect on the flexural data. Surfaces have been and are being subjected to different treatments such as refiring in modified environments and deep lapping in order to define the nature of the surface/subsurface damage, if it exists.

The microstructural work has not revealed any obvious damage; however, it was found that even by proceeding from a shop grind to a metallurgically lapped surface, certain features such as exposed pores, interfaces between alumina matrix and second phase, and evidence of the original ground surface did not totally disappear. The study of the fracture source distribution provided quantitative evidence that damage on the order of 0.005 in (approximately five maximum grain diameters) would have a significant effect on the flexural data. Results from the surface treatments, deep lapping, and refiring show that these different preparations did not affect the flexural strength of the material. Other indirect evidence (statistical data) show this material to be insensitive to surface effects within the range of surface finishes investigated.

The effect of grinding variables on the strength and surface finish of alumina, R. Sedlacek, F. A. Halden, and P. J. Jorgensen, *SP348*, pp. 391-397 (May 1972).

Key words: Alumina; diamond grinding; surface finish; tensile strength.

The tensile strength of alumina is used as a criterion for the evaluation of the effects of variables encountered in diamond grinding of ceramics. The variables studied include the grit size of diamond, rate of material removal, and spark-out. The difference in performance of natural and synthetic diamond is shown, and the feasibility of dry grinding is discussed. The ground surfaces were examined using profilometry, and transmission electron and scanning electron microscopy. The strengths of test specimens having ground or as-fired surfaces are compared.

Edge effect on the modulus of rupture of ceramic substrates, *W.* C. Lo, *SP348*, pp. 399-400 (May 1972).

Key words: Alumina substrate; edge damage; flexural strength.

Because of its simplicity, the modulus of rupture (or flexural strength) test is often used to evaluate the mechanical strength of ceramics. For large flat substrates, the natural tendency is to test specimens cut from the substrate.

Depending on the method of cutting and the resulting edge condition of the specimen, the flexural strength can be significantly different. This is illustrated by 3-point loading data on CO_2-laser-scribed and diamond-sawed specimens. The modulus of rupture of a laser-cut sample is about 70 percent of that of a diamond-sawed sample.

SP349. **Heavy-atom kinetic isotope effects, an indexed bibliography,** M. J. Stern and M. Wolfsberg, Nat. Bur. Stand. (U.S.), Spec. Publ. 349, 39 pages (June 1972).

Key words: Author index; bibliography; heavy-atom isotope effects; isotope effects; kinetic isotope effects; reaction kinetics; subject index.

A bibliography of heavy-atom kinetic isotope effects has been compiled covering the complete literature from the earliest entry found (1911) through 1965. Review articles and theoretical papers are listed through 1968. The bibliography is divided into a list of the references, an author index and a subject index. The subject index has been annotated to describe, in brief, the type of reaction being observed. The following areas have been excluded: geochemistry (except for specific laboratory reactions), living systems, mass spectrometry and electron impact, electrochemistry, diffusion-controlled processes, hot-atom chemistry, photochemistry involving selective excitation of isotopes and processes involving no chemical change.

SP350. **Time and frequency: a bibliography of NBS literature published July 1955-December 1970,** B. E. Blair, Nat. Bur. Stand. (U.S.), Spec. Publ. 350, 52 pages (June 1971).

Key words: Atomic clocks; atomic standards; clock dissemination; crystal oscillators; definition of second; flicker noise; frequency; frequency stability; lasers; length standards; measurement standards; spectral density; speed of light; standard frequency broadcasts; statistics of time/frequency measurements; time; time/frequency dissemination; time scales; timing (HF, LF, satellite, TV, VLF); wavelength standards; WWV; WWVB; WWVH; WWVL.

This publication gives bibliographic references to NBS time and frequency papers (principally those of the Time and Frequency Division or its predecessor sections) published over the past 15 years. The NBS material is classified under five general sections: Time and Frequency Standards; Time Scales, Time; Distribution/Reception of Time and Frequency Signals; Statistics of Time and Frequency Analyses, Frequency Stability; and General, Summary, and Status Reports. An additional section lists outside publications which describe the use of NBS time and frequency services or illustrate their varied use in seismic research, industrial practice, navigation, and propagation studies, among others. The bibliography documents past progress, will aid access to available literature, and gives an indication of the present direction, scope, and status of NBS time and frequency research.

SP351. **Analytical chemistry: key to progress on national problems.** Proceedings of the 24th Annual Summer Symposium on Analytical Chemistry sponsored by *Analytical Chemistry*, ACS Division of Analytical Chemistry, and NBS Analytical Chemistry Division, and held at the National Bureau of Standards, Gaithersburg, Md., June 16-18, 1971, W. W. Meinke and J. K. Taylor, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 351, 481 pages (Aug. 1972).

Key words: Agriculture; air pollution; analytical chemistry; biomedicine; clinical chemistry; electronics; oceanography; solid state; water pollution.

This book is the formal report of the proceedings of the 1971 Summer Symposium in Analytical Chemistry held at the National Bureau of Standards, June 16-18, 1971, and cosponsored by the Analytical Chemistry Division of NBS, *Analytical Chemistry*, and the American Chemical Society's Division of Analytical Chemistry. It contains six invited papers by subject matter experts comprehensively reviewing urgent research problems for which advanced analytical techniques need to be developed in the important areas of agriculture, air pollution, clinical chemistry and biomedicine, oceanography, solid state research and electronics, and water pollution. Summaries of related discussions by leading analytical chemists serving as panel members or in attendance at the Symposium are included. Hundreds of important analytical problems retarding progress in these important areas are described and extensive references are given to permit a deeper insight into the problem areas. Accordingly this volume should not only stimulate interest in important problems but should provide a valuable guide for highly relevant analytical research for some time to come. *These proceedings include the following papers (indented):*

The chemical analysis of things as they are, G. E. F. Lundell, *SP351*, pp. 1-18 (Aug. 1972).

Opportunities for analytical chemistry in solid state research and electronics, R. A. Laudise, *SP351*, pp. 19-77 (Aug. 1972).

Key words: Analytical chemistry; electronic materials; materials characterization; solid state research; stoichiometry; trace analysis.

Current practices and problems in analysis in solid state research and development are reviewed. A plea that the analyst assume a broadened responsibility for characterization of materials is made. Examples of solid state problems which were caused by inadequate appreciation and application of analysis are given. In particular, it is pointed out that trace analysis at and below the ppb level, the careful assessment and mapping of physical perfection by x-ray and related techniques and the use of solid-state physical measurements such as conductivity and magnetic resonance will become more important in the future. Mapping techniques and perfection techniques are reviewed in some detail. Recent new methods of stoichiometry assessment are described, and it is suggested that the determination of perfection and defects should become an orderly subdiscipline under the aegis of analytical scientists. The case is made that, insofar as both research and technological progress in solid state and electronics are rate limited by the availability of materials with appropriate properties, it is limited in many cases by our ability to characterize materials. It is concluded that with a modest reorientation of viewpoint and disciplinary content, analytical science could become the core discipline of materials characterization.

Analytical problems in biomedical research and clinical chemistry, G. N. Bowers, Jr., and J. Meyer II, *SP351*, pp. 77-159 (Aug. 1972).

Key words: Biomedical research; clinical chemistry; clinical enzymology; enzyme standardization; health science; hospital laboratory; medical research.

The key to progress in national problem areas in health rests over the long term with the success of our country's biomedical research efforts. Analytical chemistry can contribute significantly to these vital efforts by providing the sound base of quantitative chemical measurements required by these health investigations. But health research must not be construed too narrowly. The responsibility for the chemistry related to our national health needs cannot be assigned exclusively to any one scientific group. Indeed, some of the most profound insights may well originate far beyond the usual confines of the medical research community. This will be especially true in the environmental health areas where analytical chemists from many fields will make important contributions.

The elucidation and cure of disease processes are becoming ever more dependent upon chemistry. As a direct result of successful recent past biomedical research, the demand for diagnostic chemistry tests has increased faster than almost any other health service. Service chemistry is thus closely related to medical research and also medical education activities, as will be demonstrated by experience with transaminase assays in heart attacks and calcium determinations in hyperparathyroidism.

To support the rational development and utilization of automated analytical systems in health service and research laboratories, there is a clearly defined need for high purity standard reference materials and certified reagents. Clinical laboratories urgently require the development of high accuracy referee methods to improve the specificity and systematic bias of routine methods.

In short, *life is a chemical system.* Meaningful quantitative chemical measurements are essential to our understanding of its complex internal interactions as well as our profound interdependency upon other life forms in the environment.

Analytical problems in agricultural science, G. W. Irving, Jr., and W. C. Schaefer, *SP351*, pp. 161-243 (Aug. 1972).

Key words: Agricultural pollution; agricultural products analysis; agricultural science; amino acid analysis; biomedical research; clinical chemistry; diagnostic chemistry; food analysis; pesticide residue analysis.

This paper presents a review and analysis of the widespread applications of analytical chemistry and analytical instrumentation in the research and regulatory programs of the Agricultural Research Service of the Department of Agriculture. Analytical chemistry is one of the essential sciences needed in advancing the commodity and people-oriented programs which can achieve the national goals of the Department. Chemical analysis will be shown to play a vital role in assuring an adequate supply of farm and forest products and in assuring the consumer a better product while minimizing costs for processing and distribution. In people-oriented programs, such as consumer health, safety and pollution abatement, analytical methodology is the key procedure for providing the basic data to get action programs into motion.

Along with the far-ranging applications of analytical chemistry in agriculture come many unsolved analytical problems. In fact, few agricultural scientists will admit complete satisfaction with any of their current methodologies. Yet some problems are more important than others. An assessment of these problems is made including an analysis of their relative importance in conjunction with the urgent needs of agriculture. Possible ways of classifying or categorizing these problems will be suggested. For example, amino acid analysis touches almost every branch of agricultural science whereas pesticide analysis is more restricted but has a great many more complexities. For any given pesticide, methodologies may be needed for controlling its application and for measuring its residues in free and bound form, its metabolites, trace contaminants, and the inert ingredients in its formulation.

Other problems are discussed for which there appears no current solution. This will challenge the ingenuity and creativity of analytical chemists in the future.

Analytical problems in air pollution control, A. P. Altshuller, *SP351*, pp. 245-295 (Aug. 1972).

Key words: Air pollution; air quality instrumentation; air quality measurements; anion analysis; Clean Air Act; elemental analysis; measurement of atmospheric gases and vapors; measurement of atmospheric particles.

The role of measuring techniques in activities ranging from research to regulatory activities of the Environmental Protection Agency will be discussed. Field and laboratory instruments and manual techniques will receive consideration. Both point-sampling and remote types of instrumentation developments will be reviewed. Chemical and physical transformations contribute to the formation of new or modified pollutant species. Air quality measurements must be capable of properly following such transformations. Especial emphasis needs to be given to the conversion of gaseous into various submicron particulate species. The mass, particle-size distribution and details of chemical composition of these particles is required. Examples will be given of new and improved types of air quality measurements, stationary source and mobile source emission measurements which may be needed to meet air quality and emission standards.

Analytical problems in water pollution control, K. H. Mancy, *SP351*, pp. 297-430 (Aug. 1972).

Key words: Aquatic environment; environmental analysis; trace analysis; water analysis; water pollution; water pollution control.

The analytical chemistry of natural and waste waters requires subtle correlation between theory and experience, an insight into the nature and mode of action of interferences, and the ability to interpret analytical results in correlation with pertinent field observations. Because of the complexity of the system under investigation, water pollution characterization is one of the most challenging tasks to confront the analytical chemist.

Design of measurement systems begins with defining (a) WHY the analysis is needed, (b) WHAT are the parameters to look for, and (c) HOW to perform the analysis. Water pollution measurement programs usually incorporate a multitude of physical, chemical and biochemical procedures. The characterization of physicochemical and biochemical transformations in aquatic environments takes into account interactions between atmosphere, hydrosphere and lithosphere and their influence on the aquatic habitat. Trace characterization of persistent organic residues or heavy metals is based on defining their distribution dynamics in the aquatic system, *e.g.*, storage and release by bottom sediments and accumulation and tolerance by aquatic biota.

Recent trends in water pollution measurement rely heavily on advanced instrumental methods and automated analytical techniques. *In situ* sensor systems and remote noncontact optical measurement have been applied for monitoring water quality in rivers, lakes and waste effluents. The effects of environmental factors and interferences on the reliability of the measurement system have been under intensive research.

As America's water pollution problems become more complex, more complex measurement techniques are needed to cope with them. Above all, the effectiveness of pollution control programs are limited by their measurement reliability.

SP352. **World index of plastic standards,** L. H. Breden, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 352, 458 pages (Dec. 1971).

Key words: Index of plastics standards; plastics standards, world index; standards, plastics.

This computer-produced Index contains the printed titles of more than 9,000 national and international standards on plastics and related materials which were in effect as of December 31, 1970. These standards are published by technical societies, trade associations, government agencies and military organizations. The title of each standard can be found under all the significant key words which it contains. These key words are arranged alphabetically down the center of each page together with their surrounding context. The date of publication or last revision, the standard number, and an acronym designating the standard-issuing organization appear as part of each entry. A list of these acronyms and the names and addresses of the organizations which they represent are found at the beginning of the World Index.

SP353. **The Menzel symposium on solar physics, atomic spectra, and gaseous nebulae in honor of the contributions made by Donald H. Menzel.** Proceedings of a symposium held at the Harvard College Observatory, Cambridge, Massachusetts, April 8-9, 1971, K. B. Gebbie, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 353, 213 pages (Aug. 1971).

Key words: Atomic energy levels; gaseous nebulae; non-LTE thermodynamics; solar physics; transition probabilities.

A symposium in honor of Donald H. Menzel's contributions to astrophysics was held on his 70th birthday at the Harvard College Observatory, Cambridge, Massachusetts, 8-9 April 1971. Menzel and his school have made distinguished contributions to the theory of atomic physics, solar physics, and gaseous nebulae. The work on planetary nebulae represented the first investigations of non-equilibrium thermodynamic conditions in astronomy; the solar work extended these investigations to stellar atmospheres. The applied atomic physics laid the basis for what we now call laboratory astrophysics and, together with work on non-equilibrium thermodynamics, inspired the founding of the Joint Institute for Laboratory Astrophysics. Menzel has served as a distinguished consultant to the National Bureau of Standards, and publication of this volume represents a grateful acknowledgment of his service to the Bureau. The papers summarize the current status of work in the three fields he pioneered.

SP354. **Dental materials research.** Proceedings of the 50th Anniversary Symposium held at the National Bureau of Standards, Gaithersburg, Md., Oct. 6-8, 1969, in Recognition of Fifty Years of Dental Research at NBS, G. Dickson and J. M. Cassel, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 354, 238 pages (July 1972).

Key words: Adhesives; composite restorative materials; dental materials research; dental restorative materials; future dental needs; laboratory testing and clinical research; mechanical properties; metals research; specifications.

A Symposium on Dental Materials Research was held at the National Bureau of Standards, October 6-8, 1969, on the occasion of the fiftieth anniversary of the dental research program at NBS. The Symposium brought together outstanding researchers in the dental materials field from throughout the world for a comprehensive examination of the present state of research and a look at future dental needs and expectations. The program covered the broad dental materials field—from an examination of the oral environment to a consideration of future needs from the viewpoints of dental practice, dental education, dental industry, and basic science. Invited papers covered metals research, new developments in nonmetallic restorative materials, dynamic methods for determining the mechanical properties of dental materials, and problems of evaluating dental materials and making such evaluations useful to clinical dentistry through the

development of specifications. *These proceedings include the following papers (indented):*

Dental research at the National Bureau of Standards—reminiscences, W. Souder, *SP354*, pp. 3-6 (July 1972).

Key words: Amalgam, dental; American Dental Association; dental materials; Dental Research Section, NBS; interferometer, dental; specifications, dental.

In 1918 dental amalgams had a high rate of failure and few data on their physical properties were available. Using the interferometer for determination of the dimensional changes of amalgam and scientific test methods of other properties, NBS began to obtain information on the physical properties of dental materials. The specification for dental amalgam developed in the early days with numerical limits for physical and clinical properties and details of test methods has served as a model for specifications for dental materials for over 40 years. Although the early results were challenged and the program opposed by some, the dental profession soon recognized the value of the work and requested its expansion. In time schools, dental associations, and manufacturers joined in commending the research program.

Dental research at the National Bureau of Standards—history and individuals, W. T. Sweeney, *SP354*, pp. 7-11 (July 1972).

Key words: Amalgam, dental; American Dental Association; casting, dental; dental research; Dental Research Section, NBS; guest workers; Paffenbarger, George C.; Schoonover, Irl C.; Souder, Wilmer; specifications, dental.

Dental research at NBS was initiated in 1919 by Dr. Wilmer Souder with work on dental amalgams. Dr. Souder built the Section on the principle of cooperation between research laboratories, manufacturers and the dental profession. In the 1920's research associates, first from the Weinstein Research Laboratory and later from the American Dental Association were added to the NBS dental research staff. Dr. N. O. Taylor and Dr. George C. Paffenbarger were the first ADA Research Associates. In 1945 while Dr. Irl C. Schoonover was Chief of the Section, the laboratory staff was further enlarged by the addition of Guest Workers from the Armed Services. Among the many important areas of research were precision casting, dental cements, polymers for dentures bases, composite restorative materials, high speed turbine handpieces, panoramic x-ray equipment, studies of natural tooth structure and development of standards and specifications.

The need for basic research in dental materials, F. A. Peyton, *SP354*, pp. 15-17 (July 1972).

Key words: Basic research related to dental materials; dental materials; interdisciplinary research; training of dental researchers.

The field of dental materials has benefited from basic studies of the silver-tin alloy system, of cobalt alloy systems, of polymers, and of many other areas. Future basic studies of the surface phenomena of wetting, spreading of liquid films, adhesion, diffusion into dental tissues, boundary interactions, and principles of viscoelasticity related to dental materials offer productive opportunities. Basic research is essential if advances are to be made in the improvement, modification, refinement, and development of serviceable materials for the practice of dentistry. It is anticipated that such studies will increase in importance in the next quarter century and that basic scientists in many fields will be contributing to the improvement of dental service.

Research needed by the Federal Dental Services, H. I. Copeland, *SP354*, pp. 19-21 (July 1972).

Key words: Capabilities and needs of Federal Dental Services; dental research laboratories, Federal; dental staff; Federal Dental Services.

The dental research laboratories of the Federal Government function within the Departments of Commerce; Health, Education and Welfare; and Defense. These laboratories and the multidisciplined scientists therein along with those of the Veterans Administration provide a much needed national resource. The Federal Dental Services have problems in common with each other and with the profession at large, in addition to having problems unique to themselves. Each Federal Dental Service needs a scientific staff capability to solve its own immediate problems or to contract for the solutions.

Research needed by the dental industry, J. F. Glenn, *SP354*, pp. 23-26 (July 1972).

Key words: Clinical and laboratory data correlation; dental industry research needs; dental materials; dental research, necessity for rapid communication of.

Dental industry requires new research information which must come from nonindustrial research-oriented institutions. Two major requests of dental industry are for basic research and better clinical correlation with laboratory data. Many compilations of physical test data on a variety of existing materials or ill-defined experimental ones are being reported, but the major need is for evaluation of these same materials in well controlled clinical applications. More rapid access to results of investigations, especially government-supported grant research, is needed.

Research needed for dental education and practice, R. W. Phillips, *SP354*, pp. 27-30 (July 1972).

Key words: Dental education; dental materials, research needs; dental practice future; dental research; materials, dental, research.

The current research effort in dentistry, and that which will occur during the next decade indicate that dental practice will be characterized by certain trends. These trends will require an acceleration of research on adhesive film forming systems, sealants for pit and fissures and means of improving anticariogenic characteristics of restorative materials. The interdisciplinary aspects of dental materials will be increasingly important. Greater focus will be on the biological properties of materials, materials and devices for oral rehabilitation, materials for implantation and the interaction of tissue and substances used to restore lost tooth structure. Further definition of the oral cavity can be expected to become a responsibility of the materials scientist. Increased emphasis can be expected in dental education on a more intimate basic science-clinical application orientation.

Amalgams in dentistry, K. D. Jørgensen, *SP354*, pp. 33-41 (July 1972).

Key words: Amalgam, dental; amalgam, dental, effect of technique on corrosion; clinical failure of amalgam; corrosion, dental amalgam; dental materials; marginal fracture, dental amalgam; mercuroscopic expansion, dental amalgam; porosity of dental amalgam.

Corrosion is a major factor in the failure of amalgam restorations through the deposition of corrosion products

which may cause chronic periodontitis or through corrosion fracture of the margins which may cause secondary caries. Galvanic corrosion attacks only the tin-mercury γ_2 phase. Mercury released by this corrosion causes a mercuroscopic expansion resulting in a deflection of the amalgam from the cavity wall at the margin. Corrosion can be considerably reduced by minimizing the porosity of the amalgam restoration through overfilling the cavity, burnishing the margins, eliminating excess by carving and using zinc-containing amalgams.

Basic metallurgy of dental amalgam, L. B. Johnson, Jr., and H. G. F. Wilsdorf, *SP354*, pp. 43-59 (July 1972).

Key words: Amalgam, dental; amalgam, metallurgy; amalgam, strength; corrosion of dental amalgam; dental materials; metallurgy of dental amalgam.

An "equilibrium" mixture of components of dental amalgam would contain the phases β_1, γ_1 and γ_2 shown by Gaylor. Because dental amalgam is formed clinically at relatively low temperature only γ_1 and γ_2 are generally found. The tensile strengths of the Ag-Hg and the Sn-Hg matrix phases of dental amalgam are considerably below the tensile strength of the amalgam while the tensile strength of Ag_3Sn is considerably above that of the amalgam. Cleaning the alloy powder with 5 percent HCl promotes better bonding between matrix and Ag_3Sn and significantly increases the tensile strength. The γ_2 phase of amalgam is the only phase subject to destructive corrosion. The γ_2 phase has been successfully eliminated from amalgam by two methods: (1) by inclusion of powder consisting of the Ag-Cu eutectic in the alloy and (2) by substitution of 10 percent Au for Ag in the alloy.

Casting alloys in dentistry, K. Asgar, *SP354*, pp. 61-66 (July 1972).

Key words: Castings, dental, accuracy; castings, lost wax technique; dental materials; gold alloys, dental; high heat casting technique; hygroscopic expansion; investment, dental; thermal expansion casting technique; wax, inlay casting.

A major difference between the two techniques, hygroscopic and high heat or thermal expansion, used for casting gold alloys is that the wax pattern can offer some resistance to hygroscopic expansion of the mold while it does not resist thermal expansion. Researchers have condemned the hygroscopic technique because of nonuniform expansion of the wax pattern but have not given sufficient attention to other nonuniform dimensional changes which are present in both techniques and which may combine to affect favorably or unfavorably the accuracy and retention of the casting. Studies in this field should not be limited to simple measurements of thermal, setting and hygroscopic expansions of the investment but should be expanded to include strength of the investment along with its roughness, strength and behavior of waxes, and shrinkage patterns of molten metals. A need for new types of investments is presented by the recent development of many new nonprecious alloys for dental castings.

Basic metallurgy of dental casting alloys, J. P. Nielsen, *SP354*, pp. 67-73 (July 1972).

Key words: Alloys, dental casting; ceramic-metal systems; chrome-cobalt alloys; dental materials; gold alloys; metallurgy, dental alloy; porcelain-gold materials; solder, gold alloy.

The complex dental casting alloys have arrived at their present useful state mostly by trial and error. The three areas of technical significance for these alloys are: inertness in the oral environment, fabricability (including soldering), and alloy strengthening. Basic metallurgical studies are being made in this area, and as the gap between the art and basic metallurgy is closed, improvement in properties and the cutting down of precious metal content can be expected. There are prospects of new alloy systems and improvement in casting technique, particularly in automatic casting. Ceramic metal systems need further study. For the long range, investigations of the prosthetic material-human tissue reactions are necessary. To assist studies in this field a dental materials handbook on properties of dental alloys and related materials should be compiled and published.

Dental porcelain, J. W. McLean, *SP354*, pp. 77-83 (July 1972).

Key words: Aluminous porcelain; ceramic materials, dental; dental materials; dental porcelain; dispersion strengthening of glass; porcelain, dental; porcelain-gold techniques and materials.

Current research on dental porcelain has been concentrated on methods of improving fracture resistance of porcelain restorations. Enamelling of metals or dispersion strengthening of glasses offer the greatest possibilities for this purpose. The fusion of porcelain to metal copings has proved very successful under clinical conditions, but the necessity for masking the metal substructure presents difficulties in obtaining the desired aesthetic characteristics. Replacement of the metal copings by a higher strength ceramic should improve aesthetics and reduce productive costs. Dispersion strengthening of glass with high strength alumina crystals has resulted in the production of a new range of aluminous porcelains for jacket crown and bridge pontic construction.

Dental silicate cements, A. D. Wilson, *SP354*, pp. 85-92 (July 1972).

Key words: Aluminum phosphate, amorphous; dental materials; dental silicate cements; electron probe microanalysis; glass, alumino-silicate; silica gel; silicate cements, dental; silicate cements, mechanism of hardening, microstructure of, chemical nature; silicate cements, susceptibility to acid attack.

A systematic search for improvement of dental silicate cements requires detailed knowledge of their formation and structure. Experimental evidence shows the effective bonding medium in these cements is an amorphous aluminum phosphate. Physicochemical examination of a number of dental silicate powders showed them to be powdered fluorine-containing alumino-silicate glasses. The mechanism of the cement-forming reaction was studied for one cement following extraction of soluble ions by water at various time intervals after preparation. Infrared spectroscopy was used to record the changing absorption spectra of the setting cement. The microstructure of a number of fully hardened cements was studied by a variety of techniques: optical and electron microscopy, electron probe microanalysis infrared spectroscopy and x-ray diffraction. Dissolution in acidic media of aluminum phosphate bonded silicate cements is an inherent defect stemming from the fundamental chemistry of the system.

Composite restorative materials, R. L. Bowen, J. A. Barton, Jr., and A. L. Mullineaux, *SP354*, pp. 93-100 (July 1972).

Key words: Biomaterials; composites; dentistry; fillers; glass; methacrylates; monomers; prostheses; resins; restorative material.

This article describes the development of dental composite materials, which have quickly established a place in the practice of dentistry because of the shortcomings of alternative esthetic direct filling materials. The goal-directed basic research in which the composite materials were developed was initiated at the National Bureau of Standards in 1956. Late in 1957, a monomer was synthesized that is suitable for use with reinforcing fillers. Commercial dental composite materials available in 1969 use this resin together with particulate fillers and various additives; they have lower polymerization shrinkage and coefficient of thermal expansion, and higher compressive strength and stiffness relative to unreinforced resins. Compared to silicate cements, the composites have lower solubility, higher tensile strength, and comparable compressive strength. Composite restorative materials, when they have been fully developed, should provide the dental profession and the public with greatly improved restorations for anterior teeth.

Cements containing *o*-ethoxybenzoic acid (EBA), G. M. Brauer, *SP354*, pp. 101-111 (July 1972).

Key words: Crown and bridge cements; dental cements; EBA cements; EBA sedative bases; intermediate restorative; *o*-ethoxybenzoic acid cements; pulp capping materials; zinc oxide-EBA-eugenol cements.

Cements containing *o*-ethoxybenzoic acid (EBA) are reviewed. Studies of the mechanism of hardening of zinc oxide-eugenol cements indicated the potential usefulness of other chelating agents in dental cements. Products with greatly enhanced physical and mechanical properties are obtained by the partial substitution of EBA for eugenol. Similar to zinc oxide-eugenol cements, these materials are well tolerated by the tissues, but they also stimulate the formation of reparative dentin. Physical properties of the EBA-containing cements approach those of the biologically and physiologically less desirable zinc phosphate cements. The EBA cements have become commercially available and have been well accepted as luting agents for fixed restorations and as insulating bases. They appear to be the materials of choice for indirect pulp capping. Resin modified EBA restoratives show good stress-bearing characteristics and should find applications as an intermediate restorative. Possible studies to further improve these versatile materials are discussed.

Organic adhesives, H. Alter and A. Fookson, *SP354*, pp. 113-123 (July 1972).

Key words: Critical surface tension; dental adhesion improvement through liners, coupling agents, fillers, and surface treatment; dental adhesives to include acrylates, cyanoacrylates, epoxy resins and polyurethanes; dental materials; polyurethane.

The materials and means for improving joint strengths in a wet environment between dentin or enamel and restoration or cavity liner are reviewed. Critical surface tension, γ_c, a descriptive property of surfaces, offers a basis to evaluate capacity of adhesives to wet tooth surfaces. Used as a pretreatment, an adhesive may function by displacing water. Attachment to tooth surface through hydrogen bonding may also occur. Adhesion may be improved by use of liners, coupling agents, fillers and tooth surface treatments such as etching processes. Dental adhesive materials include acrylics, cyanoacrylates, epoxy resins and polyurethanes, the latter having apparently good promise as a dental adhesive of the future.

Viscoelastic behavior, P. L. Oglesby, *SP354*, pp. 127-144 (July 1972).

Key words: Amalgam, dental; creep; dental materials; denture base reins; indentation test method; mechanical properties, dental materials; rocking beam oscillator; stress relaxation; torsion pendulum; viscoelastic methods.

Since the mechanical responses of many dental materials are functions of time as well as of applied stress, viscoelastic theory, and experimental methods should be used in describing and characterizing these materials. Both static and dynamic methods may be used. Viscoelastic theory useful for characterization of dental materials and for interrelation of responses under different types of static and dynamic tests includes the Boltzmann superposition principle for linear materials and as modified and extended for non-linear materials, the time-temperature superposition principle and approximation methods for calculation of relaxation and retardation spectra. Methods which have been applied to dental materials such as amalgam, polymeric restorative materials, elastic impression materials and natural tooth structure include creep, stress relaxation, indentation and forced vibration methods.

Low frequency determination of mechanical properties, R. L. Myerson, *SP354*, pp. 145-160 (July 1972).

Key words: Activation energy; dental materials; glass, sodium phosphate; internal friction; mechanical properties; polymers, dental; torsion pendulum.

The torsion pendulum is a valuable tool for use in determining the mechanical properties and molecular structure of dental materials. With the torsion pendulum the modulus of a material may be determined from the frequency of oscillation; the internal friction can be obtained from the rate of damping. Change in internal friction with change in frequency provides insight into type of structure and relaxation mechanisms. Activation energy of processes can be determined from shift in peak energy absorption temperature with change in frequency. A principal advantage of low frequency testing is in the resolution of dispersions or of internal friction peaks. The torsion pendulum method has been applied to various polymer materials in studies of the relationship of composition and transitions, effects of cross-linking, comparison of cast poly(methyl methacrylate) and powder-liquid molded poly(methyl methacrylate) and the relationship of impact resistance to peak energy absorption temperatures. Studies have been made of the relationships between peak temperatures and composition and cross-linking in sodium phosphate glasses. A review of equipment is presented.

Ultrasonic methods for determination of mechanical properties, G. Dickson, *SP354*, pp. 161-168 (July 1972).

Key words: Dental amalgam; dental materials; elastic properties; mechanical properties; nondestructive testing; ultrasonic techniques.

Elastic characteristics, shear modulus, Young's modulus, bulk modulus and Poisson's ratio for materials can be determined by a variety of ultrasonic methods, most of which involve the measurement of the velocity of sound in the material. The methods are precise, rapid, nondestructive and applicable to small specimens. As a number of reports in the literature indicate, ultrasonic methods offer particular advantages to the study of dental materials and mineralized tissues.

Stress analysis of dental structures, R. G. Craig, *SP354,* pp. 169-175 (July 1972).

Key words: Brittle coatings for stress analysis; dental materials; denture, artificial, stress analysis; photoelasticity, dental applications; porcelain-gold restorations, stress analysis; stress analysis of dental structures.

Because of the complex geometry of dental structures, most stress analysis studies in dentistry have been experimental. Brittle coatings have provided generally semiquantitative information on the magnitude, direction and sign of surface stress of fixed bridges, removable partial dentures, complete dentures and the mandible under various loading conditions. Data from electrical resistance strain gages attached to the metal surfaces of pontics on a gold bridge with various load applications are shown. Applications of both two and three dimensional photoelastic techniques are illustrated. This method, which provides information on the magnitude, direction and sign of boundary and internal stresses is dependent upon how well the model represents the real structure. Other stress analysis methods involve photoelastic coatings, thermophotoelasticity, moire fringe patterns, holography and x-ray diffraction.

Relations between mechanical properties and clinical behavior, D. B. Mahler, *SP354,* pp. 177-180 (July 1972).

Key words: Amalgam, dental; correlation of laboratory and clinical evaluations; creep of dental amalgam; dental materials; dynamic creep; fracture, marginal of dental amalgam; mechanical properties of dental materials; rheological properties of dental amalgam.

A dilemma in the field of dental materials is that in many instances the critical physical properties that are relevant to the failure of restorative materials have not been identified or when identified the limiting values which separate successful from unsuccessful materials have not been established. To determine the critical property relevant to clinical marginal fracture of dental amalgam restorations, dynamic creep and other physical properties including compressive, tensile and transverse strength and transverse deflection of nine amalgam alloys were determined. Clinical evaluation of restorations made using alloys widely separated in dynamic creep showed that marginal fracture was associated with the rheological properties of dynamic creep, static creep and slow compressive strength, but showed little relationship to the other physical properties measured. Although the relationship between creep and marginal fracture may not be a cause and effect mechanism, creep appears to be reasonably predictive of clinical marginal fracture.

Need for research to develop performance characteristics, H. P. L. Schoenmakers, *SP354,* pp. 183-186 (July 1972).

Key words: Clinically related strength properties of dental materials; dental materials; dental materials, correlation of bulk and marginal properties; dental materials, performance characteristics; dental restorations, the role of oral environment factors in stability thereof.

To develop the most important characteristics of restorative materials, an understanding of the processes by which margins of such restorations become damaged is needed. Bulk and margin properties should be correlated. The mechanical forces developed in mastication and chemical attack by the oral environment are important factors. Tensile strength appears a more meaningful data than either shear or compressive strength. Research for selection of proper tensile test procedures is needed. Cracks and voids in specimens complicate their strength behavior. The role of temperature in laboratory evaluation is important. The mechanisms of corrosion and erosion of dental restorations require further research.

Need for correlation between laboratory testing and clinical research, B. Hedegård, *SP354,* pp. 187-189 (July 1972).

Key words: Aging processes, relation to dentistry; clinical research, dental; correlation of laboratory and clinical results; dental materials; dentistry, preventative; dentistry, restorative; epidemiological information, dental.

Although priority must be given to basic and clinical research in preventive dentistry, this does not eliminate the need for research on materials and methods for restorative dentistry which is in itself a preventive measure. There is an urgent need for collaborative and correlative studies involving properties of materials to be studied in the laboratory and tested in the clinic. Clinical research with materials is slow, and with the present incomplete information on oral environment and function, it is often difficult to assess properly the results, but there is no alternative. With sound clinical research on a larger and more penetrating scale, data and information may be obtained that will make it possible to set up more meaningful test procedures in the laboratory. And that is the goal: to be able to characterize the dental material in the laboratory and correctly predict its clinical performance.

Biological evaluation of dental materials, G. Ryge, *SP354,* pp. 191-200 (July 1972).

Key words: Biological evaluation of dental materials; clinical evaluation of dental materials; correlation of laboratory and clinical performance; dental materials; restorative materials; toxicity tests.

Biological evaluation of dental materials includes (1) screening for toxic or other untoward effects of the materials, and (2) clinical evaluation of materials that pass the screening tests. Screening tests must take into account the functional requirements of various types of and service conditions for dental and auxiliary materials. Methodology for evaluation of clinical performance of materials must include examiner training and calibration in the use of rating scales. Emphasis is placed on the need for correlation of laboratory properties with clinical performance.

Corrosion testing in the mouth, K. Nagai, *SP354,* pp. 201-205 (July 1972).

Key words: Base-metal alloys, dental; copper-zinc dental alloy; corrosion, clinical tests; corrosion of dental alloys; dental amalgam; dental materials.

For many years various base-metal alloys were used as substitutes for gold alloys for dental restorations in Japan. The adoption of an official requirement that these alloys should not have a weight loss of more than 3 mg/cm^2 when immersed in solutions of 0.05 percent hydrochloric acid, 1 percent lactic acid, 1 percent sodium chloride, and 0.1 percent sodium sulfide for three days, prompted a study of corrosion of a copper-zinc alloy and dental amalgam in the mouth. Cast copper-zinc specimens had average weight losses in the mouth in the range of 0.022 to 0.034 mg/cm^2 per day. Conventional amalgams had losses as small as 0.0063 mg/cm^2 per day. Weight losses in the test solutions ranged up to 150 times those in the mouth while weight losses in artificial saliva in vitro were about twice those in the mouth. It is believed that the lower corrosion in the mouth (which varies from place to place) results from a cleaning and inhibiting action by the saliva.

International specification program—Australian experience, A. R. Docking, *SP354,* pp. 209-211 (July 1972).

Key words: Accreditation of dental materials, Australian experience; Australian dental specifications; dental materials; dental standards; specifications, dental.

The Australian dental specifications as a basis for a certification program were developed through the Standards Association of Australia and not within the dental association. Products are accredited by the Australian Dental Association on the basis of meeting these specification tests. The Commonwealth Bureau of Dental Standards assists in preparation of specifications and in accreditation of products. Approximately thirty Australian dental standards have been issued. Participation in international specification work has proved of great benefit especially in the raising and maintenance of the quality of dental goods used by the Australian dental profession.

Development of European specifications and testing, P. Laplaud, *SP354,* pp. 213-215 (July 1972).

Key words: Certification; dental specification; European dental specifications; FDI; ISO; terminology, dental.

The development of a European specification program is difficult because of the many differences of race, nationality, politics, and social systems. One of the first problems is the establishment of a common dental terminology. The lack of sufficient data on the relationship of properties and clinical results is another difficulty. However, Europe has a long heritage of standardization in other fields and this has made it logical to think of the ISO as the proper organization to introduce international dental standards into Europe. Many European countries have already achieved promising results on a national basis. Cooperation on a regional or continental level in the development of a specification and certification program will help to provide better dental health for the public.

Development of South American specifications and testing—Brazilian experience, L. W. Süffert, *SP354,* pp. 217-220 (July 1972).

Key words: Brazilian experience, dental materials specifications; dental materials; dental specifications; dental specifications and testing, South American.

A successful program of specifications for dental materials requires extensive knowledge of and participation in the program on the part of teachers in dental schools. In turn the dental teachers can involve dental industry and dental societies. In Brazil a specifications program in dental materials was initiated by holding annual meetings to which persons recognized as authorities in dental materials were invited to lecture and give assistance in specification aspects. Certification testing of dental materials has been initiated in only two dental schools, but it is planned to have dental materials departments at selected dental schools responsible for three or four materials in a general certification testing program.

USA specification and evaluation programs, J. W. Stanford, *SP354,* pp. 221-224 (July 1972).

Key words: Dental materials and devices, specifications for and certification of; dental specifications; specifications; standards, dental.

Reliable and valid laboratory tests which delineate satisfactory materials and rule out unsatisfactory ones are essential to the development of a satisfactory specifications program. Factors guiding the American Dental Association in the formulation of specifications are: Relevant tests; correlation of laboratory, structural, and service tests; and quality of product. An important change in organization for the development of dental specifications involves the formation of the USA Standards Committee for Dentistry, operating under the United States of America Standards Institute. The Certification Program provides a means for recognition of those materials complying with existing specifications. A new evaluation program on dental devices is currently issuing pertinent status reports on the safety and efficiency of such devices. Safety and usefulness are based primarily upon information established under conditions of clinical use.

SP355. **Universal testing machine of 12-million-lbf capacity at the National Bureau of Standards,** A. F. Kirstein, Nat. Bur. Stand. (U.S.), Spec. Publ. 355, 18 pages (Sept. 1971).

Key words: Force calibration; large test facilities; structural testing; universal testing machine.

A 12-million pounds-force capacity universal testing machine, which is believed to be the largest of its kind in the world, has been put into operation in the Engineering Mechanics Laboratory of the National Bureau of Standards in Gaithersburg, Maryland. This hydraulically operated machine, which has an overall height of over 100 feet, was designed to test full scale structural components and to apply the forces needed to calibrate large capacity force measuring devices. The testing machine is capable of applying axial forces of 12,000,000 lbf in compression, 6,000,000 lbf in tension, and a transverse force of 4,000,000 lbf to a flexural specimen.

SP356. **Damage in laser materials: 1971.** Proceedings of a symposium sponsored by the American Society for Testing and Materials and by the National Bureau of Standards, May 19-20, 1971, NBS, Boulder, Colo., A. J. Glass and A. H. Guenther, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 356, 174 pages (Nov. 1971).

Key words: Laser damage; laser materials; self-focusing.

The third ASTM Symposium on Damage in Laser Materials was held at the National Bureau of Standards in Boulder, Colo., on May 19-20 of this year. The symposium is held as part of the activity of Subcommittee II on Lasers and Laser Materials, of the ASTM. Subcommittee II is charged with the responsibility of formulating standards for laser materials, components, and devices. The chairman of Subcommittee II is John D. Myers, of Owens-Illinois, Inc. Co-chairmen for the damage symposia are Dr. Arthur H. Guenther, of the Air Force Weapons Laboratory, and Professor Alexander J. Glass, Chairman of the Department of Electrical Engineering at Wayne State University.

Approximately 50 attendees at the symposium heard 17 papers on topics relating to laser-induced damage in glass, crystalline materials, nonlinear optical materials, thin film dielectric coatings, and mirrors. Particular attention was given to the processes of plasma formation at dielectric surfaces, and to the role played by self-focusing in bulk damage in solids. The principal recommendations for future investigations are summarized below.

The proceedings of these Symposia represent the major source of information in the field of damage in laser materials. The Symposia themselves, along with the periodic meetings of Subcommittee II, provide a unique forum for the exchange of information regarding laser materials specifications among the manufacturers and users of laser devices, components and systems. The symposium also serves as a mechanism of information gathering, to enable the Subcommittee to write informed and realistic specifications.

SP357. **The mechanisms of pyrolysis, oxidation, and burning of organic materials.** Based on Invited Papers and Discussion, 4th Materials Research Symposium held at the National Bureau of Standards, Gaithersburg, Md., Oct. 26-29, 1970, L. A. Wall, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 357, 199 pages (June 1972).

Key words: Burning; hydrocarbons; organic materials; oxidation; polymers; pyrolysis.

A symposium on The Mechanisms of Pyrolysis, Oxidation, and Burning of Organic Materials was held at the National Bureau of Standards in October 1970. This volume contains the nineteen papers presented and much of the discussion which followed.

These papers review and discuss the current status of kinetic studies on the reactions of organic materials in both gas and condensed phases. The topics covered include: pyrolysis of hydrocarbons, pyrolysis of polymers, oxidation of polymers, oxidation of organic compounds, burning of organic compounds and burning of polymers. Particular emphasis is placed on the elucidation of the mechanisms of reaction in terms of free radicals or other transient species and physical effects. *These proceedings include the following papers (indented):*

The genesis of free radical chemistry, F. O. Rice, *SP357,* pp. 1-6 (June 1972).

Key words: Alchemy; free radicals; genesis; phlogiston; valency.

Modern chemistry is a late-comer among the sciences and came into being only at the beginning of the 19th century when the phlogiston theory was abandoned to be replaced by Dalton's Atomic Theory. As Dalton's Theory became firmly established, there grew with it the belief known as the doctrine of valency which resulted, by the middle of the 19th century, in the denial of the very existence of free radicals.

In the early 20th century, the work of many scientists—Hinshelwood, Bodenstein, Taylor—in the fields of photochemistry and kinetics led to the belief that free radicals not only existed but played an important part in the mechanism of chemical transformations. Paneth's discovery that free radicals could be detected by their removal of certain metallic mirrors was followed by Rice's demonstration that organic compounds did decompose thermally into free radicals and then the Rice-Herzfeld theory that showed it was possible to explain quantitatively the mechanism of the thermal decomposition of organic compounds. In *The Annual Review of Physical Chemistry* (1971), a chapter on Paraffin Pyrolysis contains the following sentence: "All in this field are not agreed that the reactions can basically be described in terms of the Rice-Herzfeld radical chain mechanisms and that, in general, chains are long."

Pyrolysis of organic compounds in the gas phase, A. S. Gordon and R. H. Knipe, *SP357,* pp. 7-15 (June 1972).

Key words: Decomposition; kinetics of decomposition; molecular mechanisms; pyrolysis of hydrocarbons; radical mechanisms; unimolecular decomposition.

A critical review of the pyrolysis of organic compounds is made. The review is divided into hydrocarbons, halides, and oxy compounds. Most hydrocarbon reactions have an important unimolecular component, either the initial step in the case of chain reactions (e.g., saturated hydrocarbon decomposition) or a one-step reaction which may involve a transient biradical structure. There are many types of pyrolysis reactions in the latter category.

For halocarbon pyrolysis, there are two reaction paths, one involving a unimolecular rupture of the carbon-halogen bond and the other a unimolecular elimination of the hydrogen halide molecule via a polarized activated complex. The preferred path is determined by the self-quenching efficiency of the radical path. If highly efficient, the molecular elimination path will dominate and vice versa. In some systems, the two paths are competitive.

Oxy hydrocarbons such as acids and esters pyrolyze via the polarized complex molecular elimination path. Ethers appear to pyrolyze via a free radical chain mechanism while ethylene oxide is initiated by a unimolecular rearrangement to acetaldehyde with excess energy. The vibrationally excited molecule can decompose into two radicals and initiate chain decomposition.

Pyrolysis of hydrocarbons, M. H. Back, *SP357,* pp. 17-25 (June 1972).

Key words: Acetylene; dissociation; elementary reactions; ethane; ethylene; hydrocarbons; kinetics; mechanism; methane; olefins; paraffins; propylene; pyrolysis; rate constants; unimolecular theory.

Some current problems arising from studies of the pyrolysis of hydrocarbons are discussed and two stages of these studies are distinguished. The first stage concerns the description of the mechanism of the pyrolysis in terms of a series of elementary reactions. The types of reactions occurring during the pyrolysis of olefins are discussed from this point of view and the effects of temperature and pressure on these elementary reactions are shown to produce predictable changes in the overall pyrolysis. Some problems in the mechanism for the pyrolysis of acetylene are discussed and a mechanism proposed which relates the reactions occurring in both the high and low temperature regions. The second stage in pyrolysis studies is attained when the mechanism of the reaction may be satisfactorily described in detail and experiments may then be designed to measure the rate constants of the elementary processes. Several studies on the paraffins have attained this goal and the results are examined for consistency with related measurements.

Factors involved in the degradation of polymers in melts, C. R. Patrick, *SP357,* pp. 33-43 (June 1972).

Key words: Degradation of polymers in melts; diffusion-controlled reactions between macroradicals; diffusivities of molecules and radicals in molten polymers; geminate recombination of radicals; pyrolysis of hydrocarbons; rates of reaction in liquids and gases; reaction equilibria in liquids and gases.

The full interpretation of degradation of molten polymers would be facilitated by a better understanding of the elementary chemical processes involved. Suitable analogs of these reactions may often be studied in detail only in the gas phase. Relationships between the kinetics of elementary reactions in gas and liquid phases are desirable. On the basis of thermodynamic arguments, it is concluded that Arrhenius parameters for bimolecular reactions in the two phases should differ, to a small but significant extent, greater than usually accepted, whilst those for unimolecular processes commonly should not. Diffusion may determine the rates of some reactions in liquids particularly of reactions between radicals. Evidence on the mobilities of large and small molecules, models for radicals, in molten polymers, is summarized. Expressions for diffusion-controlled reactions are compared and applied to reactions in molten polymers. Complicating effects in the size dependence of the rates of diffusion-controlled reactions between macroradicals are

surveyed. Other complicating effects, notably of geminate reactions between radicals, are discussed. A case is made out for comparing more extensively the kinetics of thermal degradation of gaseous paraffins, and of molten paraffins and polyethylenes.

Pyrolysis of polymers, L. A. Wall, *SP357,* pp. 47-60 (June 1972).

Key words: Chain scission; crosslinking; polymers; pyrolysis; stripping.

The nature of their pyrolysis products, monomer, oligomers and carbonaceous residues enables one to group polymers into three classes, those that decompose by net main chain scission; by stripping of the main chain, for example the thermal dehydrochlorination of polyvinyl chloride; and by crosslinking of the main chain followed by some production of volatiles. Highly unsaturated or aromatic chains tend to follow the latter course.

At the present time, a theoretical framework exists which permits, provided adequate experiments are performed, the elucidation of the decompositions of the first type. For most of the well-known polymers in this class, this framework of knowledge gives very acceptable mechanistic explanations or interpretations of the decomposition process based on observations of rate of weight loss, of molecular weight changes and composition of volatile products.

Knowledge of the decomposition of the second class of polymers is at an intermediate state of development. However, an important practical research objective would be the acquisition of methods for converting the mechanisms of decomposition of class one substances to that for class two type.

For the third class of materials, knowledge of their pyrolysis mechanisms is nonexistent. This is largely due to the fact that methods for quantitatively following solid-phase processes of decomposition are relatively difficult and unsatisfactory.

Patterns and problems in the pyrolysis behaviour of synthetic addition polymers, G. G. Cameron, *SP357,* pp. 61-70 (June 1972).

Key words: Free radicals; polymer abnormalities; polymer degradation; polymer pyrolysis; transfer reactions.

The types of pyrolytic decomposition reactions undergone by synthetic addition polymers are outlined. Particular attention is given to two classes of polymer—those which undergo unzipping to monomer and those which fragment randomly along the backbone to yield low polymer. Free radical transfer reactions, usually involving tertiary hydrogen atoms, can play an important part in these degradation reactions. The thermal stability of addition polymers is not always predictable from known reactions of small molecules. This is often due to the presence of labile irregularities which are chemically incorporated in the macromolecules and which can initiate thermal decomposition. Also, since polymers are susceptible to chain reactions and neighbouring group effects, these abnormalities can affect the stability of a large proportion of the sample. The effects on pyrolysis of abnormalities such as unsaturation, chain branches, head-to-head links and oxidation products are discussed.

On certain problems connected with the inhibited oxidation theory, Yu. A. Shlyapnikov, *SP357,* pp. 73-78 (June 1972).

Key words: Antioxidants; inhibition of oxidation; initiation of oxidation; oxidation mechanism; oxidation theory.

The oxidative reactions of organic compounds and polymers are discussed in terms of free radical mechanisms, with particular emphasis on initiation, inhibition, and stabilization phenomena.

Mechanism of peroxydation of polymers, A. Chapiro, *SP357,* pp. 79-82 (June 1972).

Key words: Hydroperoxides versus diperoxides; influence of polymer phase on peroxidation; influence of temperature on peroxidation; peroxidation of polyethylene; peroxidation of polymers; peroxidation of polypropylene; peroxidation of poly(vinyl chloride).

The irradiation of polymers in the presence of air leads to polymeric hydroperoxides POOH and diperoxides POOP. When such irradiated polymers are used to initiate the polymerization of a monomer, hydroperoxides generate equal amounts of graft copolymer and homopolymer, whereas diperoxides only generate graft copolymer. This technique was used to study the peroxidation of various polymers under different irradiation conditions. It was found that polypropylene irradiated at temperatures ranging from 10 to 60 °C undergoes hydroperoxidation by a chain reaction. At 0 °C and below (in the vitreous polymer) polymeric radicals are formed but remain trapped. Poly(vinyl chloride) also leads to hydroperoxides when irradiated at 20 to 60 °C but no chain process develops below the glass transition temperature. Irradiation of the plasticized polymer leads to a hydroperoxidation by a short chain mechanism. It is concluded that the propagation of the hydroperoxidation chain, involving hydrogen abstraction by PO_2 radicals, only occurs above T_g when the mobility of polymeric segments is sufficient to ensure the interaction of PO_2 with neighboring molecules.

Polyethylene irradiated at room temperature chiefly generates diperoxides POOP. The chain hydroperoxidation only sets in above 35 °C. Below this temperature, recombination of PO_2 radicals occurs faster than hydrogen abstraction. The behaviour of polymers with respect to peroxidation is discussed and compared with that of low molecular weight model compounds.

Oxidative degradation of polymers and organic compounds via unimolecular decomposition of peroxy radicals, J. Marchal, *SP357,* pp. 85-92 (June 1972).

Key words: Kinetics; mechanism; organic compound; oxidative degradation; peroxy radical isomerization; poly(ethylene oxide); polymer; polypropylene; poly(propylene oxide); polystyrene; polytetrahydrofuran; room temperature; 1,4-dioxane.

Autoxidation of various polymers and organic compounds is shown to include, already at room temperature, chain scissions involving unimolecular decomposition of secondary and tertiary peroxy radicals. Rate and product data are consistent with a scheme including a six-membered ring transition state leading to three fragments, one of them being an alkoxy radical. This oxidative degradation scheme at room temperature does not correspond to a known mechanism.

Mechanisms of oxidation of polyolefins below 150 °C, F. R. Mayo, *SP357,* pp. 95-98 (June 1972).

Key words: Alkoxy radicals; carbonyl compounds; chain initiation; chain propagation; chain termination; kinetics; oxidation; peroxy radicals; polyolefins; polypropylene.

This paper applies what we have learned about oxidations of simple aliphatic hydrocarbons below 150 °C to oxidations of bulk polyolefins. The principal difference between these groups is due to the production of initiating radicals in pairs and to the greatly restricted mobilities of all radicals. Data are given for the efficiency of initiation by di-*t*-butylperoxy

oxalate of the oxidation of atactic polypropylene at 45 °C and for the effect of peroxide concentration on efficiency and kinetic chain length. The following other topics are discussed: chain propagation and geminate and statistical termination by alkylperoxy radicals, nonterminating reactions of two tertiary alkoxy radicals, formation and reactions of alkoxy radicals, sensitivity of oxidation products to further oxidation, intramolecular propagation of alkylperoxy radicals, and the question of the formation of carbonyl groups in oxidations of polyolefins.

Polymer-gas reactions (air pollutants: NO_2 and SO_2) as function of pressure, UV light, temperature, and morphology – a survey, H. H. G. Jellinek, *SP357*, pp. 101-109 (June 1972).

Key words: Air pollutants; butylrubber, degradation, effect of NO_2; degradation, effect of morphology; effect on polymers of NO_2, SO_2, air and UV light; nylon, degradation, effect of NO_2; polymer-gas reactions; polystyrene, atactic, degradation, effect of NO_2; polystyrene, diffusion of NO_2 and degradation; polystyrene, isotactic, degradation, effect of SO_2.

Reactions of various polymers, such as polystyrene and its stereo-specific isomers, butylrubber, nylon, etc., with nitrogen dioxide and sulfur-dioxide were studied by the author and co-workers in recent years. Mechanisms of these reactions in presence of these gases, near ultraviolet light and oxygen were elucidated. Diffusion phenomena have also been investigated and their importance has been pointed out. More recently, work has been initiated on the influence of polymer morphology on degradation of polymers in presence of these gases, near UV radiation and oxygen. Unexpected effects have been observed during chain scission near room temperature. Thus, for instance, isotactic polystyrene of various crystallinities, as far as extent and type are concerned, show marked differences in their degradation characteristics. Thus, for instance, crystalline polymers show faster degradation than amorphous ones, which seems to be contrary to expectations. However, this phenomenon can be explained in quite a consistent manner. The importance of all these reactions in connection with air pollution is briefly discussed.

Controlled gaseous oxidations of organic compounds, C. F. Cullis, *SP357*, pp. 111-117 (June 1972).

Key words: Concurrent reactions; consecutive reactions; controlled oxidation; conventional additive experiments; cool-flames; intermediate products; isobutane; isotopic tracer techniques; isotopically-labelled additives; macroscopic stages; mutual influences; *n*-butane; *n*-heptane; O-heterocycles; radio gas chromatographic analysis; selective inhibition; selectivity; self-inhibition; thermal control; 1-butene; 2-butene.

The homogeneous gaseous oxidation of organic compounds generally leads to a wide variety of products and this may be ascribed not only to the occurrence of a number of consecutive and concurrent reactions but also to the fact that the various constituent elementary steps tend to interact with one another in complex ways. Several methods are outlined for minimizing the extent of unwanted consecutive reactions but it appears to be much more difficult to restrict undesirable concurrent reactions. If the mutual influences of the various part-reactions are to be understood and controlled, it is important to elucidate the nature and role of the intermediate molecular products. Although here carefully planned experiments involving the artificial addition of reactive intermediates can yield some information, a much fuller understanding of the quantitative importance of the different competing reaction paths can be obtained from experiments with isotopically-labelled intermediates. Several examples are given of the use of isotopic tracer techniques in the unravelling of the mechanism of complex gaseous oxidation reactions.

Some current problems in oxidation kinetics, S. W. Benson, *SP357*, pp. 121-129 (June 1972).

Key words: Acetylene reaction with O_3; activation energy for oxidation; chain lengths in oxidation; elementary steps in oxidation; epoxidation; gas-phase oxidation; kinetics liquid-phase oxidation; mechanism; O_3 addition to unsaturates; oxetane formation in oxidation; oxidation; peroxy radicals; radical isomerization; surface effects in oxidation termination rates; transition state for termination.

Experimental data on low temperature (< 150 °C) and high temperature (> 250 °C) oxidations are examined from the point of view of reported quantitative inconsistencies. Activation energies for $tBuO_2$ metathesis reactions with alkanes appear to be 7 kcal/mole higher than for comparable reactions of HO_2. Related isomerization reactions are examined in the light of these differences without reaching any simple conclusions. The Russell mechanism for a 6-membered, cyclic, transition state for termination of primary and secondary alkyl peroxy radicals is shown to be either inconsistent with thermochemical data, or else unique to solution reactions. Addition reactions of O_3 with olefins and acetylenes are shown thermochemically to have the possibility of following concerted and biradical pathways, respectively.

Recent data showing strong inhibition by PbO-coated surfaces of both oxidation and pyrolysis of i-C_4H_{10} are examined in terms of mechanism.

Kinetics and mechanisms of flames and flame suppression, R. M. Fristrom, *SP357*, pp. 131-140 (June 1972).

Key words: Chemical kinetics; combustion, gas phase flame kinetics; flame mechanisms; flame suppression; inhibition; suppression.

A survey is given of the processes important in gas phase combustion with emphasis on chemical kinetics.

Gas phase combustion processes are important to the burning of polymers because the major exothermic reactions occur there. The combustion of many plastics can be roughly divided into a pyrolysis stage occurring at or close to the surface producing combustible gases and a gas phase oxidation stage in the surrounding atmosphere where the evolved gases are burned. Since the pyrolysis is usually endothermic, it is driven by the heat transferred from the gas phase flame by conduction and radiation.

Reaction schemes are outlined for some typical simple gas phase flames and these are related to the complex chemistry of the polymer combustion. A discussion is given of possible mechanisms for gas phase flame inhibition. Sources of information on chemical kinetics are listed and a bibliography is given of compilations of gas phase chemical kinetic rate parameters.

Carbon formation in premixed flames, K. H. Homann, *SP357*, pp. 143-150 (June 1972).

Key words: Acetylene-oxygen flame; benzene flames; bunsen flames; carbon formation; carbon limit; concentration profiles; cyanogen-oxygen flame; flame front curvature; hydrocarbon radicals; hydrogen diffusion; oxidation reactions; particle size; transport processes.

In this paper a survey is given on the processes leading to the formation of solid soot particles in premixed flames. Like most combustion products carbon formation is not exclusively determined by flame chemistry but is also dependent on transport processes. A local increase in the overall C/O ratio in the burning zone which is connected to the back diffusion of hydrogen and hydrogen atoms can reinforce carbon formation. This gives rise to the different types of carbon appearance in burner flames. It is shown that the C/O ratio at the site of carbon formation can be very different from that of the initial mixture.

For the formation of soot particles the presence of both highly unsaturated hydrocarbons and hydrocarbon radicals is necessary. The process of particle growth which cannot be described by equilibrium condensation theory shows two distinct phases: (1) A first phase of rapid growth which is due to the addition of higher unsaturated hydrocarbons to a particle surface with radical character. During this phase the number density of particles decreases while the individual particles retain their almost spherical shape. This is followed by (2) a phase of slow growth governed by the heterogeneous decomposition of a variety of unsaturated hydrocarbons on the particle surface which has lost most of its radical-like properties.

Fluorocarbon combustion, fluorine supported combustion kinetics?, E. A. Fletcher, *SP357*, pp. 153-158 (June 1972).

Key words: Chlorine; combustion; explosion limits; flame speed; fluorine; fluorocarbons; freons; ignition limits; kinetics.

Some interesting characteristics of the combustion behavior of freons and fluorocarbons are presented. The flame speeds and spontaneous ignition limits of chlorine burning in fluorine are easily described by simple models using well-characterized kinetics. The flame speeds of CF_3Cl-F_2 and CF_3Br-F_2 mixtures can be discussed in terms of simple thermal theories. The striking differences in the combustion behavior of homologous fluorocarbons are shown to depend on big differences in the rates at which the fuel molecules are initially attacked by the competitive combustion reactions, but the kinetics are not yet understood.

Burning of polymers, C. P. Fenimore and F. J. Martin, *SP357*, pp. 159-168 (June 1972).

Key words: Burning of polymers; flame retardants; flammability.

After a rod of solid polymer mounted vertically in a slowly rising stream of oxidant/inert gas mixture is ignited at the top end, the oxidant content of the mixture may be varied until that composition is found which will just support burning down the whole length of the sample. For many polymers this limiting volume-fraction of oxidant can be determined with a precision of about one percent and it serves as a convenient measure of flammability of the material.

Experiments show that the simplest model for such burning is one in which the oxidant does not react directly with the polymer, but is consumed in a nearby flame zone which heats and pyrolyzes the polymer to yield fuel gases. This model appears to be valid for some systems, but not for others.

Experiments may be carried out in which the compositions of the sample and the oxidizing atmosphere are varied in a systematic way. The measured flammabilities, together with a simple model of the burning process permit inferences about the manner in which composition variations affect the burning. The mode of inhibition by flame retardant additives may be inferred in this way.

For example an inhibitor which interferes directly with the gasification of the condensed phase should work independently of the flame reactions for the simple two-stage candle-like burning; it should still inhibit when the polymer is burned in N_2O rather than O_2. Such has been observed when chlorine has been substituted into polyethylene.

By contrast an inhibitor which poisons the flame reactions may be specific for reactions with oxygen and not work with another oxidant such as N_2O. Such is the case of Sb_2O_3 added to slightly chlorinated polyethylene.

Effects of different inert gases, of initial temperature and of pressure have also been observed.

Pyrolysis and combustion of cellulosic materials, R. Alger, *SP357*, pp. 171-178 (June 1972).

Key words: Burning of polymers; cellulose; combustion of polymers; decomposition; fire spread; ignition.

Despite centuries of experience with burning cellulosic materials, men still do not agree on the interpretation of their observations. These divergencies of opinion generally involve mechanisms at the microscopic level where areas of ignorance still abound. This review deals with some of these opinions and the supporting experimental evidence pertinent to three chronologically related areas of fire research; namely, pyrolysis, ignition, and fire spread. Some of the ignition concepts and the models for fire spread are not limited to cellulose but should apply to a variety of solids.

The surface pyrolysis boundary condition for the combustion of polymers, R. F. McAlevy III, and W. S. Blazowski, *SP357*, pp. 185-192 (June 1972).

Key words: Combustion; flammability; kinetics; polymer burning; pyrolysis; rapid heating; surface pyrolysis; surface temperature measurement; thermal degradation.

The pivotal boundary conditions for polymer combustion involve the surface pyrolysis-vaporization characteristics. Generally, conditions at the burning surface (e.g., 500 °C or so) are so different from those encountered in classical bulk pyrolysis experiments that these data cannot be extrapolated reliably – data must be obtained at the conditions of interest. A critical review of experiments designed to produce such data, and the possible interpretations of these data are presented.

The authors have employed a combustion self-heating technique. In the experiment a planar diffusion flame is established between an axi-symmetric, "stagnation-point" flow of oxidant and the pyrolysis-product vapors emerging from the polymer surface lying below. The surface temperature, regression rate, and oxidant mass flow rate (the principal control variable) are measured. Recent results of this experiment are presented and discussed.

SP358. 56th National Conference on Weights and Measures 1971, F. C. Bell and H. F. Wollin, Report Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 358, 252 pages (Mar. 1972).

Key words: Administration, weights and measures; conference, weights and measures; laws, weights and measures; technical requirements, weights and measures; weights and measures.

This is a report of the proceedings of the 56th National Conference on Weights and Measures, held July 12-16, 1971, at the Shoreham Hotel, Washington, D.C., and attended by state, county, and city weights and measures officials and representatives of the Federal Government, business, industry, railroads, and associations.

SP359. **Metrology and standardization in less-developed countries: The role of a national capability for industrializing economies.** Proceedings of a seminar held at Airlie House, Warrenton, Va., February 1-4, 1971, H. L. Mason and H. S. Peiser, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 359, 390 pages (Dec. 1971).

Key words: Africa; Asia; engineering standards; industrialization; Latin America; less-developed countries; measurement standards; NBS; quality control; U.S. AID.

The National Bureau of Standards held a 4-day Seminar in an effort to learn how its experience in metrology and standardization for the science and technology of U.S.A. might be used most effectively for less-developed countries. With financial support of the Agency for International Development, participants came from Argentina, Brazil, Ethiopia, Ghana, Guatemala, India, Israel, League of Arab States, New Zealand, Peru, and Vietnam; from several international agencies; and from industries, professional societies, and government in the U.S.A. The papers presented and the informal discussions were organized around the session titles:

Perspective

The Sociological, Economic, and Managerial Environment in Industrializing Countries

Making Scientific and Technological Measurement Meaningful

The Dissemination of Information

Promoting More Effective Use of Science and Technology

Additional Case Histories

Promoting Economic Strength and Commercial Equity

Guidance for NBS Technological Assistance Effort

It was concluded that industrializing economies would benefit from NBS activities in these fields, and specific suggestions were offered to that end. *These proceedings include the following papers (indented):*

Objectives of the Seminar, J. Bernstein, *SP359*, pp. 1-4 (Dec. 1971).

Expectations from the Seminar, L. M. Branscomb, *SP359*, pp. 5-8 (Dec. 1971).

Keynote Address—The role of a national capability in metrology and standardization in industrializing economies, J. D. Perkinson, *SP359*, pp. 9-13 (Dec. 1971).

NBS programs to provide infrastructure services for science and technology in U.S.A., L. M. Kushner, *SP359*, pp. 15-23 (Dec. 1971).

Overview—The anatomy of an industrializing economy, G. Kalmanoff, *SP359*, pp. 31-36 (Dec. 1971).

A case study from Latin America, J. A. Sabato, *SP359*, pp. 37-41 (Dec. 1971).

Labor saving versus capital saving industrial technology for the developing countries, J. E. Stepanek, *SP359*, pp. 43-55 (Dec. 1971).

The role of technology in politics and economics, G. N. S. Maia, *SP359*, pp. 57-61 (Dec. 1971).

Overview—The economic role of metrology capabilities, E. U. Condon, *SP359*, pp. 71-78 (Dec. 1971).

Needs for measurement controls in developing industrialization, J. L. Hayes, *SP359*, pp. 79-84 (Dec. 1971).

Problems in establishing accurate measurements in industrializing economies: A case-study of basic standards activities in the Israel NPL and some possible lessons to be learned, H. Tabor and L. R. Farkas, *SP359*, pp. 85-90 (Dec. 1971).

Instrument problems in a developing economy, L. C. do Prado, *SP359*, pp. 91-94 (Dec. 1971).

Needs for standard reference materials for calibration and quality control, J. P. Cali, *SP359*, pp. 95-105 (Dec. 1971).

Overview—The role of Federal information activities, M. S. Day, *SP359*, pp. 115-125 (Dec. 1971).

Government responsibility for information for industry, A. Fontes, *SP359*, pp. 127-130 (Dec. 1971).

Publications: Documentation indexes, W. T. Knox, *SP359*, pp. 131-134 (Dec. 1971).

Extension productivity services via a developing country standards institute, P. M. Tam and N. C. Beck, *SP359*, pp. 135-141 (Dec. 1971).

Standardization in Africa: Problems and programs, Z. Felleke, *SP359*, pp. 143-149 (Dec. 1971).

Overview—The role of NBS capabilities, F. K. Willenbrock, *SP359*, pp. 159-162 (Dec. 1971).

Applying the computer, J. P. Nigro, *SP359*, pp. 163-165 (Dec. 1971).

Problems in industrial and technological research in Ghana, E. Lartey, *SP359*, pp. 167-171 (Dec. 1971).

Implementing metrology through operations analysis and systems engineering, S. E. Russek, *SP359*, pp. 173-175 (Dec. 1971).

Product development and market research, S. Marshak, *SP359*, pp. 177-180 (Dec. 1971).

The effect of local government policies on transfer of technology, G. E. Pratt, *SP359*, pp. 185-189 (Dec. 1971).

The sale of instrument manufacturing technology to small private industries in developing economies, P. K. Rohatgi, *SP359*, pp. 195-198 (Dec. 1971).

The Iranian Institute of Standards and Industrial Research, H. K. Work, *SP359*, pp. 199-200 (Dec. 1971).

Institutes for engineering education as a source of metrology, standardization and quality control in industrializing economies, P. K. Rohatgi, *SP359*, pp. 201-205 (Dec. 1971).

Design and development through metrology (abstract), P. Prakash, *SP359*, p. 206 (Dec. 1971).

Nondestructive testing, H. S. Peiser, *SP359*, pp. 207-208 (Dec. 1971).

Problems and attitudes in operating and maintaining a national standards laboratory in a small developing country, D. Pelli, *SP359*, pp. 209-211 (Dec. 1971).

Overview—The spread of standardization, F. L. LaQue, *SP359*, pp. 213-219 (Dec. 1971).

Overview—The role of standardization in industrializing economies, A. N. Ghosh, *SP359*, pp. 221-233 (Dec. 1971).

Weights and measures standards: laws, inspection, enforcement, M. Salama, *SP359,* pp. 235-238 (Dec. 1971).

The value of engineering standards in assisting industrialization in a less-developed country, R. B. Smith, *SP359,* pp. 239-242 (Dec. 1971).

The Colombia government faces the problem of quality control, H. F. Fernandez, *SP359,* pp. 243-247 (Dec. 1971).

Quality control and product certification, S. C. Le Roux, *SP359,* pp. 249-250 (Dec. 1971).

A systems approach to a conference synthesis, W. E. Cushen, *SP359,* pp. 257-264 (Dec. 1971).

Using national measurement standards, R. D. Huntoon, *SP359,* pp. 265-276 (Dec. 1971).

Preparing product specifications, N. A. Hall, *SP359,* pp. 277-280 (Dec. 1971).

Disseminating information, E. L. Brady, *SP359,* pp. 281-283 (Dec. 1971).

SP-360, Superseded by Special Publication 367.

SP361. Volume 1. **Performance concept in buildings.** Invited papers. Proceedings of a symposium jointly sponsored by the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), the American Society for Testing and Materials (ASTM), and the International Council for Building Research Studies and Documentation (CIB), Philadelphia, Pa., May 2-5, 1972, B. E. Foster, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 361, Vol. 1, 819 pages (Feb. 1972).

Key words: Buildings; components; design procedures; experience in use; materials; performance evaluation; performance requirements; user requirements.

Volume 1 contains all of the invited papers accepted for the joint RILEM-ASTM-CIB Symposium on the Performance Concept in Buildings. Opening addresses and reports of the rapporteurs will be included in Volume 2. The Symposium was held in Philadelphia, Pa. on May 2-5, 1972. The subject matter covered in the papers includes physiological, anthropometrical, psychological, sociological, and economic human requirements and methods of evaluation; physical requirements and methods of evaluation in mechanical, acoustical, thermal, dimensional stability, compatibility, fire properties, and geometry areas; operation and maintenance requirements and methods of evaluation in such areas as maintenance, repair, replacement, and versatility; techniques and problems in applying the performance concept to design; and experience gained in application of the performance concept in design, building, and building use. *These proceedings include the following papers (indented):*

Design specification—operational goals, parameters, synthesis, and performance criteria, J. F. Halldane, *SP361, Vol. 1,* pp. 1-12 (Feb. 1972).

Key words: Design evaluation; design specification; design synthesis; environmental systems; goal statements; parameter definition; performance criteria.

Evaluation, specification and monitoring in design has traditionally been based on the physical aspects of building environments. With a growing concern for human behavior there is a realization that the evaluation of environmental systems finally rests on whether the activities of people are satisfactorily supported by that system. Present methods of specification restrict the physical requirements in the interests of behavior but fail to note the design goals that are intended to be addressed. Further, the categorization of parameters, both physical and non-physical, tend to be isolated into problem areas rather than groups that can be correlated. Performance is also narrowly interpreted in terms of physical entities alone.

A system is presented that coordinates environmental systems through a goal-parameter-synthesis-criterion specification which forms a base for design evaluation. The discussion includes the need for operational goals, a definition of non-physical parameters through an overt communication, a limiting stimulus system which links the organismic and environmental parameters, and criteria appropriate to the performance of operational goals. To illustrate the system certain lighting problems are studied from human behavior to light distribution. Rather than encouraging an attitude of regulatory compliance the system fosters alternative possibilities in design.

Human requirements for buildings, T. Cronberg, Å. Hallquist, R. Hansen, J. Nordan, and A. Saeterdal, *SP361, Vol. 1,* pp. 13-22 (Feb. 1972).

Key words: Human activities; performance criteria; physical environment; planning and design basis; user characteristics.

We build in order to establish certain required environmental conditions.

This set of conditions should be according to the users' requirements. This paper will discuss the users' activities and the users' characteristics as a basis for defining the users' requirements. Further we discuss a possible procedure for identifying the requirements and indicate the use through examples. The paper holds that it is necessary to take the variations in user's characteristics into consideration when defining the requirements. Further the paper tries to expand the use of users' activities to include all kinds of activities that may have consequences for the physical solution. The intention of what is put forward here is to initiate a further discussion of the continuation of this kind of work. It is not meant to give a solution to these problems.

On structuring performance requirements for buildings, T. Cronberg, A. Saeterdal, Å. Hallquist, and J. Nordan, *SP361, Vol. 1,* pp. 23-30 (Feb. 1972).

Key words: Organization of performance factors; performance requirements; required conditions; users' activities; users' characteristics.

This paper treats the problem of transforming users' requirements into relevant properties of a physical solution. From users' characteristics and activities we arrive at the required environmental conditions. Together with the data from the given conditions, this forms the basis for the performance requirements. These (data) must be structured in a way making it operative for design. By classifying the requirements according to their basic functions we are able to get from this point to a set of properties relevant for a chosen type of physical system.

Performance requirements of the thermal environment for human occupancy, R. G. Nevins and P. E. McNall, Jr., *SP361, Vol. 1,* pp. 31-42 (Feb. 1972).

Key words: Air motion; air temperature; comfort; mean radiant temperature; performance; relative humidity; thermal environment; thermal neutrality.

Recent physiological and psychological research is analysed from an engineering point of view to determine the

ranges of the variables which provide satisfaction with the thermal environment. The preferred values of the thermal variables, dry bulb temperature, mean radiant temperature, water vapor pressure in the air and air velocity, are presented for various levels of activity and clothing. Permissible steady-state deviations are defined for practical satisfactory environmental control. The effect of variations with time is discussed and recommendations are given for limiting criteria. The environmental variations associated with different human activities and clothing ensembles are analysed.

The necessary shift in dry-bulb air temperature to maintain subjective comfort in response to variations in the other thermal parameters is presented as the suggested functional requirement and as a means for assessing the quality of existing or proposed environments. Simulation of the total building system is suggested including Man, the Building, Climate and the Environmental Control System. A man-analogue is described for use with design simulation models or for performance ratings with on-site measurements.

Performance requirements of buildings and the whole problem, W. M. Peña and J. W. Focke, *SP361, Vol. 1,* pp. 43-55 (Feb. 1972).

Key words: Analytical procedures; architectural programming; buildings; performance requirements; problem seeking; statement of the whole problem; user needs.

Because so many groups of people (the client owner group, the client user group, and governmental agencies) participate in establishing performance requirements for an architectural project, the approach must be rational enough to withstand public scrutiny and analytical enough for the data to be classified and interrelated for greater mutual understanding.

Programming is a process leading to the statement of an architectural problem and the performance requirements to be met in offering a solution. Architectural programming is problem seeking, resulting in those qualitative and quantitative statements that describe the whole problem in terms of function, form, economy and time. The performance requirements deal with what is to be achieved without regard to the physical response.

The search for performance requirements is evident in each of the five steps of the programming process which follow:

1. Establish Goals (Qualitative)
2. Collect, Organize and Analyze Facts (Quantitative)
3. Uncover and Test Programmatic Concepts (Qualitative)
4. Determine Needs (Quantitative)
5. State the Problem (Qualitative)

The steps and considerations form an analytical framework for classifying and processing data (coming from sources) into information. This framework is also useful in avoiding information clog and as a format for dialogue among the many participants.

A typical problem can involve the rote application of a hardware system without concern for the user. However, if the approach emphasizes the performance requirements of the user, then we have defined a unique problem. A hardware system may then be a part of the solution but it will be applied in the context of the whole problem.

Performance requirements of housing in response to the life cycle: a behavioral approach, L. A. Pastalan, *SP361, Vol. 1,* pp. 57-62 (Feb. 1972).

Key words: Age and perception; complexity; home range; life cycle; life space; loss continuum; macro space; mastery; micro space; redundant cuing; sensory acuity; sensory deterioration; spatial sets; user needs.

This paper concerns the development of a conceptual model dealing with performance requirements of housing in response to the changing physiological and psycho-social needs over the life cycle of the user.

The model relates the range of user needs to the human development continuum beginning with infancy and its extension to old age (100 years plus). Attention is focused on physiological and behavioral change from development in infancy and young adulthood to deterioration in old age. Changes over time in sensory acuity, energy levels, health status and activities of daily living are linked to three basic propositions regarding residential environments and user requirements: 1) The stimulus function must respond to differential sensory changes over the life cycle; 2) The orientation function of residential spaces must have high predictive value for young children and old people as well as young and middle-aged adults in order to elicit behavior appropriate to the setting; and 3) Spaces must be organized in such ways as to assure the expression of autonomy or jurisdictional control over personal space of each user while at the same time providing opportunities for social interaction with significant others.

Performance of systems of constructed facilities, A. C. Leme and F. Moavenzadeh, *SP361, Vol. 1,* pp. 63-71 (Feb. 1972).

Key words: Maintainability; measures of effectiveness multidimensional decisions; reliability; subjective evaluation.

The performance of a constructed facility must be evaluated in terms of the facility's role within the larger social economic-political system of which it is part. It is suggested that performance may be measured in terms of three principal parameters: serviceability, reliability, and maintainability. Serviceability is the degree to which the facility provides satisfactory service to the user, here understood to include a broad range of the recipients of benefits of the facility. Reliability is the probability that service will be adequate throughout the design service life of the facility. Maintainability is a measure of the degree to which continuing effort is required during the service life to keep serviceability at an acceptable level. This approach emphasises the user as the basis for evaluation, and the need to consider the entire service lifetime of a facility in decision. The implementation of procedures to permit usage of these parameters in decision making requires application of techniques from psychology and economics, and from probability theory.

The relationship of the performance concept to the planning process—developing performance requirements for community mental health centers, D. B. Hattis, *SP361, Vol. 1,* pp. 73-8 (Feb. 1972).

Key words: Building procurement; building system hospital planning; office building; performance.

The performance concept is best explained as the description of a system in terms of its output rather than its part. When this concept is applied in the procurement process any system the formal instrument used to effect the procurement is a performance specification.

Several advantages of performance specifications over prescriptive specifications have been suggested, particularly in the areas of economy and technological innovation.

When applied to building, performance specifications can be used at various scales of elements or systems, thus producing a "hierarchy of performance." It has been found that when used at a particular scale, the need to define the scope of the system of a performance specification requires the prescription of elements at the next higher scales.

There are several criteria for determining the scope of a system to be used on any particular project, but in general it is easier for "clear" building types than for "ambiguous" ones.

In attempting to define the scope of a system for "ambiguous buildings," one often finds oneself substituting the question "What is a house?" for the question "How should a house perform?" The former question leads to concern for earlier decisions in the planning process.

Institutional performance and building performance: some nplications of the Judicial Facilities Study, B. Handler, *SP361, ol. 1,* pp. 83-91 (Feb. 1972).

Key words: Activities; communication; courthouse; human performance; institutional performance; judicial system; mutual adaptation; objectives; operations; physical determinism; physical environment.

The performance of the institution or organizations which buildings serve has not been regarded as within the province of architectural analysis. Failure to evaluate institutional requirements can result in buildings which hamper rather than help the performance of institutions. A critical examination of the objectives and operations of the judicial system was a major theme of the Judicial Facilities Study, designed to develop standards and guidelines for courthouse design in the United States. How these facility standards were derived from a detailed examination of the judicial system is explained in terms of: the ways in which judicial system requirements and personal human requirements were handled; the present and future purposes and human needs the system and its facilities seek to fulfill; the manner in which the operations of each court function and specialized proceeding were examined; the ways in which activities, interpersonal relations, communication patterns, environmental and spatial characteristics were analyzed. Certain conceptual and theoretical considerations implicit in the approach to the study are discussed. The assumptions of conventional architectural analysis are stated, and the physical determinism inherent in them criticized. An alternative hypothesis is advanced, namely, that the effect of the physical environment on human performance varies with institutional performance. Buildings and the operations of the institutions they house are seen as interdependent, mutually adapting to each other as the people involved attempt to achieve correspondence between the two. The ideal of perfect consonance is viewed as able to be approached only if the designer has a thorough understanding of the institution both as it is and as it ought to be.

The complementary use of research and negotiations with sers in the development of performance standards, T. Mann nd R. Bender, *SP361, Vol. 1,* pp. 93-100 (Feb. 1972).

Key words: Arguments; decision-making; IBIS (Issue Based Information System); negotiations; research, structured planning discourse; user needs, aspirations, values.

Two assumptions underlying much of the current discussion about industrialized building systems for housing are: (1) research should investigate the needs of users of housing, and (2) the resulting findings can be cast into explicit performance standards or specifications to permit industry to develop and mass produce housing systems conforming to these standards and to the needs of users.

These assumptions are questioned. If user requirements research is to produce useful results, it must focus upon users in actual decision-making situations and be complemented with procedures of negotiation, conflict-detection, argumentation, debate, bargaining and conflict-settling.

An approach is discussed which puts research into the implementation phase of actual projects as a part of the planning discourse and decision-making process.

Application of unobtrusive observation techniques in building performance appraisal, W. F. E. Preiser, *SP361, Vol. 1,* pp. 101-109 (Feb. 1972).

Key words: Behavioral cost; building performance; cultural context; unobtrusive observation; user behavior; user feedback.

The performance of buildings is commonly measured in economic terms such as return on investment, or in otherwise readily quantifiable terms, such as amount of time required for maintenance, heat transfer, acoustic properties, or durability of materials. "Behavioral cost," which might be defined as dysfunctional aspects in the human organism caused by elements in the social and the designed environment, traditionally has escaped rigorous measurement and quantification. It became evident only through indirect indices such as statistics on pathologies, absenteeism, job turnover, etc. It is suggested that in addition to the commonly used performance measures, building performance be based on normative user behavior that is explicitly stated in building program specifications. Several approaches to this problem area are outlined.

A performance evaluation study in a public plaza using observational techniques is reported. The findings indicate that a strong relationship exists between informal stationary activity and space defining elements in the plaza, such as benches and columns. Certain conclusions for the programming of a plaza are drawn.

Verbalized user response and the building performance concept: a case study in university residence hall evaluation, W. F. E. Preiser, *SP361, Vol. 1,* pp. 111-119 (Feb. 1972).

Key words: Attitude scale; building performance; comparative user response; user behavior; user satisfaction; verbalized response.

Building performance appraisal focused upon user behavior is a recognized need. Theoretical frameworks exist for the analysis, programming, and design of buildings with human behavior as the basic unit of analysis, particularly with reference to normative states of equilibrium within a given cultural and environmental context. These states may be expressed in terms of user satisfaction through verbalization. Based upon Thurstone's scale of equal-appearing intervals, an evaluative tool for the qualitative assessment of building performance has been developed. The method attempts to measure the subjective importance and acceptance of features of the built environment by the users. The data thus derived may complement traditional "hardware" criteria in the appraisal of buildings. The evaluation procedure, consisting of six steps, was applied to students living in residence halls at Virginia Polytechnic Institute and State University.

1. Construction of Attitude Statements.
2. Selection of Statements.
3. Scaling of Attitude Statements.
4. Statistical Evaluation.
5. Selection of "Best" Scoring Statements.

6. Validation Procedure and Construction of Comparative Response Profiles of 3 Residence Halls.

Some conclusions resulting from the building evaluation are outlined for consideration in future programming of residence halls.

Identification of performance criteria using multidimensional scaling of user evaluations, H. G. Blasdel, *SP361, Vol. 1,* pp. 121-129 (Feb. 1972).

Key words: Color schemes; field studies; glare; illuminance; matrix analysis; multidimensional scaling; performance criteria; preference scaling; scaling; user evaluations; visual environment.

The relative significance, accuracy and completeness of performance criteria for environmental control systems in buildings require testing through user evaluations in addition to customary laboratory research. Because of the inherent variability in human judgment, and the difficulty of interpreting direct quality estimations, such evaluations have not been widely used. Multidimensional scaling allows the reduction of comparative evaluations into a quantitative system of perceived environmental attributes. A questionnaire was used in evaluation of luminous environments as an example of the technique. Results provide for identification of perceived attributes and the scaling of the observed environments with respect to those subjective parameters so that physical measures may be related to human responses.

These methods differentially weight the salience of each attribute for each individual's judgment matrix, allowing access to data on individual differences that can assess the need for variety in a building system. The attribute structures may be applied to setting quality criteria across a wide range of environmental variables so that cost-benefit analysis may be done against overall performance rather than separate criteria.

Performance: the new language of design, D. J. Parsons, *SP361, Vol. 1,* pp. 131-139 (Feb. 1972).

Key words: Cost; design; industrialization; performance; user needs; value system.

With the scattered development of tools for user needs analysis, the measurement and specification of performance, product analysis, and building evaluation, there is a growing need for unification of these concepts into a single framework. A definition of the performance concept is presented which mediates between the measurement of benefit and the costs of design solutions. With performance as a mediating concept, we are able to formulate user needs as the correlation between performance and benefit, and to analyze products in terms of the relationship between their cost and their performance. The Performance/Benefit correlation (user need) is a user characteristic *independent* of product Cost; while the Cost/Performance relationship is a product characteristic *independent* of Benefit to the user. This paper clarifies the relationship between this definition of the performance concept and various forms of analysis, design, and evaluation common to the design of buildings. It further explores possible shifts in the practice of design as skills become more specialized in the building industry.

Consideration of externalities to the basic performance/cost evaluation of buildings in the design process, G. S. Birrell, *SP361, Vol. 1,* pp. 141-148 (Feb. 1972).

Key words: Building; competitive market; construction; cost; evaluation; materials; performance; price; user; value.

Starting from (1) an adequate analysis of buildings into subsystems and their functional elements; (2) the statement of required technological performance for each element of a proposed building; and (3) the budget cost for each element of a proposed building, the question arises – what else should the designer include in his evaluation of each building element to maximize overall User Satisfaction?

These externalities to the basic technological performance and cost of each element are described and discussed and their relationship to each other exposed on a Value Axis. They comprise a range of factors from Hypothetical Minimum Cost to User Values. They are interrelated and influenced by the Project Roles which are responsible for each section of the Value Axis on each Project. Such externalities play an important part in the integration of the elements to create a desirable overall project and the designer should direct his attention to them to achieve optimum overall balance between Performance and Cost.

The conclusion reached is that while the above ratio of technological performance to cost of each element is a desirable starting point for building evaluation, the externalities on the Value Axis also play a considerable part in selecting the building materials which can provide maximum building User Satisfaction.

Architectural economics related to comfort, productivity and glass, J. T. Malarky, *SP361, Vol. 1,* pp. 149-159 (Feb. 1972).

Key words: Building economics; capital costs; human comfort; human performance; insulated glass; operating costs; people costs; single glass.

For many years, the most sophisticated and objective professionals have believed that thermal and visual "environmental factors" can exert a profound influence on the physical comfort and productivity of building occupants. Some experienced owners, such as the General Service Administration, believe that 90 percent of the owners' total cost in an office building can be charged properly against people and only about 10 percent against land, building and debt service. Experienced tenants regularly pay more money for carefully controlled and selected environments.

Glass "environmental factors" such as glass surface temperature, influence productivity and can be evaluated in a practical way. For exploratory use and for professional evaluation and criticism, an empirical people-productivity/glass-performance evaluation system is proposed. This evaluation system illustrates a practical relationship between glass "environmental factors," comfort and productivity. A comfort-productivity relationship equation is developed. A practical example illustrates the effect architectural glass could have on productivity and profits.

The notion of performance in building: building requirements, G. Blachère, *SP361, Vol. 1,* pp. 161-164 (Feb. 1972).

Key words: Assembly; compatibility of components; physical properties of a building, of a product; users' requirements.

A building is built for a given purpose, i.e., to meet the requirements of the man for whom the building is built, the user's requirements. These are related to the whole building and can be expressed in terms related to man by numerical figures for the best known requirements such as physiological and economic ones, and by words in other cases, i.e., for psychological or sociological needs, roughly speaking.

To meet the users' requirements, a building has to present a set of physical (including chemical, geometrical, and mechanical) properties. Various sets of physical properties may be suitable to meet the same set of requirements.

Generally speaking a building is built of elements, and elements are made of products (raw materials, semifinished products, sections, components).

It is possible to relate the properties of a built element to the properties of the constituent products, by considering the various physical characteristics and also the compatibility of adjacent parts.

Some details will be given on the users' physiological, psycho-sociological and economic requirements at the level of the whole building; on absolute needs and relative requirements; on the variation of requirements in space and time.

What are the natures of performance and evaluation for the three levels: building, components, materials, G. Blachère, *SP361, Vol. 1*, pp. 165-170 (Feb. 1972).

Key words: Agrément; building components; durability; materials; performance; tests.

For a whole building what is required is the satisfaction of the users' requirements. For example for a dwelling the requirements are temperature, noise level, illumination level, air purity level, convenience of internal space, convenient relationship between the various rooms and an adequate view from the inside, etc.

The means of evaluation are the sciences which relate the physical properties of the building to the effect on the inhabitants, or reference to a long and satisfactory use of some techniques or direct proof by the real occupation of the building by users and the observations of the latter.

What is needed for components is that they possess the physical properties which enable the built elements to play their correct part in the building as a whole.

These properties are expressed in scientific terms, i.e., by reference to physical characteristics measured by any methods, in terms of technological indexes based on long experience or on tradition, or in terms of physical requirements. There is also the important problem of durability (cf. the paper on Agrément).

As for raw materials, it is not possible to have requirements of any sort by performance or otherwise, because there is no defined link between materials and a building. We can only judge a material plus its shape, i.e., roughly speaking, a component.

Techniques for developing performance specifications for buildings, M. Brill, *SP361, Vol. 1*, pp. 171-180 (Feb. 1972).

Key words: Environmental characteristics; performance; performance specifications.

A tested technique is offered, which can serve as a generating model for performance specifications for any building type. The technique recognizes the primacy of the user's needs as the generator of information, while acknowledging that manufacturer's information requirements must be formatted in different terms. A matrix is used as a display device to show the set of all possible environmental characteristics for all possible subsystems.

The environmental characteristic headings are: Conditioned air, Illumination, Acoustics, Stability, Durability, Reliability, Safety, Activity support, Maintainability, Esthetics, Waste management, Potable water, Food handling, Communication, Accessibility.

The Building subsystems whose performances must satisfy these requirements are: Structure, HVAC, Finished floor, Finished ceiling, Luminaires, Space dividers, Exterior walls, Plumbing Utilities, Sanitary fixtures, Food services, Cleaning systems, Energy source, Energy systems, Transportation systems, Roofs, Windows, Doors, Security systems, Sealant systems, Communication systems, Materials handling, Waste removal.

Each intercept is examined for interaction between demand (the user's needs) and supply (the capability of the subsystem to respond to, or alter the demand). Where an intercept is seen as interactive, three kinds of information are generated—a *Requirement* which is a prose statement of the specific need; *Criteria*, some measure of the acceptable range of solution; and *Test Method*, the mechanism whereby surety of performance is guaranteed. A method of correlating Requirements, Criteria, and Test Methods into performance specifications by subsystem is described.

This technique attempts to deal with physiological requirements only and some discussion is presented for its applicability to psychological and sociological requirements.

A consistent basis for functional and ultimate criteria, R. N. Wright and A. H.-S. Ang, *SP361, Vol. 1*, pp. 181-190 (Feb. 1972).

Key words: Building criteria; design; optimization; reliability; safety; serviceability; structures.

Objectives in the process of building include minimization of cost as well as performance in meeting functional requirements and safety with respect to property loss or personal injury. The performance concept contributes to these objectives by expressing performance requirements in a manner allowing fair competition among available solution schemes. This paper discusses the formulation of functional and ultimate criteria for structural performance using rational consideration of uncertainties in the information available for decision making.

Functional requirements define limit states of serviceability which are independent of solution scheme. Requirements for safety, however, relate to ultimate limit states which differ in mechanisms and consequences for different structural schemes. This paper shows that performance requirements for safety can be expressed in a scheme-independent manner by accounting for the scheme-dependence of ultimate limit states with reliability-based criteria.

Total performance is described by the expected loss which includes expected initial costs and probable costs of occurrence of functional and ultimate limit states. This formulation guides the expression of performance requirements in ultimate limit states as scheme-independent prescriptions of required reliability. Both statistically defined and statistically undefined uncertainties are accounted for. The fail-safe concept provides very high reliability against catastrophic ultimate limit states.

Performance concept and the system approach—some comments, I. Karlén, *SP361, Vol. 1*, pp. 191-200 (Feb. 1972).

Key words: Building; design process; ER-system; performance; performance concept; quality description; system approach.

This paper will comment on two main approaches for use of the performance concept: behaviour in use and output of a process. The system approach, applying inter alia the performance concept, can be used in different stages of the building process, particularly for description of the wanted result, the final system. The author tries to give examples of applications on different product levels. The ER Quality description system is one example. The author comments on the help given by classification in the applications and the relations between classification categories, levels and classification.

The performance concept in building: the working application of the systems approach to building, R. G. Robbie, *SP361, Vol. 1*, pp. 201-206 (Feb. 1972).

Key words: Buildings; design process; performance; performance concept; performance-judgement approach; proposed international generic building classifications; proposed international subsystem classification models; systems approach; user needs.

The paper reviews the meaning of the systems approach to building in its practical context. Attention is drawn to the local factor in building when consideration is given to performance requirements. A characteristic which separates theory from accomplished practice in building. It is suggested that the local factor in building could make the notation of the pure performance approach to building something of a hoax, or at least common and current misconception in the industry. The realities of building performance assessment on major systems programmes are noted and a suggestion is made that the concept of the (pure) Performance Approach or Concept of Building should be discarded. It is recommended that the Performance Judgement Approach or Concept be adopted as a more accurate representation of the daily realities of performance-based building practice.

The paper proposes the establishment of an international Generic Building Classification for the bulk of common building uses. It reviews the apparent divergent meaning of performance specifications as they appear to be finding application in Europe and North America. A proposal is made for the establishment of international sub-system classification models and two examples are given for schools and housing.

The paper concludes with an appeal for a major increase in user requirements research and the development of science-based skill in the building industry. It appeals also for a major rationalization of all skills in the industry in the expectation that with building code rationalization the building industry would then have the comprehensive resources necessary to make the performance concept in building a reality.

The relationship between the performance concept and the systems concept, J. Vilett, *SP361, Vol. 1*, pp. 207-212 (Feb. 1972).

Key words: Building industry; building production process; building systems; innovation; performance approach; semantics; systems approach.

There is considerable confusion in current architectural, engineering and construction literature concerning the distinction and relationship between the performance and systems concepts. It would be useful to maintain a clear theoretical separation of these ideas. Although there is value in their simultaneous application to many types of project, each also has the capability for independent application to certain aspects of the building process. The rationale for this proposition is based on a comparative analysis of the two concepts in terms of definitions, objectives, origins, scope of applicability, and advantages and disadvantages.

Computer based code systems and the performance concept, J. P. Eberhard, *SP361, Vol. 1*, pp. 213-218 (Feb. 1972).

Key words: Building codes; building systems; computer systems; performance standards; simulation of building requirements; systems design.

Building codes are part of a building code system which is intended to provide an organized process by which such codes are: communicated, updated, enforced, administrated and evaluated. Historically this code system has been manually operated by the use of printed documents. There is some evidence to indicate that it would be economically and technically possible to convert most of this system to one which was computer based. A computer based code system could be self-improving, resource conserving, provide an information based to the design process, raise the level of sophistication of evaluation methods, and make the code requirements more nearly responsive to the performance requirements of building users.

Performance analysis, Tenho Sneck, J. Saarimaa, and Timo Sneck, *SP361, Vol. 1*, pp. 219-226 (Feb 1972).

Key words: Application of performance concept; building levels; external factors; internal factors; performance analysis; performance evaluation; stages of building.

A performance analysis technique for building elements, products and materials is described. In order to be able to evaluate the total performance of an object all influencing factors must be known. The technique is based upon the listing of the external factors affecting the object. The internal factors of the object have to withstand the effects of the external factors. By juxtaposition of the external and internal factors, requirements concerning the desired properties can be written. The analysis can be made by the aid of check lists for external and internal factors.

Building performance appraisal, T. A. Markus, *SP361, Vol. 1*, pp. 227-235 (Feb. 1972).

Key words: Appraisal; building performance; constraints; environmental system; evaluation; resources.

This paper outlines a model of an interactive system with five main components:

1. the goals and objectives of an organization;
2. the activity and behaviour appropriate to the achievement of these objectives;
3. the environment suitable for the activity;
4. the hardware required for the creation of a suitable environment; and
5. the resources required as inputs into the system and the values achieved as outputs.

It sets out the main stages in appraisal – modeling, measurement and evaluation, and then discusses the role of performance criteria under three categories: the "ideal," norms and constraints. The paper concludes with a brief reference to a published appraisal of a school and some of the findings resulting from it.

A systems approach for the evaluation of performance of buildings in design process, S. G. Haider and N. Khachaturian, *SP361, Vol. 1*, pp. 237-248 (Feb. 1972).

Key words: Building design; design process; evaluation; performance; systems approach; user requirements; value system.

Buildings are man-made physical systems which are essential, in one way or another, for almost all activities in the society. The worth of a building is some combined measure of its performance in the functional, technological economic, perceptual-aesthetic and sociological contexts. However, most of the work done in the evaluation of performance of buildings has been directed to specialised aspects within isolated contexts and is often limited to particular types of buildings. There is a need for considering the evaluation of overall performance of a building within the design process framework of a building as a system. This

paper is intended to be a step towards the fulfillment of this need.

In the design process, the concept of value system that forms the basis of performance specifications and criteria; synthesis of building scheme which specifies the form, materials and construction methods; and operations on information are briefly discussed. The value system is systematically analysed into criteria and constituent measures which in turn are shown to be functions of design parameters and performance variables of building scheme. The evaluation process starts with the performance ratings at the level of constituent measures and successively integrates them into a single measure of the overall worth of the building design.

An innovative approach for building system analysis and esign, M. J. Macalik, *SP361, Vol. 1,* pp. 249-253 (Feb. 1972).

Key words: Building system analysis; design; innovation; mathematical model; predictive technique.

The intent of this paper is to introduce a new computer program formulated to aid in the evaluation of performance of building systems and components. The new program is designed to define, within a range of possibilities, the scope of future innovation in building systems and components necessary to improve their performance for the user and their profitability to the manufacturer.

A general overview of operation BREAKTHROUGH, E. V. eyendecker, *SP361, Vol. 1,* pp. 255-260 (Feb. 1972).

Key words: Department of Housing and Urban Development; housing; industrialized housing; innovative housing; National Academies of Sciences and Engineering; National Bureau of Standards; Operation BREAKTHROUGH; performance; performance criteria.

Operation BREAKTHROUGH was initiated with the overall objective of increasing housing production by breaking through the barriers which constrain the use of innovative materials and systems in producing housing. Twenty-two housing systems were selected by the Department of Housing and Urban Development (HUD) to participate in the program by erecting housing on selected prototype sites. The Building Research Division of the National Bureau of Standards (NBS) was selected to write performance based criteria and evaluate the housing for HUD. A technical panel formed by the National Academies of Sciences and Engineering is providing HUD with independent advice on the results of the NBS evaluations.

Philosophy and scope of structural performance criteria, F. Y. Yokel and N. F. Somes, *SP361, Vol. 1,* pp. 261-266 (Feb. 972).

Key words: Deflection; load capacity; performance criteria; performance evaluation; stiffness; strength; structural engineering; structures; user requirements; vibration.

In the program entiled "Operation BREAKTHROUGH," the U.S. Department of Housing and Urban Development is supporting and guiding the development of industrial housing systems and encouraging innovation in housing technology. Evaluation criteria that were developed by the Building Research Division of the National Bureau of Standards' Institute of Applied Technology will be applied to all "Operation BREAKTHROUGH" housing systems. This paper presents the philosophy for the development of Structural Performance Criteria, which are derived from the user requirements of safety, activity support, low maintenance cost, absence of stress and anxiety and visual acceptability. One example is quoted to illustrate the form of these criteria, which comprise three groups: strength, stiffness and rigidity, and resistance to local damage.

Philosophy for physical simulation using performance criteria, N. F. Somes and F. Y. Yokel, *SP361, Vol. 1,* pp. 267-274 (Feb. 1972).

Key words: Accelerated aging; building systems; extreme loads; performance criteria; performance evaluation; service loads; stiffness; strength; testing; variability.

Physical simulation may be defined as a testing procedure designed to closely simulate the actual structure in order to determine the response of the prototype structure to the loads it is likely to receive during its service life. Criteria for physical simulation include the selection of critical assembly, the consideration of critical load conditions, the allowance, the allowance for the effects of the service life environment and taking account of variability in structural elements and subsystems. The paper discusses each of these criteria in detail, and presents a philosophy.

Field testing of conventional buildings for static and dynamic deflections, G. C. Hsi, H. S. Lew, F. Y. Yokel, and N. F. Somes, *SP361, Vol. 1,* pp. 275-288 (Feb. 1972).

Key words: Building; design criteria; drift; field test; floor vibration; wood frame.

In order to evaluate innovative materials and systems it is necessary to develop performance criteria for aspects of structural behavior which hitherto have not been considered for traditional materials and solutions. It is reasonable to set levels of performance required by these new criteria so as to achieve a performance which has been acceptable to society over a long period of time. Unfortunately, there is a lack of data on the performance of traditional buildings. This paper describes recent field testing of several conventional buildings in order to confirm the suitability of performance criteria established for static and dynamic deflections within the "Operation BREAKTHROUGH" program.

Performance of components: a procedure for the preparation of specifications for building components, H. W. Harrison, *SP361, Vol. 1,* pp. 289-296 (Feb. 1972).

Key words: Building components design; building procedures; contracting procedures; performance specifications; properties of building materials; standardization.

The United Kingdom Building Research Station has been assisting a number of public bodies – central government departments, or consortia of local authorities – in the preparation of performance specifications, and monitoring their use in the purchase of components for educational, housing and other building programmes. The procedure used is described. Reference is made to the problems involved in obtaining alternative proposals from manufacturers and in assessing their suitability, also to the use of the CIB master list of properties.

User requirements and performance design, J. King, *SP361, Vol. 1,* pp. 297-301 (Feb. 1972).

Key words: ABS (Academic Building Systems); EFL (Educational Facilities Laboratories, Inc.); environmental criteria; evaluate; performance criteria; performance design; RAS (Recherches en Amenagements Scolaires); SCSD (School Construction System Development); SEF (Study of Educational Facilities); SSP (Schoolhouse Systems Program); URBS (University Residential Building System); user requirements.

To establish performance goals for buildings based on extensive user requirement studies has been the basic underlying goal behind the building systems which have been developed for educational buildings in North America. Evaluating the quality of buildings has generally been a subjective question. Establishing performance criteria begins to tie quality to measurable objectives rather than more ephemeral issues. Finding those performance objectives which can be described, which are relevant to the building, which are relevant to education, and which protect the economic interests of the owning institution is neither simple nor direct. Conflicts between immediate economic advantage and long range flexibility, between comfort and economy, between low first cost and long-range operational economy make for difficult decision making.

Weighing the comparative importance of the conflicting interests of the user-client (student/teacher/dormitory resident) and the owner-client (school system/college/university) is the most subtle area of decision making and the toughest. The evaluation of whether the resulting buildings meet the performance criteria is a comparatively simple matter. Reexamining whether the performance criteria adopted was appropriate and consistent with the direction the institution has taken since the building has been built, occupied and used is a more significant and of course a more difficult question to get at.

Paths to performance—some recent projects employing the performance concept, W. Meyer, R. Bender, and C. Arnold, *SP361, Vol. 1,* pp. 303-315 (Feb. 1972).

Key words: ABS; building systems; college buildings; dormitories; HVC; laboratories; lighting/ceiling; performance specifications; procurement process; SCSD; structure; subsystem; URBS.

Two building research, and development programs, organized and directed by our firm (BSD), have utilized the performance concept, each with a different approach and end result. Both projects were based on earlier experience coordinating the School Construction Systems Development (SCSD) program.

Based on an analysis of user requirements, performance specifications and/or requirements were developed on the URBS (University Residential Building System) program for University of California student housing, and on the ABS (Academic Building Systems) program for Indiana University and University of California academic buildings.

The URBS project involved performance specifications to guide the development by manufacturers of five *new* subsystems for student housing. Specifications for the subsystems were written to accommodate cooperation between bidders and to assure an integrated design proposal. Product development to meet the URBS performance specifications was based upon a large, guaranteed market. The ABS program on the other hand, could not guarantee a future market and therefore assumed the selection of *existing*, already developed, products for its five subsystems.

Based on the experience gained from the URBS and ABS projects, the paper calls for the encouragement of public agencies to collect and develop, as necessary:

- methods expressing man's environmental needs in performance terms;
- scales for displaying various *levels* of performance;
- methods for relating *levels* of performance to various activities or spaces as they occur in buildings; and
- models for using performance-oriented requirements in building and building systems procurement processes.

The "Recherches en Aménagements Scolaires" (R.A.S.) project— a case study—strategy implemented for the development of a building system for educational facilities through the Performance Concept, M. Bezman, *SP361, Vol. 1,* pp. 317-330 (Feb. 1972).

Key words: Bid evaluation; building systems; criteria and tests; educational facilities; life cost; performance specifications; prototypes; S.C.S.D., R.A.S.; strategy; systems approach; technology and feasibility; user needs.

The R.A.S. Project (Research in School Facilities), was conducted by the author for the Montreal Catholic School Commission. Both the recognition of a basic problem common to all school districts, and the acceptance of a problem solving direction experimented with in California through the S.C.S.D. Project, are at the origin of the R.A.S. Project. The problem is the inadequacy of traditionally accepted methods to provide educators with appropriate and adaptable facilities within limited financial boundaries and the direction is the adoption of the "Systems Approach" for viewing and solving the problem, and the "Performance Concept" as a means for achieving the objectives subsequently defined.

The Performance Concept approach was instrumental in harnessing Canada's industrial resources and potential for the development of a building system (presently under implementation) integrating the following sub-systems:

1. Structural
2. Heating-Ventilation-Cooling
3. Ceiling-Lighting
4. Internal Space Subdivision
5. Electric-Electronic Distribution

The strategy enforced and the means implemented through the various stages of the project, as well as the subsequent results are discussed throughout.

The paper covers:

- the project's specific context,
- the main surveys conducted to establish a basis for Performance Specifications, from user requirements to evaluation of resources,
- the major Performance Requirements developed to identify the problems for which a solution was sought,
- the Performance Criteria defined to qualify and quantify the required levels of performance,
- the evaluative methods implemented during the pre-bid, bidding and development phases of the project (scientific measurement, empirical evaluation and economic evaluation) to test and evaluate the building systems "as a whole" and at the level of their individual sub-systems.

The development of performance criteria for university facilities, R. F. Hallenbeck, *SP361, Vol. 1,* pp. 331-337 (Feb. 1972).

Key words: Acoustical environment; administrative procedures; communication; environmental criteria; functional criteria; interior finishes criteria; luminous environment; measurement; outdoor lighting criteria; performance criteria; process description; university facilities.

Since its inception in 1962, the State University Construction Fund has been responsible for the planning, design and construction of campus facilities for the State University of New York. It is estimated that as of September 1971, the Fund has completed, or placed under design or construction, facilities costing 2.31 billion dollars. In concert with this large-scale effort, the Fund has undertaken the development of performance criteria for its physical facilities in two

groupings – Environmental Performance Criteria and Functional Performance Criteria. It is contemplated that criteria in these two areas will be synthesized into a third area of criteria for Construction System Performance upon completion of research in progress. Difficulties in generating industry wide acceptance of measurable performance criteria has lead to the exploration and development of a variety of means of communicating Fund requirements to the design professionals who prepare plans and specifications for university facilities. These interim approaches to communication of performance requirements include: State-of-the-Art documents, specification statements, administrative procedures, design development process descriptions, space planning and design criteria and check lists. Much remains to be done in the direction of more precise and comprehensive communications within the construction industry with measurable performance criteria a mainstay of this goal.

Experience and lessons from an innovative housing project sing the performance concept, W. Allen and P. Rich, *SP361, ol. 1,* pp. 339-344 (Feb. 1972).

Key words: Building systems; education; government sponsored research, need for; housing – industrial, innovated, prototype, low-rise high-density industrialization; performance requirements.

A large low-income project of low-rise construction has been completed in an industrialised building system selected by competitive bidding based upon performance criteria written by the architects. Provisional building designs were prepared in advance as part of an innovative community plan and formed part of the guidance in formulating the criteria. Initial screening reduced the number of bidders to three, all of whom had then to be assisted to develop conformity to the criteria. This part of the project demonstrated the need for whole-dwelling performance requirements established nationally.

Examples are given of the ways in which the design requirements of low-rise high-density development influenced the performance criteria. They are the need to park cars beneath 3- and 4-storey construction, the assembly constraints due to narrow pedestrian passages, a need for stepback balconies and terracing, and party floors which meet fire and sound requirements.

Unconventional performance-based specification items were also exemplified. Concrete finishes were prescribed by Munsell classification, and were also required to deter scribbling. Weather-tightness of joints, thermal performance (in some detail), sound insulation and fire were covered.

The bidding procedure required a new sequence and form for contract documents and this is described.

Prototype dwelling had to be built for agreement on quality of finish and to remove difficulties from the assembly process. Some criticisms are made of the inadequacy of preliminary trials which is unavoidable at this stage as present conventions operate, and this is noted as a cause of some defects which later became evident.

Other lessons are identified. The performance approach requires equivalent development of evaluation and testing procedures, and changes in legal and contractual matters. The vital role of building research organisations for monitoring and feed-back is emphasised for the collective learning process of the professions and industry. The relation between responsibility and deficiencies in the absolute state of knowledge for innovational situations is noted. The educational unpreparedness of the industry is emphasised as a barrier and cause of enhanced risk.

Finally, five major factors of building education and administration which need review by governments promoting innovation are identified.

Evaluation process of performance and cost as applied to existing housing prior to rehabilitation, C. Forsberg and G. S. Birrell, *SP361, Vol. 1,* pp. 345-356 (Feb. 1972).

Key words: Analysis; cost; evaluation financing; housing; improvements; individual; inspection; minority groups; performance; real world; rehabilitation; synthesis; system; user needs; user values.

This paper presents a process for evaluating the performance of existing homes and planning suitable changes for users who would like to improve this performance. The process was evolved as a result of field research work in aiding minority group families evaluate their homes. The process is intended to enable a housing advisory group assist families in satisfying their individual User Needs. Given that family's home and their priorities for its improvement, income, and available financing, the process derives realistic rehabilitation choices available. Topics discussed include technical/human housing user interface problems, presentation of information, housing requirement analysis process, individual housing user value rating analysis, housing user financial analysis and the organization of the advisory service. This paper maintains a simple level of description and discussion to keep the system uncomplicated enough to operate in the harshness of real-world field work of aiding minority groups rehabilitate their homes.

Performance specifications for office space interiors, T. E. Ware, *SP361, Vol. 1,* pp. 357-374 (Feb. 1972).

Key words: Building process; building systems; "closed" systems; management; office buildings; "open" systems; performance specifications.

The Public Buildings Service of the General Services Administration, which creates a $200 million annual market for Federal office buildings, commissioned the Building Systems Section of the Building Research Division of the Institute for Applied Technology, National Bureau of Standards, to conduct an experiment demonstrating the feasibility of the Systems Approach to designing, specifying and constructing complex buildings. Thus, the Government is using its building program for its own benefit while making a public experiment intended to replace prescriptive specifications with Performance Specifications based upon a specific definition of user's needs. This approach will modify – perhaps drastically in some instances – the products, rules, people, resources and energy involved in the building process. It is not intended to supplant the traditional design process or construction process, but rather, it is intended to combine all the elements in the design and construction process to more precisely and efficiently produce a desired result. The principles of this project are examined in such terms that their application to other projects may be expedited.

Performance requirements for windows, E. Paulsen, *SP361, Vol. 1,* pp. 375-384 (Feb. 1972).

Key words: Air-tightness; performance characteristics; performance parameters; rain-tightness; sealed glazing units; wind loading; window.

A window is defined as any part of a vertical external wall which is predominantly filled by transparent or translucent material and where the primary function of a window is to furnish the adjacent room with sufficient daylight and provide a clear and undistorted view to the outside.

Statements of performance requirements are given under the following headings: Transparency and vision, light transmission, glare, control of solar radiation, thermal insulation and condensation, sound insulation, airing (ventilation), airtightness, rain-tightness, strength and stiffness, control of opening light, security against illegal entry, fire resistance, escape from fire, appearance, dimensions, durability of operating parts and durability of materials.

Evaluation of window performance, A. G. Wilson and J. R. Sasaki, *SP361, Vol. 1,* pp. 385-394 (Feb. 1972).

Key words: Performance criteria; performance evaluation; window characteristics; window evaluation; window functions; window requirements; window standards.

Windows are used in the enclosure of buildings to permit entry of natural light, a view of the outdoors, and ventilation. In addition, windows must perform the same function of separating interior and exterior environments as the remainder of the enclosure. Functions related to transparency may be in conflict with those relating to other desired attributes of the building space; this creates the need for considering cost versus benefit on a system basis in establishing performance criteria. This paper deals with the current status of evaluation of windows as environmental separators.

Many aspects of performance cannot be adequately predicted from basic principles, hence a number of standard tests are evolving for evaluation of some of the primary ones. The tests are widely used in product standards, along with relevant criteria, to classify windows and to define certain minimum requirements. Standard test methods, however, have some important limitations in relation to predicting and specifying performance in-use. Some performance characteristics, particularly those involving heat and mass flow, are interdependent although they are usually evaluated independently or are influenced by factors that are excluded or fixed in standard test methods. Where in-use performance of windows is critical, it may be necessary to resort to more complex tests that attempt to take account of all the major factors influencing the final result. This is economically practical only on major construction projects. The development of information to assist the designer in predicting window performance for the majority of situations, utilizing data obtained from standard tests, is, therefore, a desirable goal. The designer will, however, always need to exercise judgment in relating the limited information provided by tests, or other methods of prediction, to the real situation.

Effect of envelope design on cost performance of office buildings, M. Anson, W. B. Kennedy, and J. W. Spencer, *SP361, Vol. 1,* pp. 395-406 (Feb. 1972).

Key words: Cost analysis; design criteria; external envelope; office building; performance evaluation.

Building design ideally should cover a sufficient range of design alternatives to enable selection of a combination of the performance variables which is as near optimum as can be obtained with the money available. In practice most design variables do not relate simply to the performance variables, and the best that can be done is to check the various performance levels of a design selected on the basis of past experience, amending those features found to be unsatisfactory. This conventional procedure can be improved as much by the development of suitable computational routines as by further refinement of direct measurement of performance.

This paper reports substantial progress with the computation of air-conditioning costs, which when both initial operating costs are taken into account is the biggest cost item in an office building. The peak air-conditioning load, the sum of the initial costs of the plant, and the envelope plus plant operating, maintenance, and replacement costs over the life of the building have been calculated for 122 variations of a hypothetical building situated in Melbourne (38 °S, 145 °E).

The study showed that the return on investment could be increased from 10 to over 11% for a hypothetical building with 150,000 sq. ft. of rentable space depending on envelope design. For smaller buildings this increase could be even higher because the ratio of the envelope area to volume of the building increases as volume decreases.

Tables and graphs are presented which give some consideration to the relative economic effectiveness of building envelope materials and fenestration.

Use of modern computer programs to evaluate dynamic heat transfer and energy use processes in buildings, T. Kusuda and F. J. Powell, *SP361, Vol. 1,* pp. 407-418 (Feb. 1972).

Key words: ASHRAE Task Group Energy Requirements; computer application; heating/cooling load; room temperature; thermal environment.

Salient features of the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Task Group procedures for calculating heating and cooling load are described. It is stressed that the significance of the thermal storage effect is to be found in the conversion of the heat gain process into the cooling load, even in commercial buildings.

An NBS computer program (NBSLD) was used to augment the ASHRAE methodology. This program was designed to predict the indoor temperature of buildings with limited air conditioning or none at all. Various calculation results obtained by NBSLD are illustrated, some of which are compared with the experimental results.

A simple cooling load calculation illustrated in Chapter 28 of the 1967 ASHRAE Handbook of Fundamentals is used to compare the results obtained by the NBSLD program and the program developed by the U.S. Post Office Department (USPOD), which is an adaptation of the ASHRAE Task Group Procedure.

The application of total energy systems to housing development, P. R. Achenbach and J. B. Coble, *SP361, Vol. 1,* pp. 419-430 (Feb. 1972).

Key words: Energy conservation in housing; energy systems for housing; environmental quality in housing; field study of energy systems; total energy systems; utility system performance.

A pilot investigation of the performance of a total energy system was undertaken by the National Bureau of Standards to evaluate the potential for decreasing the amount of fuel required to provide the utility services to an apartment complex of 500 units and for better control of noise and air pollution. This installation is being made at a site in Jersey City as a part of the BREAKTHROUGH program of the Department of Housing and Urban Development. The selection of the site followed a feasibility study of eleven sites distributed over the United States and the preparation of a performance specification which set forth the design conditions, the requirements for reliability, stability and safety of the system and the environmental quality that must be attained.

The pilot total energy plant is being extensively instrumented to determine its thermal efficiency; the daily and seasonal load patterns; the reliability of the utility services;

the level of noise and pollution control; the maintenance and repair requirements; the owning and operating costs; and the occupant response to his environment.

A morphological performance evaluation technique for moisture problems in buildings, J. Saarimaa, *SP361, Vol. 1,* pp. 431-449 (Feb. 1972).

Key words: Building moisture problems; effects; evaluation; morphological research; movement; sources.

The paper gives a picture of an evaluation technique which may be suitable in solving moisture problems of buildings. The final goal of the procedure is the setting up of the performance requirements which are needed for building elements and products in order to ensure the expected performance of constructions. The evaluation is done with the help of a matrix which is built up as follows: The problem may be divided in the following main factors:

1. Moisture sources
2. Moisture movement and fixation
3. Effects of moisture
4. Performance requirements

Each factor will then be given all the possible values it can get in reality. The main factors form the first vertical column of the matrix, and the possible values of these factors are put on the horizontal lines. The principles and the procedure of the evaluation technique will be discussed. The values of the various "factors" will be introduced, and examples given on the results obtained.

Sizing of water heating equipment, L. G. Spielvogel, *SP361, Vol. 1,* pp. 451-463 (Feb. 1972).

Key words: Domestic hot water systems; hot water heating; hot water system design; hot water usage; survey of hot water use.

This paper contains the results of studies made on 162 buildings throughout the U.S.A. to determine the nature of hot water use in order to establish design criteria for sizing water heating equipment in various types of buildings.

An extensive search of the literature was conducted and analysed, and there is an extensive bibliography and list of references on this subject available.

Meters were installed in the cold water inlet to water heating systems and hourly readings were taken for periods of up to 1 1/2 years. Data was collected and organized in 10 categories of buildings, men's college dormitories, women's college dormitories, motels, nursing homes, office buildings, food service facilities, apartment houses, elementary schools, junior high schools, and high schools. Test data was analyzed with respect to peak hourly, daily and average flow rates in order to compare with previously available information. Further analysis was done on multiple-hours use of hot water, and curves were drawn representing an infinite number of relationships between storage capacity and recovery capacity, any of which will adequately meet the requirements for hot water in each type of building.

Some of the factors that influence hot water consumption are discussed. The influence that hot water temperature has on demand and consumption is analyzed. New definitions are developed for efficiencies in connection with water heating systems. Limited information on energy consumption of water heating systems is discussed. Safety factors are recommended. There is some discussion on instantaneous flow rates based on data extrapolation.

Typical profiles for each category of building are shown with hour-by-hour flows for the day in which the peak hourly demand occurred, the day in which the peak daily demand occurred and the hour-by-hour average of all test data for the particular building selected.

With this information it is now possible to make an economical selection of water heating equipment, based on both first cost and operating cost. Comparing the recommended sizing methods with those methods previously used shows a significant reduction in both storage capacity and recovery capacity for most types of buildings.

The development of performance criteria and test procedures for the piping of sanitary drain, waste and vent systems in residential service, R. T. Holtz, *SP361, Vol. 1,* pp. 465-476 (Feb. 1972).

Key words: Criteria for DWV pipe; drain, waste, and vent systems; environmental factors; evaluative methods for DWV pipe; thermoplastic pipe.

The development and use of new plastic materials for drain, waste and vent piping emphasized the need for the identification and definition of service requirements to be used as a basis for minimum performance criteria for these products. Such criteria would have to take account of all of the pertinent application and service factors to which a typical DWV product might be exposed, and to provide for safe and satisfactory performance under these conditions for the projected life of the building. The availability of such criteria would enable the development of materials and the design and engineering of DWV products to more accurately meet the needs of this plumbing service. It would also facilitate the design and evaluation of systems fabricated from various materials.

Several years ago, a task force was established under the auspices of Standards Committee A112 of the American Standards Association (now American National Standards Institute—ANSI) to:

1. Determine the service criteria for residential drain, waste and vent systems;
2. Establish the design criteria and test conditions for plastic DWV materials to meet the service requirements.

The task force, composed of experienced sanitary engineers and others knowledgeable in plumbing engineering identified the following general categories of service criteria: Chemical, Mechanical, Thermal and Environmental. Objective minimum or maximum conditions for each of these criteria in these categories were determined, and test conditions were recommended, based on an assumed fifty year usage.

Following completion of the service criteria, the group determined test procedures, simulating end use conditions and established design criteria consistent with the minimum service criteria for DWV systems. This paper emphasizes the methods used in the study, the service conditions identified as pertinent to DWV exposures, and the criteria established. It then discusses how these criteria were adapted to facilitate adequate performance through appropriate design of plastic DWV piping.

Simplified acoustical measurement procedures for building code enforcement, M. J. Kodaras, *SP361, Vol. 1,* pp. 477-481 (Feb. 1972).

Key words: Acoustical field measurements; building code enforcement; noise control enforcement; noise control in dwellings.

New and revised building codes now contain specific requirements for acoustical privacy in multifamily dwellings. These performance specifications for sound transmission loss, impact sound insulation, maximum per-

missible sound power radiated by mechanical equipment and isolation of structural vibration sources must be subject to field measurements to assure compliance with the building code provisions. In most cases the results of these field measurements need only indicate a "pass" or "fail" result.

This paper reviews some of the simplified field test procedures now in use and in process of development.

The effect of illumination systems upon visual performance, I. Lewin and J. W. Griffith, *SP361, Vol. 1,* pp. 483-490 (Feb. 1972).

Key words: Illumination systems; lighting; performance concept; task contrast; veiling reflections; visual performance; visual task.

One of the critical human factors in building design is the provision for an adequate level of visual performance, in relation to the speed and accuracy of vision. It has only recently been recognized fully that the amount of illumination on a visual task may be of secondary importance to that of another variable, the "task contrast." The concept of "Contrast Rendition Factor" will be developed, where the amount of contrast produced on a written task by any given illumination system may be evaluated in relation to a reference standard. Recent researches will be reported which indicate the ineffectiveness of present conventional illumination systems.

Further research undertaken in the development of unconventional systems of illumination will be reported, and it will be shown that a unique distribution of light within a working area can produce very substantial visual performance increases, without increasing the electrical input to the system.

Whereas the paper will include some theoretical concepts in relation to visual performance, its chief purpose will be to provide practical guidelines for the improvement of this factor.

The performance concept in the service of technical evaluations of building innovations, D. E. Dobson, *SP361, Vol. 1,* pp. 491-502 (Feb. 1972).

Key words: Agrément; durability prediction; economic aspects; evaluative judgement; need for clarity of purpose; performance concept; plastics in fire; rain penetration; robustness of construction; technical evaluation; uniformity of assessment; weathering.

The introduction gives a broad picture of the increasing effort of the National Building Research Institute (NBRI) in the field of technical evaluation and performance requirements. Terminology is also defined. This is followed by a section in which work on certain selected aspects of performance is discussed. The concluding sections deal generally with the performance concept and its cardinal position in the evaluation of innovations in building, and bring out some of the practical limitations of the concept and the continuing need for the exercise of evaluative judgement.

Technical evaluation of components: agrément, G. Blachère, *SP361, Vol. 1,* pp. 503-506 (Feb. 1972).

Key words: Agrément; assessment; durability; new materials; new processes.

It is a problem for a builder to know whether a component presents the physical properties which are needed for it to play its part correctly in the finished whole.

Various means are available to give this proof:

– the use of science and exact physical measurements,
– the use of traditional knowledge recorded in codes of practice and standards,
– the direct proof by performance tests.

Unfortunately among the properties required is durability and often it may not be possible to test it by one of the preceding methods, because scientific knowledge may be lacking, experience does not exist for new components, and performance testing takes too long where durability is concerned. Nevertheless it is necessary to have, if not a proof, at least a judgement about the durability of new materials, components, and building systems, and if a completely logical proof is not possible, the advice of the best experts based on a broad examination and various tests is the best that can be found. Such is the agrément procedure. People such as manufacturers, builders, and administrative authorities needing the best advice on the durability of new things, can ask for an agrément issued by a group of experts drawn from all parts of the building field, utilizing the results of measurements of natural or semi-natural tests on a full or reduced scale, and experience with short term use.

It is possible to draw up a check list of the various properties that may be required of an element in service and of the means of testing them. Some examples of such properties and tests will be given.

For convenience of the users of agrément a control of the manufacture of approved products is possible and may be indicated by a mark.

An agrément procedure is used in all the Western European countries which belong to the UEAtc, and which cooperate in writing common directives for agrément and in recognizing each other's agrément certificates.

Performance requirements in a systematic method for selecting building materials, K. Shirayama, K. Imaizumi, K. Kamimura, K. Kondo, F. Saito, T. Nireki, K. Ito, F. Tomosawa, S. Sugawara, H. Suzuki, K. Kawase, Y. Takahashi, S. Oka, Y. Mimura, M. Ito, *SP361, Vol. 1,* pp. 507-518 (Feb. 1972).

Key words: Building; classification; comparison; elements; materials; performance requirements; selection.

The purpose of the study on "Systematic Method for Selecting Building Materials" is to establish a system or rational method for solving the problem of how to select and how to use building elements or materials. This selection system is composed of the following steps:

1. Identify the conditions concerned with the use of building elements or materials and put them in order. These conditions are named "Given Conditions."
2. Select necessary performance requirements for the buildings or components according to the "Given Conditions."
3. Transform performance requirements of the building to those of building elements or materials.
4. Evaluate performance or properties of existing building elements or materials based on the results obtained by suitable proposed methods of tests, calculation, and so on.
5. Select building elements or materials by means of comparing their evaluated performance or properties with those required.

The outline of this systematic selecting method is presented putting stress on the following points.

a. Classification and arrangement of the performance requirements.

b. Selection of necessary performance requirements according to the "Given Conditions."

c. Relation and transformation between the performance requirements of different levels.

Proposed method of test for evaluating performance of buildings, building elements, and materials, K. Shirayama, K. Imaizumi, K. Kamimura, K. Kondo, F. Saito, T. Nireki, K. Ito, F. Tomosawa, S. Sugawara, H. Suzuki, K. Kawase, Y. Takahashi, S. Oka, Y. Mimura, M. Ito, *SP361, Vol. 1,* pp. 519-529 (Feb. 1972).

Key words: Building elements; building materials; evaluation; performance; performance requirements.

In order to select suitable building elements or materials rationally, it is essential to make clear their performance corresponding to the requirements. To achieve this, fifty standard testing methods, with evaluating methods of test results, were prepared.

These testing methods are classified into the following three groups:

a. Tests for materials (Materials-related tests)
b. Tests for building elements (Building element-related tests)
c. Tests for space or building (Space or building-related tests)

In each testing method, the following items are included.

1. Designation of testing method with its classification symbol.
2. Relevant performance requirements.
3. Scope
4. Test specimen description
5. Procedure
   5-1 Outline
   5-2 Apparatus
   5-3 Conditioning prior to test
   5-4 Details
6. Evaluation method and grade determination
7. Report
8. Notice, other relevant testing methods.

Titles of all proposed methods are tabled and some of them are referred to in detail.

Performance of components with special attention paid to the practical implementation, G. Christensen, *SP361, Vol. 1,* pp. 529-534 (Feb. 1972).

Key words: Components; dirt repelling; evaluation; feedback; open system; performance requirement; scratch resistance; testing; water-spray repelling.

It is explained how the use of the Performance concept on the level of components has an open building system as a prerequisite and further that a number of compatibility problems thus must be solved.

Manufacturers and designers have a common need in describing the attributes offered or required by a component on a Performance base. An example of the basic principle for such a common Performance language is shown.

The principle is used for describing the Performance attributes for bathroom walls regarding scratching resistance, ability to repel dirt, and ability to reject water spray. The background for the use of these tests is also discussed.

It is finally underlined how important it is to explain to the building industry that the Performance concept is created as an invitation to new technical solutions within building and it is not meant as a new set of restrictions to be used instead of traditional building regulations.

Increasing the application efficiency of performance tests with analytic procedures, S. K. Suddarth and D. H. Percival, *SP361, Vol. 1,* pp. 535-543 (Feb. 1972).

Key words: Analysis and performance tests combined; computerized analysis; plane frame structures; test results; use of structural analogs.

A method is illustrated for combining more advanced analytical procedures with performance tests of plane frame structures. A fundamental part of the method is the development of an analog, or mathematical model, of the real structure. This analog, which may be as simple or as complex as the situation warrants, is processed by a computerized system to produce a complete structural analysis. In use, performance tests of parts of the frame, particularly joints, can be used to evaluate needed parameters in the analog of the entire structure.

Three quite different examples are given showing how the analog reproduces the deformation patterns corresponding to the full-scale test structures. Acceptance of internal stresses in the analog as sufficient estimates of internal stresses in the prototype is based primarily on the deflection correspondence.

The possession of a suitable analog permits examination of a wide variety of structural variations and load cases that require verification with only a relatively small number of prototype tests.

Evaluation of structural concrete members penetrated by service systems, J. M. Hanson, W. G. Corley, and E. Hognestad, *SP361, Vol. 1,* pp. 545-556 (Feb. 1972).

Key words: Analysis; concrete beams; concrete plates; ducts; openings; serviceability; strength; structural performance; tests.

Performance requirements for structural concrete members containing openings are defined. Both strength and serviceability are considered. Results of tests carried out by the Portland Cement Association to evaluate performance of flat plate and beam and slab floors containing embedded metal ducts and of concrete joists with holes in their webs are described.

A performance approach to the design of fire-resistive buildings, L. G. Seigel, *SP361, Vol. 1,* pp. 557-566 (Feb. 1972).

Key words: Building design; fire protection; fire resistance; fire-resistive buildings; structural design.

For many years, fire-endurance requirements for building structures and fire-insurance rate schedules for buildings have been based on performance demonstrated in standard fire tests. However, many conditions that may be encountered in an actual building, such as structural restraint, and partial or nonuniform fire exposure are in no way covered by standard fire test procedures. Therefore, the results of standard fire tests (as presently defined) may not represent the performance to be anticipated in a building. The structural performance of a building during a fire depends on the temperatures reached by the structural members of the building independent of how such temperatures are attained. Therefore, an analytical approach to the determination of fire resistance should be considered based on appropriate temperature limits for the structural materials of the building. Fire-resistive design may then be accomplished by providing adequate thermal protection to the structure so that the temperature limits of the structural materials will not be exceeded.

The resistance of brick walls to lateral loading, H. W. H. West and H. R. Hodgkinson, *SP361, Vol. 1,* pp. 567-576 (Feb. 1972).

Key words: Brickwork; experimental; lateral loading; performance; research; residential structures; safety; structural masonry.

The Building (Fifth Amendment) Regulations 1970 lay down performance requirements to prevent progressive collapse, following and incident, in buildings of 5 storeys or more. Essentially either the building must be so designed as to provide alternative paths of support in the event of the removal of a main structural member, or the members must be designed to withstand a lateral load of 5 lbf/in². Laboratory tests to determine the lateral strength of various types of brick wall are briefly described and the application of the results to the evaluation of the performance of real buildings discussed. It is concluded that solid brick walls more than 7 in. thick may be "deemed to satisfy" the requirements of the Fifth Amendment.

Experimental gas explosions in load-bearing brick structures, N. F. Astbury, H. W. H. West, and H. R. Hodgkinson, *SP361, Vol. 1*, pp. 577-592 (Feb. 1972).

Key words: Building structures; damage; gas explosions; limiting pressures; load-bearing brickwork; venting.

The resistance of normal types of fenestration and cladding, masonry walls, and a full-size load-bearing brickwork structure to explosions of town gas/air and natural gas/air mixtures was determined. The explosions were generated by igniting stoichiometric gas-air mixtures in balloons, or layered mixtures in the explosion space. Peak pressures were recorded by transducers. Explosion damage to the structure is discussed. Normal windows and cladding failed at pressures below 1 lbf/in² and in so doing provided venting relief limiting the maximum pressure developed, in accord with a simple formula. Under a precompression of about 30 lbf/in² a cavity wall will crack at about 3.3 lbf/in². A 4 1/2 in. wall fully restrained by returns failed at about 5 lbf/in² and a 9 in. wall fully restrained cracked but did not fail at 15 lbf/in². In a normally vented simulation of a full-scale real domestic situation, it was not possible to raise an explosion pressure greater than just over 3 lbf/in². Possible amplification of explosion effects due to cascade or turbulence in interconnected rooms is briefly discussed and will be studied further.

Performance characteristics for timber frame joist floors, H. Hansen, *SP361, Vol. 1*, pp. 593-600 (Feb. 1972).

Key words: Deflection (floors); dwelling; floor (wood); joists; loads; performance criteria; strength (floors); vibration (floors).

Different loads which act on a floor are discussed and a factor of safety based on economic criteria is used. The paper also discusses vibration and deflection criteria for timber frame joist floors.

It is pointed out that the deflection under a single point load may be used as a performance criterion for human perception to initial vibration.

An acceptable strength and deflection performance of a wood-joist floor system is given.

Performance requirements for floors, C. Bring, *SP361, Vol. 1*, pp. 601-612 (Feb. 1972).

Key words: Colour fastness; flatness; flooring; indentation; performance requirements; properties; quality classes; rolling load; surface evenness; test methods; warmth to touch.

Several properties of floors and floorings have been studied. Test methods have been used which allow comparisons between different types of floor materials and floor constructions. On the basis of tests on actual floors and in the laboratory, classified performance requirements are proposed.

The validity of the properties for different floorings and subfloors is considered. Typical quality classes of actual floors are surveyed. Suggestions for performance requirements for the discussed properties of floors in dwelling-rooms are made by way of an example.

With the users' requirements and the future conditions in mind, relevant performance requirements can be chosen for different projects with the help of the paper. The intended quality of a floor can generally be obtained in more than one way. However, none of the alternatives fulfills all requirements. Extremely high requirements on certain properties often must be combined with low requirements on other properties for the same floor. Already extremely high requirements on two antagonistic properties—like resistance to indentation and warmth to touch—might result in the elimination of almost all floors or floorings.

Performance analysis of floors, J. Saarimaa, Tenho Sneck, and M. Wäänänen, *SP361, Vol. 1*, pp. 613-623 (Feb. 1972).

Key words: Classification of floors; evaluation of floors; external factors; floorings; floors; performance analysis; properties of floors.

The paper discusses the main principles, which may be used in setting up performance requirements for floors. Performance requirements, which define the performance of a floor may be derived from an analysis of the external factors, which affect a floor in use by juxtaposition of the external factors and the properties of the floor. The following levels of building are considered in the analysis: space, building element, product combination, product, material. The analysis of external and internal factors as well as the relation between external and internal factors has been carried out on these levels. An evaluation technique, which could be used for selection and development of floors and floorings has been developed. The method is based on the identification and classification of the external factors, classification of rooms, listing of requirements and classification of rooms according to the requirements. The main purpose of the paper is to give an example of how the ideas of performance analysis could be applied to floors.

Strength criteria of glued-laminated timber, B. Bohannan, *SP361, Vol. 1*, pp. 625-632 (Feb. 1972).

Key words: Defective material; design criteria; design stresses; glued-laminated timber; knots; lamination; lumber grades; prestressed wood; slope of grain; strength criteria; strength ratio; strength-reducing characteristics; structural

Accurate knowledge of the properties of any engineering material is essential to its proper uses. Recognizing this fact the U.S. Forest Products Laboratory has had a continuing research program to better define the strength characteristics of glued-laminated construction, a versatile engineering material. Early research in the 1930's was the foundation for the glued-laminated industry in the United States. Design and manufacturing criteria were developed based on glued members which were relatively small by today's standards. With industry growth, manufacturing techniques and architectural design developed to the extent that timbers of almost unlimited size and shape were possible, but engineering technology did not keep pace. However, an extensive research effort during the 1960's has developed related engineering technology for the large timbers. This research established the effect of several facto

involving strength and design of large timbers—a principal one being the effect of tension lamination quality on beam strength. Such research has resulted in revised specifications for glued-laminated timbers which will insure a more reliable engineering material.

Performance requirements for mechanical fasteners used in building, E. G. Stern, *SP361, Vol. 1,* pp. 633-642 (Feb. 1972).

Key words: Bolts; building assemblies; building components; building constructions; framing wood; improved nails; mechanical fasteners; mechanical fastenings; nails; screws; staples.

The selection of mechanical fasteners used for joining and fastening of materials, assemblies, and components is influenced by a variety of criteria, all of which are related directly to the anticipated performance of the assembled items. The mechanical fasteners need to be selected on the basis of their actual and economic availability, versatility, applicability, physical and mechanical properties, rigidity and damping capacity, compatibility, thermal properties, fire resistivity, reliability including their resistance to creep, maintenance and repair of the finished product, and feasibility of testing for performance evaluation and performance predictability. These performance criteria are given detailed consideration in order to facilitate the writing of performance specifications covering mechanical fasteners as well as mechanical fastening in building constructions. Whereas the subject matter is approached from the overall viewpoint, reference is made to a few selected specific applications in order to draw attention to the importance of the performance concept under given conditions.

Performance criteria for composites in building, A. G. H. Dietz, *SP361, Vol. 1,* pp. 643-651 (Feb. 1972).

Key words: Classes of composites; composites for building; evaluation; performance criteria; performance statement.

Composite materials for building are mainly particulate, fibrous, or laminar. Examples are to be found in buildings in various parts of the world. Performance criteria are especially pertinent because composites are frequently put together to meet specific situations. Great care is needed to make sure that the criteria accurately reflect requirements. A statement of performance criteria is of little value, unless the actual performance of a composite building component can be tested. Some tests are equally applicable to composites and to other materials, but others are specific for composites. They include, for example, the character of the bonds among constituents; the fire behavior of a composite, especially penetration, flamespread, and smoke evolution; the combined mechanical behavior; and durability. New types of tests, such as ultrasonic evaluation of bond, are needed in many instances. Standard tests may require adaptation for evaluation of composites.

Basic problems and conditions of long term performance of materials and structures, O. Valenta, *SP361, Vol. 1,* pp. 653-658 (Feb. 1972).

Key words: Capillary elevation (head); coefficient of permeability; kinetics of deterioration; open pores; steady and unsteady flow; tests of absorption, permeability and capillary elevation.

Appropriate choice of materials for structures of all sorts must be based on their properties and long term performance in specified conditions of their application. Besides the main mechanical physical factors, factors concerned with the pore system in relation to the possibility of water or gas penetration must be considered as basic properties in the study of long term behavior of any material in natural weathering or other conditions. Actual state of standards concerned with humidity and water permeability of materials is analysed. Absorption, permeability and capillary elevation are considered as the main characteristics of materials.

Absorption test—its purpose and methods are discussed in the light of the mechanics and kinetics of water penetrating into a porous body. Some standards British, Russian, American and Czechoslovak are then quoted and analysed as to their interpretation and compliance with the need to describe the pore system effectively. The need of scientific base of such tests is stressed.

Permeability test—its purpose and methods are given with special emphasis to the need of providing us with the coefficient of permeability. British, Russian, German and Czechoslovak standards for testing are then surveyed from this point of view.

Capillary elevation test in relation to the importance of the capillary elevation head is analysed and Czechoslovak standards are quoted.

Mechanics and kinetics of water permeation into materials, its factors and their determination are considered as to their effect and importance for their performance in structures. Both steady and unsteady flow of water are considered in relation to the determination of the coefficient of permeability. Capillary properties of the pore system should be provided by test. The importance of these characteristics for the analyses of tests as well as of practical cases is then stressed by cases of practical application.

Pore properties in the evaluation of materials, J. M. Haynes and Tenho Sneck, *SP361, Vol. 1,* pp. 669-675 (Feb. 1972).

Key words: Materials; performance evaluation; pore size distribution; porosity; specific surface.

Many technologically-important materials are porous, and can be characterised by such pore parameters as porosity, specific surface and pore size distribution. The pore structure of such materials often plays a dominant role in controlling their useful properties. Attention is therefore drawn to some of the difficulties to be encountered in performance evaluation of such materials, when measured pore parameters have to be taken into account.

The definition of a low intensity fire, D. Gross and J. B. Fang, *SP361, Vol. 1,* pp. 677-686 (Feb. 1972).

Key words: Buildings; calorimetry; combustibility; fire intensity; flame spread; furnishings; heat release; thermal radiation; wastebaskets.

A reproducible fire of low intensity may be used for the realistic performance evaluation of interior finish materials and of structural building elements. The burning behavior of furniture and the contents of wastebaskets are defined in terms of the rates of heat release, heat transfer to the surrounding walls, and heat losses by radiation and convection. Experimental measurements of temperature and radiation levels within a room are summarized for a variety of combustible contents and mass loadings. Selected low intensity fires have been examined for repeatability and for potential use in evaluating fire safe requirements for interior finish materials in terms of the spread of flame, generation of smoke and overall fire growth pattern.

The interaction between mortar and masonry units as a basis for standards for masonry mortars, Tenho Sneck, *SP361, Vol. 1,* pp. 687-692 (Feb. 1972).

Key words: Fresh mortar; interaction between masonry mortars and units; masonry mortar; mortar evaluation; mortar standard; suction of masonry unit; winter masonry.

The paper describes a draft standard for masonry mortars which is based on the application of the performance concept on the "product" (material) level. The approach is based upon a statement that the solutions have to give optimal service, under the action of the external factors. In this case, the object of the analysis is fresh mortar. The most important external factor affecting the mortar is the suction exerted by the masonry units. The removal or non-removal of water has deciding effects on the mortar joint as a whole. Therefore, the properties of the mortar have to be matched to the properties of the unit. The evaluation of the mortar is based on the interaction of the mortar and the masonry unit. Testing methods and the general background of the evaluation are described. The final evaluation lies in the hands of an expert panel.

A performance evaluation of thin bed adhesive mortar in concrete masonry construction, L. A. Kuhlmann, *SP361, Vol. 1,* pp. 693-709 (Feb. 1972).

Key words: Adhesives; concrete masonry; cost performance; ground concrete block; mortar.

The rising cost of labor in recent years has prompted the concrete block industry to develop new methods of building walls. Of the many techniques created, the concept of gluing together dimensionally accurate concrete units has been the most successful. For the past 10 years, projects have been built with an adhesive mortar and block, providing an arena for demonstrating the performance characteristics of this concept. Both physical properties from ASTM test methods and economics from case histories prove that this concept is acceptable and practical.

Performance requisites for concrete building components and their achievement with gap-graded concrete, S. Li, D. A. Stewart, and V. Ramakrishnan, *SP361, Vol. 1,* pp. 711-718 (Feb. 1972).

Key words: Aggregate grading; cement content; concrete construction; creep; durability; economy; gap-grading; shrinkage; strength; structural concrete.

Performance requirements for all reinforced and prestressed concrete building components are established and criteria for evaluating such performance requirements are given. Their achievement with gap-graded concrete is substantiated with experimental results and field observations.

Relating materials quality to materials performance to structural performance of concrete, B. Mather, *SP361, Vol. 1,* pp. 719-724 (Feb. 1972).

Key words: Aggregates; cement; concrete; concrete quality; materials; performance; portland cement; structural performance.

Portland cement, aggregates for portland-cement concrete, admixtures for concrete, and curing materials for concrete are usually procured for use in construction under specifications that stipulate levels of quality as indicated by the results of standardized tests of samples. The information obtained from these tests is believed to be related directly or indirectly to levels of performance of the material itself, the composite of which it is a constituent, the structural element of which it is a component, and the structural system of which it is an element. The testing is limited to determinations that can be completed in the time available for testing and at an appropriate cost. The levels of quality are selected to be few for simplicity and are frequently higher than needed to insure adequacy of performance in the specific situation; rarely lower. Attention has primarily been directed to those few cases where less than adequate performance has resulted. Greater economies and more prudent utilization of natural resources will result if attention were directed to those much more numerous cases where stipulated levels of quality are higher than needed.

Proposed method for prediction of corrosion of reinforcement in concrete, J. Saarimaa, *SP361, Vol. 1,* pp. 725-732 (Feb. 1972).

Key words: Concrete; corrosion; durability; material properties; morphological research; performance analysis; reinforced concrete; reinforcement.

A performance evaluation technique suitable for the evaluation of corrosion of reinforcement in concrete is explained. The durability of the reinforcement is a consequence of the combined effects of the environment, the properties of the concrete and the reinforcement, and of the processes caused by the external factors which affect steel concrete. In order to be able to solve the complicated problem a systematical method of evaluation is needed. The prediction could be made with the help of a matrix which consists of a list of all the important factors affecting the corrosion of reinforcement. The evaluation can give both qualitative and quantitative information on corrosion. The evaluation technique is feasible for evaluation of the probability of corrosion of reinforcement in a defined construction. It can also give information on how a construction should be dimensioned in order to avoid corrosion of reinforcement.

The performance concept applied to building materials—an unattainable ideal, F. A. Blakey and K. G. Martin, *SP361, Vol. 1,* pp. 733-740 (Feb. 1972).

Key words: Building materials; concrete; functions in building; material prescriptions; performance concept; plastics; property tests.

The performance concept is the only logical basis for building regulations for the selection of building systems and for the whole design process, which does not implicitly restrict the designer on his choice of materials and form. Nevertheless, experience has shown that it remains an impractical ideal when one attempts to apply the concept to specification and control of materials. This is probably most evident for concrete and for plastics, two materials which are discussed in this paper.

There is no dearth of tests for concrete which may be used to assess the performance of the material in various ways, but there remain many important properties for which it is impossible to specify rational limits for the properties measured. There are also many tests which produce results, but these measures are of little value because they are obtained in conditions which are too far removed from the practical conditions in which the material will be used. Shrinkage and standard crushing tests for concrete are considered as examples of these viewpoints and yet might appear to be successful and valid applications of the performance approach.

Plastics may also be characterized by a variety of tests relating to many chemical and physical properties, and being manufactured to meet certain of these properties would also appear to offer opportunity for control by specification based upon performance tests. However, the functions most frequently required of plastics in building application include aesthetics, weathering, and fire resistance; and the

development of performance specifications to encompass such properties is shown to encounter problems at every step.

In view of these and other examples to be cited, it is proposed that there should be a widespread return to prescription specifications to complement quality and valid performance property testing. The tests needed to police a prescription specification are usually simpler and quicker to carry out than performance tests and are equally satisfactory for control of uniformity.

Evaluation of performance of materials performance and dimensional stability of resin binders, K. Gamski, *SP361, Vol. 1*, pp. 741-750 (Feb. 1972).

Key words: Adhesion; composites; dimensional stability test; fillers; performance; resin binders.

Although there are standard methods for evaluating the performance of composites based upon traditional binders such as hydraulic or bituminous binders, we have no methods for evaluating binders and composites made of resin.

The author describes some tests capable of being used and possibly standardized, among which is the dimensional stability measurement test. This test could be adapted to resin binders and composites on one hand, and on the other hand, adapted to large dimensional elements both prefabricated and constructed on site.

Natural and artificial weathering performance of rigid polyvinyl chloride (PVC) and other plastic materials, H. F. Stedman, *SP361, Vol. 1*, pp. 751-760 (Feb. 1972).

Key words: Atmospheric pollutants; color—difference and representation; impact resistance; plastics; rigid polyvinyl chloride (PVC); test methods; ultraviolet (UV) radiation; water vapor; weathering—artificial and natural; yellowing.

Rigid polyvinyl chloride and other synthetic plastics as exterior building materials are relatively new, but their use, fabrication and distribution are well-documented. Weathering performance of these materials is taking time to evaluate because of the wide range of variables involved, the general inertness of the substances and the lack of knowledge of the proper test parameters to use. An artificial weathering test method has been developed which takes into account the vital role of moisture in the degradation of plastics. Dual consideration is given to the deleterious effects of ultraviolet radiation alone. Many of the results of this combined method of evaluation have correlated well on an accelerated basis with outdoor performance. The efficacy of outdoor weathering emphasizes the need for a closer examination of UV radiation sources and test atmospheres. Color and surface changes are followed during weathering, and measures of stability are expressed as color difference units and gloss variations. Color acceptability may be evaluated by means of color triangulation. Changes in impact resistance in rigid PVC are as important as the influence of atmospheric pollutants during the natural weathering process. Both phenomena require duplication artificially with the hope of determining time equivalence between the two media.

Evaluation of structural adhesives for use in housing systems, W. W. Reichard, L. W. Masters, and J. H. Pielert, *SP361, Vol. 1*, pp. 761-775 (Feb. 1972).

Key words: Accelerated aging; adhesives; bonded structures; durability; glass fiber reinforced plastics; housing systems; Operation BREAKTHROUGH; paper honeycomb; performance criteria; structural sandwich.

As a result of the structural evaluation procedures developed for the "Operation BREAKTHROUGH" program, critical factors occurring in adhesive bonded structural assemblies were identified. The effects of aging, sustained-loading and adverse environmental conditions on these bonded areas were evaluated using small test specimens.

Typical results from this evaluation on two BREAKTHROUGH systems are presented. The results indicate that the accelerated aging procedure used here has a deteriorative effect on the strength of these systems. However, the magnitude of this effect was not judged to be great enough to reduce the strength of the final design below that required by the application. The results presented also show that the effects of adhesive thickness, temperature and sustained loading can be very significant and must be fully considered in design and structural evaluation.

Performance requirements for bituminous roofings, A. J. Hoiberg, *SP361, Vol. 1*, pp. 777-787 (Feb. 1972).

Key words: Bituminous; cost; durability; performance; roof behavior; roofing.

Factors related to performance of the shingle and the built-up membrane bituminous roofings are discussed under the general headings of durability, roof traffic considerations, appearance and economic evaluation. Durability relates to resistance to weather including wind and hail, and ability to withstand stresses within the membrane such as caused by thermal and moisture changes and by differential membrane and deck movements. Additional testing of roofing systems for ability to withstand movements is suggested and research methods which seem adequate are cited. Testing and requirements for fire resistance and hazard are described. Model analysis and testing are suggested to determine parameters and properties of materials required to be able to design properly performing traffic decks. Appearance is a primary design consideration for strip and individual shingles, whereas membrane systems mostly are applied for protection only. If a non-black appearance is desired, surfacing of the membrane with aggregate or a coating is feasible and additionally can improve durability. A method of economic analysis to determine the annual cost of a roof over its projected life is proposed. This includes in addition to first cost and annual capital charge, terms for maintenance, and the cost of surface renewal modified by a present worth factor. Quality control of the component parts and in application are key factors, once an adequate design of a roof system has been determined. Bituminous roofs can be varied greatly in design, and with proper care in construction will provide long time satisfactory performance at minimum cost in comparison with other systems.

Abrasion test and wear resistance of concrete terrazzo flooring tiles, I. Soroka, *SP361, Vol. 1*, pp. 789-797 (Feb. 1972).

Key words: Abrasion test; Böhme machine; concrete terrazzo flooring tiles; DIN 52108; wear resistance.

The paper summarizes a series of tests, in which the reliability of the Böhme abrasion machine (DIN 52108) in evaluating the wear properties of terrazzo concrete tiles was investigated. In view of the performance of such tiles under service conditions it was concluded that this procedure is not always reliable. It was therefore suggested that the acceptance procedure of such tiles should not be limited to an abrasion test but should also specify a minimum cement content in the terrazzo course. This minimum cement content should be 450 kg. per cu.m while the maximum amount of abrasion should not exceed 1.8 mm.

Performance tests for finish floors state-of-the-art, W. C. Wolfe, *SP361, Vol. 1,* pp. 799-806 (Feb. 1972).

Key words: Carpets; cleanability; conducting; durability; flooring; identation; resilience; slip resistance; static charge; test methods; water resistance; wear.

The need for performance standards in buildings and in finish flooring is recognized but performance requirements and criteria need to be established. Requirements for finish flooring, based on user needs, were divided into three categories in a symposium at the 72d Annual ASTM meeting. These were Health and Safety; Comfort, Convenience and Efficiency; and Economics. Criteria are dependent on the art and science of testing.

Sanitation factors, such as *cleanability and air pollution* are difficult to define. Statistics show a number of deaths and injuries from falls but the number of accidents due to *slippery floors* is unknown. *Fire safety* is not discussed as this is outside the scope of our work.

In the second category, *resistance to the movement of wheeled vehicles* is a problem with carpet but not with other types of finish floors. One question about *resilience as related to foot comfort* is whether this is related to fatigue or to foot problems. *Water and solvent resistance* is a problem in certain areas, such as bathrooms, kitchens, and industrial locations. The question of *noise or acoustics* is outside our scope.

Wear and durability is related to economics as it is a determining factor in life-cost. Since finish flooring is judged on appearance as well as function, it is important to consider change of appearance in wear testing as well as actual loss of material or wearing through.

The state of the art in test development is reviewed and exploratory work at NBS is presented in the areas of cleanability and stain resistance; slip resistance; indentation and resilience; static charge and conductivity; water resistance; and durability or wear.

SP361. Volume 2. **Performance concept in buildings.** Opening addresses, rapporteur reviews, and discussions. Proceedings of a symposium jointly sponsored by the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), the American Society for Testing and Materials (ASTM), and the International Council for Building Research Studies and Documentation (CIB), Philadelphia, Pa., May 2-5, 1972, B. E. Foster, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 361, Vol. 2, 169 pages (Sept. 1972).

Key words: Buildings; components; design procedures; experience in use; materials; performance evaluation; performance requirements; user requirements.

Volume 2 records the proceedings of the Joint RILEM-ASTM-CIB Symposium on the Performance Concept in Buildings which was held in Philadelphia on May 2-5, 1972. Volume 1 contains the 82 papers accepted for the Symposium and was published prior to the meetings. This second volume contains the opening addresses; the reports of the rapporteurs, which include a review of the papers and a general discussion in each of six areas; such discussion as was submitted in writing; a general summary of the Symposium with conclusions drawn by the closing rapporteur; and statements by representatives of the three sponsoring organizations outlining the present and probable future activity of these organizations in furthering the performance concept in buildings. The subject matter covered in the papers includes physiological, anthropometrical, psychological, sociological, and economic human requirements and methods of evaluation; physical requirements and methods of evaluation in mechanical, acoustical, thermal, dimensional stability, compatibility, fire properties, and geometry areas; operation and maintenance requirements and methods of evaluation in such areas as maintenance, repair, replacement, and versatility; techniques and problems in applying the performance concept to design; and experience gained in application of the performance concept in design, building, and building use.

SP362. **Chemical kinetics in the C-O-S and H-N-O-S systems: A bibliography—1899 through June 1971,** F. Westley, Nat. Bur. Stand. (U.S.), Spec. Publ. 362, 68 pages (Apr. 1972).

Key words: Bibliography; carbon oxysulfides: carbon sulfides; chemical kinetics; gas phase; hydrogen; nitrogen; nitrogen oxides; oxygen; sulfur; sulfur hydrides; sulfur oxides.

A bibliography, a reaction oriented list of references, is provided for published papers and reports containing rate data for reactions of COS, COS_2, CS, CS_2, CS_3, D_2S, H_2S, H_2S_2, HSO_2, S, SH, SO, SO_2, SO_3, SO_4, S_2, S_2O_2, S_4, S_6 and S_8 with each other and with CO, CO_2, D, D_2, H, H_2, H_2O, N, N_2, N_2O, N_2O_5, NO, NO_2, NO_3, NOS, O, OH, O_2, O_3, R and RH. Three lists of critical reviews dealing with the above reactions are included. 317 papers covering 240 reactions are listed. The period covered extends from 1899 through June 1971.

SP363. **Bibliography on atomic energy levels and spectra, July 1968 through June 1971,** L. Hagan and W. C. Martin, Nat. Bur. Stand. (U.S.), Spec. Publ. 363, 103 pages (June 1972).

Key words: Atomic energy levels; atomic spectra; bibliography; energy levels, atomic; spectra, atomic; wavelengths, atoms and ions.

The bibliography contains approximately 1100 references classified by subject for individual atoms and atomic ions. A number index identifies the references. An author index is included. References included contain data on energy levels, classified lines, wavelengths, Zeeman effect, Stark effect, hyperfine structure, isotope shift, ionization potentials, or theory which gives results for specific atoms or atomic ions.

SP364. **Solid state chemistry.** Proceedings of the 5th Material Research Symposium sponsored by the Institute for Material Research, National Bureau of Standards, Oct. 18-21, 1971 held at Gaithersburg, Md., R. S. Roth and S. J. Schneider, Jr. Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 364, 799 page (July 1972).

Key words: Chalcogenides; crystallographic shear; electro optical lattice images; lone pair geometry; non stoichiometry; oxides; refractory hard metals; Solid Stat Chemistry.

This book presents the Proceedings of the 5th Material Research Symposium on "Solid State Chemistry" held at th National Bureau of Standards, Gaithersburg, Md., on Oct. 18 21, 1971. The symposium was sponsored by the Institute fo Materials Research, NBS. The purpose of the conference was t explore the realm of new inorganic crystalline materia emphasizing crystal chemical and structural aspects, providin a forum for discussion of new research problems and technique A total of 56 invited and contributed papers were presented. I addition, the symposium included three unscheduled talks and a open discussion period consisting of four impromptu lectures o very current subjects dealing with nonstoichiometry. Th Proceedings are divided into four main groupings, I Oxides, Borides, Carbides, Silicides, and Related Materials, III Cha cogenides, and IV Open Discussion on Nonstoichiometry. A edited version is given of the floor discussion following each p per. *These proceedings include the following papers (indented*

The stereochemistry of the inert pair in some solid oxides oxide fluorides of Sb^{3+}, Bi^{3+} and Pb^{2+}, S. Andersson and Åström, *SP364,* pp. 3-14 (July 1972).

Key words: Antimony oxide fluorides; antimony oxides; bismuth oxide fluorides; lead oxides; lone pairs.

Geometrically it is shown that the inert electron pair in some solid oxides or oxide fluorides requires space comparable with that of an anion. If the lone pairs are located on certain sites in a lattice, nets consisting of lone pairs and anions are obtained which correspond to hexagonal, or cubic closest packing of atoms. Other more complex nets, comparable with those in alloy structures, are also found. The lone pairs are thus found in positions which are normally occupied by anions. Using this observation, direct structural relationships with the transition metal compounds can be shown to exist.

The single crystal x-ray structure determination of some alkali metal molybdates and niobates, B. M. Gatehouse, D. J. Lloyd, and B. K. Miskin, *SP364*, pp. 15-27 (July 1972).

Key words: Alkali metal; bronze; heptagonal holes; hexagonal tungsten bronze; lattice image; molybdate; molybdenum; niobate; niobium; oxide; single crystal; tetramolybdate; x-ray structure determination.

Crystal structures have been determined for the compounds "$Rb_3Nb_{54}O_{146}$," "$RbNb_3O_9$" $Na_xMo_6O_{17}$, $K_xMo_6O_{17}$ (x approximately 0.8 and 1.0 respectively) and $Li_2Mo_4O_{13}$ (low temperature form). Preliminary results are communicated for the compounds $Li_xMo_6O_{17}$ ($x \leq 1.0$) and $Li_2Mo_4O_{13}$ (high temperature form).

For "$Rb_3Nb_{54}O_{146}$" an unusual structure occurs where niobium-oxygen octahedra are grouped forming four, five, six and seven-sided tunnels through the structure, with the hexagonal tunnels partly filled with rubidium atoms. The unbalanced electrostatic charge is discussed in terms of the possible presence of fluoride, or fractional occupancy of oxygen sites.

Unusual features are discussed for the $M_x^IMo_6O_{17}$ structures (M^I= Li, Na, K) in terms of the presence or absence of Mo-O_6 octahedra or Mo-O_4 tetrahedra in the structure. It appears that the lithium analogue will have a somewhat different structure in spite of similarity in unit cell dimensions.

The ordering of lithium-oxygen octahedra in planes in $Li_2Mo_4O_{13}$ is pointed out in an accurate structure determination of this compound, which is basically a cubic close-packed oxygen lattice with Li and Mo occupying octahedral sites. Systematically absent oxygen atoms result in the presence of pairs of strings of cube octahedral holes in the structure.

The crystal chemistry of some new mixed oxides of tellurium IV, J. Galy, *SP364*, pp. 29-39 (July 1972).

Key words: Crystal structure; "lone pair" structures; tellurites; tellurium dioxide; tellurium hypovanadate; titanium tellurite.

The structural chemistry of some new mixed oxides between TeO_2 and some transition metal oxides is discussed.

A new structural type MTe_3O_8 has been found in the TeO_2-MO_2 systems (M = Ti, Zr, Hf and Sn). The structure of $TiTe_3O_8$ determined by x-ray single crystal analysis is cubic, space group Ia3 with a = 10.956 Å. The relationships with the fluorite structure type have been established. $ZrTe_3O_8$ as well as fourteen new compounds with the general formula $A_{1/2}B_{1/2}Te_3O_8$ (A = Sc, Cr, Fe, Ga, Rh, In, Bi and B = Nb, Ta) are isostructural with $TiTe_3O_8$.

In the system TeO_2-VO_2 the phase $TeVO_4$ has been prepared in two different crystalline forms, which we designate α and β here. A reversible polymorphic transformation occurs at 650 °C $\alpha \rightleftarrows \beta$. Both phases crystallize in the monoclinic system. The α-$TeVO_4$ crystals are black and the β-$TeVO_4$ crystals green; a melt of $TeVO_4$ gives a black glass by quenching. In α-$TeVO_4$ the coordination number of vanadium and tellurium is 6 and 3, in β-$TeVO_4$ the C.N. is 5 and 4.

The crystal structure of $NaVTeO_5$ ($KVTeO_5$, $RbVTeO_5$ and $AgVTeO_5$ are isostructural) exhibits isolated chains with $(VTeO_5)_n^{n-}$ formula surrounded by sodium atoms.

Finally, relationship between the structure of α- and β-$TeVO_4$ and other "lone pair" structures such as α-Sb_2O_4 or $SbNbO_4$, β-Sb_2O_4 and Pb_3O_4 is discussed, and comparison with such simple structures as α-PbO_2, ReO_3, PdF_3 and TiO_2 rutile also made.

Crystal structure and physical properties of a triclinic sodium tungsten oxide, H. F. Franzen, H. R. Shanks, and B. H. W. S. deJong, *SP364*, pp. 41-50 (July 1972).

Key words: Resistivity; Seebeck coefficient; sodium tungstate; structure.

A triclinic sodium tungstate was prepared by the method of electrolysis of molten mixtures of Na_2WO_4 and WO_3 which has been used extensively in the preparation of sodium tungsten bronzes. The electrical resistivities and Seebeck coefficients of several samples were measured and are reported. A single crystal x-ray diffraction study yielded the tungsten atom positions. A structure is suggested which is consistent with the tungsten positions and the electrical properties. The suggested stoichiometry is $Na_6W_{14}O_{45}$. In the suggested structure the tungsten atoms are coordinated by distorted octahedra of oxygen atoms in all cases but one, in which case the tungsten is coordinated by a trigonal-bipyramid of oxygen atoms. The octahedra share corners in planes in a fashion similar to that found in the hexagonal bronze, and the sodium atoms are located in the resulting hexagonal holes.

Electrochemical preparation and characterization of alkali metal tungsten bronzes, M_xWO_3, M. S. Whittingham and R. A. Huggins, *SP364*, pp. 51-62 (July 1972).

Key words: Crystal growth; electrolysis; non-stoichiometry; reaction mechanisms; thermodynamics; tungsten bronze.

When a current is passed through two inert electrodes immersed in a molten solution (~ 750 °C) of alkali metal tungstate, M_2WO_4, and tungsten oxide, WO_3, oxygen is liberated at the anode and a crystal of tungsten bronze, M_xWO_3, where $O < x < 1$, formed at the cathode. The potential difference between the electrodes is related to the oxygen concentration gradient across the cell. Thus, if the electrical potential difference across the cell, rather than the current or current density, is kept constant, crystals with a fixed oxygen activity and hence composition (stoichiometry) will be grown. Measurements of the decomposition potential of melts of M_2WO_4 and WO_3 of different composition, and of the oxygen activity in tungsten bronzes allows a type of phase diagram relating oxygen activity to the alkali metal/tungsten ratio in both liquid and solid phases to be constructed. Using this thermodynamic approach, it is possible to rule out certain suggested reaction intermediates in the electrolytic process and to explain both the overlapping stoichiometric ranges of some phases and the effects of reacting electrodes on the decomposition potential.

Some aspects of the investigation of intergrowth phases in Nb_2O_5-rich systems, R. Gruehn, *SP364*, pp. 63-86 (July 1972).

Key words: Analysis; hybrid phase; intergrowth phase;

niobium pentoxide; preparation; ranges of homogeneity; stability; systems.

Numerous Nb_2O_5-rich compounds with complicated compositions could be prepared as monophasic samples. The preparative and analytical work in this field was supplemented by x-ray investigations using the Guinier technique. In addition to 5 phases ($Nb_{11}O_{27}$, $Nb_{25}O_{62}$, $Nb_{28}O_{70}$, $Nb_{31}O_{77}F$, $Nb_{34}O_{84}F_2$) whose structures are known from investigations by Wadsley, Andersson, and Norin, we found 4 "hybrid" phases also called intergrowth-phases. The building principle of the hybrid phases $NbO_{2.464}$, $NbO_{2.483}$, $Nb(O,F)_{2.510}$, and $Nb(O,F)_{2.523}$ is a combination of building elements of both neighbor phases, e.g., $NbO_{2.483}$ combines component rows of the $Nb_{25}O_{62}$-structure and the $Nb_{28}O_{70}$-structure in a ratio 1:1.

It is of special interest that the phases $Nb_{25}O_{62}$, $Nb_{28}O_{70}$, $Nb_{31}O_{77}F$, and $Nb_{34}O_{84}F_2$ have small but exactly reproducible ranges of homogeneity. The fundamental reason for this deviation from the ideal composition is still unknown. It may be that the deviation from the ideal composition is due to the special properties of the building elements. According to this the non-ideal composition of a hybrid phase may be derived from the non-ideal composition of both neighbor phases, e.g., the actual composition $NbO_{2.483\pm0.001}$ of the hybrid phase may be calculated from the actual limits of the phases $Nb_{25}O_{62}$ (2.478 O/Nb) and $Nb_{28}O_{70}$ (2.489 O/Nb). A hybrid phase with the ideal composition 2.491 O/Nb ($Nb_{25}O_{62} + Nb_{28}O_{70}$) is nonexisting.

In addition to the combination of compositions of neighbor phases there may be relationship between the stabilities of the basic structures and the resulting hybrid phases.

The application of electron optical techniques to high temperature materials, J. G. Allpress, *SP364,* pp. 87-111 (July 1972).

Key words: Crystallographic shear planes; crystal structure; electron diffraction; electron microscopy; lattice images; lithium ferrites; lithium lutetium titanate; niobium-titanium oxides; niobium-tungsten oxides; tungsten oxides; Wadsley defects.

Careful studies of phase equilibria in many high temperature systems have revealed unexpectedly complex structural relationships, which are frequently very difficult to unravel by means of conventional x-ray techniques. The purpose of this contribution is to indicate how and why the electron microscope can be used to advantage in these circumstances. The value of the technique will be demonstrated by referring to the following recent applications in the field of the structural chemistry of oxides: (1) The determination of unit cell data for microcrystalline samples of alkali metal rare earth titanates, using electron diffraction. These materials have orthorhombic superlattices of the perovskite structure; (2) The use of dark field microscopy to study the precipitation of the ferrimagnetic spinel $LiFe_5O_8$ from a nonstoichiometric matrix of α-$LiFeO_2$. The morphology of the precipitate depends critically upon prior thermal treatment; (3) The direct observation of crystallographic shear planes in WO_{3-x} ($x < 0.05$) and $WO_3 \cdot yNb_2O_5$ ($y = 0.03$-0.09). The results show how changes of composition are accommodated in these systems, and provide clues as to the mode of formation and diffusion of crystallographic shear defects; (4) The study of regions of "solid solution" in the system TiO_2-Nb_2O_5 (> 50 mol % Nb_2O_5), by lattice imaging. Variations in composition are accommodated by coherent intergrowth, at the unit cell level, of thin slabs of several parent phases; and (5) The study of phases in the system WO_3-Nb_2O_5 which have structures related to that of tetragonal tungsten bronze. Several different superlattices are possible, and lattice images provide direct evidence for order-disorder, microdomain formation, and intergrowth with material having a much simpler cubic structure.

Application of infrared and Raman spectroscopy to the characterization of order-disorder in high temperature oxides, W. B. White and V. G. Keramidas, *SP364,* pp. 113-126 (July 1972).

Key words: Corundum structure; order-disorder; Raman spectra; rocksalt structure; rutile structure; spinel structure.

The vibrational spectra of oxides are remarkably sensitive to ordering effects and are a useful characterization tool. Cation ordering can be classified into: (a) preferential distribution of nonequivalent cations onto nonequivalent sites with no change in space group symmetry or unit cell size, (b) preferential distribution onto equivalent sites with decrease in space group symmetry only, (c) building of superstructures with same symmetry as parent structure, (d) both (b) and (c) combined. Experimental Raman spectra of various structures are compared with these schemes. Ordering of type (a) produces only frequency shifts with no change in spectral pattern and is exemplified by normal-inverse ordering in spinels. Ordering of type (b) produces additional bands due to selection rule relaxation and is exemplified by ilmenite, $LiNbO_3$, and Ni_3TeO_6 orderings on corundum and by spinels with 1:1 ordering on tetrahedral sites. Ordering of type (c) produces a multiplicity of bands as is illustrated by the trirutile structure. Ordering of type (d) produces very complex spectra. Examples include: P3c1 ordering on corundum, 1:1 ordering on rocksalt and the Ruddlesden-Popper superstructures. Raman spectra are sharp but intensities are highly variable. Simple ordering schemes are easy to discern, but complex schemes produce spectra difficult to interpret.

A study of V_2O_3 by photoelectron spectroscopy, J. M. Honig, H. E. Weaver, and R. D. Board, *SP364,* p. 127 (July 1972).

Key words: Metallic-insulator transition; photoelectron spectroscopy; V_2O_3.

The occupied energy states of single crystal and polycrystalline V_2O_3 have been studied by x-ray photoelectron spectroscopy both above and below the metallic-antiferromagnetic insulator (M-AFI) transition. All of the elemental vanadium and oxygen states in the range 20 to 640 eV below the Fermi level were also encountered in V_2O_3. In addition, a valence band with structure was observed in the range 0 to 10 eV. In the metallic phase this band was intersected by the Fermi level; below the transition temperature the topmost portion of the band was no longer observable and may have disappeared under increased noise. Under the experimental conditions involving a resolution of 0.3 to 0.5 eV, a search was made for the presence of localized states in the energy spectrum of the insulating phase at 77 K. No such states were encountered; unless they were masked by the residual valence band approximately 4 eV in width it must be concluded that the transition does not involve a change from a localized to an itinerant electron regime.

Observations in the electron microscope of lattice planes and migration of silver in beta alumina, W. L. Roth, *SP364,* pp. 129-137 (July 1972).

Key words: Beta alumina; electron microscope; lattice images; migration of silver; silver whiskers.

Beta alumina is the commonly accepted name for a sodium aluminate of variable composition and structure with

"ideal" formula $NaAl_{11}O_{17}$. There is considerable interest in beta alumina and its isomorphs because the monovalent ions diffuse rapidly at temperatures of 300 °C and below. Crystal structure and density studies of the sodium and silver isomorphs have shown the compound is nonstoichiometric and contains approximately 25 percent excess sodium or silver. All of the monovalent ions lie in basal planes at z = 1/4 and 3/4. The planes are separated by 11 Å and ion conduction takes place by two dimensional diffusion in these planes.

The conducting planes have been resolved in the electron microscope and their identity established by electron diffraction. High resolution photographs show lattice bending and rotation.

When relatively thick crystals of silver beta alumina are observed in the electron microscope, worm-like filaments or whiskers about 50 Å in diameter exude from the edge of the crystal. The filaments were shown by electron diffraction to be silver. The filaments are produced by diffusion of Ag^+ ions down channels in the conducting planes to neutralize the negative charge of absorbed electrons.

Beta alumina—prelude to a revolution in solid state electrochemistry, M. S. Whittingham and R. A. Huggins, *SP364*, pp. 139-154 (July 1972).

Key words: Beta alumina; diffusion; electrochemical cell; electrochemical transducer; ionic conductivity; mass transport; solid electrolyte.

For almost two decades solid state electrochemical techniques have been used to study the thermodynamic and transport properties of a number of materials. However, these studies have been restricted essentially to systems utilizing electrolytes containing mobile silver or copper ions at low temperatures, and oxygen ions at high temperatures.

Transport measurements have been made on single crystals of beta alumina, which has the nominal formula $MAl_{11}O_{17}$ where M is usually a monovalent cation, to test its suitability as a solid electrolyte. In this and related structures, the monovalent cation can be extremely mobile. By use of a group of novel nonpolarizing solid electrodes, which are fully reversible to the monovalent cation, it has been possible to study the ionic conductivity of a series of beta aluminas containing alkali metals as well as thallium over a wide temperature range. The electronic conductivity of silver beta alumina has also been determined by use of the Wagner asymmetric polarization technique over wide ranges of temperature and oxygen partial pressure.

The results of these studies clearly indicate that the beta alumina family shows excellent promise for use as solid electrolytes, exhibiting high values of ionic conductivity and a very low electronic transference number. These properties were exhibited over extremely wide ranges of temperature, − 150 to + 820 °C, and oxygen partial pressure, 10^{-24} to 1 atm. The use of beta alumina opens up many new opportunities in solid state electrochemistry, particularly in the study of materials containing monovalent cations.

Experimental study on the ionicity in the TiO phase. An application of the new method of determining the structure factor by high voltage electron diffraction, D. Watanabe and O. Terasaki, *SP364*, pp. 155-164 (July 1972).

Key words: Critical voltage for the 400 of TiO; critical voltage for the 110 of TiO_2 (rutile); determination of structure factor by high voltage electron diffraction; disappearing effect of the second order reflection in electron diffraction; ionicity in TiO crystal; many-beam dynamical interaction in electron diffraction; structure factors for electrons of TiO.

It was reported recently that the second order reflection in electron diffraction vanishes at a certain accelerating voltage E_c, owing to the many-beam dynamical interaction combined with the relativistic change of electron mass [Watanabe, Uyeda and Kogiso, Acta Cryst. **A24**, 249 (1968)]. A measured value of E_c makes it possible to determine very accurately the Fourier coefficient of the potential for the first order, and thus the corresponding value of the x-ray scattering factor [Watanabe, Uyeda and Fukuhara, Acta Cryst. **A24**, 580 (1968), **A25**, 138 (1969)].

In the present study, the method has been applied to the disordered TiO phase. The accelerating voltages E_c, for which Kikuchi lines of the 400 reflection vanish, have been measured using a 500 kV electron microscope. The measured values are 340, 354, 389 and 425 kV, respectively, for $TiO_{0.82}$, $TiO_{0.96}$, $TiO_{1.16}$, and $TiO_{1.25}$. To compare the experimental values with calculation, the values of E_c have been calculated for $TiO_{0.82}$ and $TiO_{1.25}$, using theoretical scattering factors of titanium and oxygen atoms of various atomic states. The calculations have been made for free neutral atoms Ti^0, O^0, monovalent ions Ti^{1+}, O^{1-} and divalent ions Ti^{2+}, O^{2-}. The structure factors of the first order have been determined using the measured values of E_c.

Comparison of the experimental values of E_c and the first order structure factors with theoretical ones enables us to discuss the ionicity in a TiO crystal. The result shows that the ionicity depends on the oxygen concentration in the crystal, i.e., titanium and oxygen atoms in the oxygen-deficient TiO crystal are considered to be almost neutral, while the elements in the titanium-deficient crystal appear to be in the ionic states.

The possibility of applying the present method to a TiO_2 crystal of the rutile type is discussed as well.

The structure and intergrowth of the polymorphic forms of $ZrO_2 \cdot 16Nb_2O_5$, N. C. Stephenson, J. P. Beale, and D. C. Craig, *SP364*, pp. 165-182 (July 1972).

Key words: Crystal structure; intergrowth; lattice-image; polymorphism; zirconium-niobium oxide.

The compound $ZrO_2 \cdot 12Nb_2O_5$ has been reported to exist in three polymorphic forms, one of which is isostructual with $TiNb_{24}O_{62}$.

The crystal structures of the remaining two polymorphs have been determined by examining x-ray data collected from a single crystal of the β-monoclinic form. The unit-cell dimensions are a = 39.693, b = 3.830, c = 35.488 Å, β = 116.53°. 2948 data were collected using a single crystal diffractometer and Cu$K\alpha$ radiation.

No assumptions were made about the structural features and the basic subcell unit was deduced from the Patterson function. Modifications of this subcell give rise to the remaining two polymorphs, which contain blocks of 3 x 3, 4 x 4, and 3 x 4 corner sharing octahedra. The 3 x 4 blocks are all at the one level and form sheets running parallel to (100). The 3 x 3 and 4 x 4 blocks form sheets which alternate with those just described. The manner in which the sheets fit together determines which polymorph is formed.

Although the structures were solved using standard x-ray procedures, the solutions were facilitated by using features of electron transmission micrographs. These consisted of a regular array of dots and streaks (plane group p2) arranged in lines parallel to c. The spacial distribution and contrast of these dots and streaks, together with their arrangements at antiphase boundaries and fault areas, impose certain restrictions upon structures that can be derived by modifications of the basic subcell.

In terms of structure, the areas of contrast on transmission micrographs can be identified with the different types of block junctions.

Superstructure of the orthorhombic $Nb_2O_5 \cdot 6ZrO_2$ type phase(s) in the Nb_2O_5-ZrO_2 and Ta_2O_5-ZrO_2 systems, R. S. Roth, J. L. Waring, W. S. Brower, and H. S. Parker, *SP364*, pp. 183-195 (July 1972).

Key words: Equilibrium; Nb_2O_5-ZrO_2; ordered defects; α-PbO_2-type phase(s); single crystals; superstructure; Ta_2O_5-ZrO_2.

The phase previously described as $Nb_2O_5 \cdot 6ZrO_2$ has been found to have a composition varying from a Nb_2O_5:ZrO_2 ratio of about 2:9 to 2:15. The solidus temperatures of the intermediate compositions studied seem to follow a smooth curve from 1435 to 1640 °C rather than a stepwise function expected from a series of compounds. The x-ray diffraction powder patterns indicate a series of phases with subcells similar to α-PbO_2 and orthorhombic symmetry. Superstructure lines indicate that these phases have a multiple *b* axis. The composition 2:9 corresponds approximately to a structure with a *b*-axis multiplicity of seven. The 2:11 composition appears to have a multiplicity of eight, 2:13 a multiplicity of nine and the last composition 2:15, a multiplicity of ten. The intermediate compositions 1:5, 1:6 and 1:7 show superstructure lines halfway between those of the simpler phases on either side, corresponding to multiplicities of 15, 17 and 19 respectively. These multiplicities and compositions thus appear to belong to a homologous series $M_{n-1}O_{2n}$ where *n* varies from 14-20. However the phase equilibria data do not rule out the possibility of a homologous series M_nO_{2n+1}. Compositions in the Ta_2O_5-ZrO_2 system apparently have the same composition *vs* multiplicity arrangement, however, their melting points are considerably higher.

Single crystals of these phases, prepared by both direct cooling of a melt and utilization of a barium vanadium oxide eutectic flux, have enabled the multiplicities to be completely verified and are now being used for crystal structure determinations. This stabilization of the high pressure form of ZrO_2 (the orthorhombic structure type) by means of higher valence cations provides an alternate process to the anion deficient stabilization of the cubic fluorite phase.

Physical and geometrical principles of crystallographic shear in rutile, L. A. Bursill, B. G. Hyde, and M. O'Keeffe, *SP364*, pp. 197-204 (July 1972).

Key words: Crystallographic shear; rutile; swinging shear planes; TiO_2; TiO_2-Cr_2O_3 system.

Recent studies by electron microscopy and diffraction have elucidated many of the structural patterns of formation of homologous series of oxides derived from the rutile structure by crystallographic shear. In this paper, the physical and geometrical principles underlying the formation of planar defects are considered. It is shown that the only crystallographic shear planes expected in systems derived from rutile are those containing $< 111 >$ as observed, e.g., in TiO_{2-x} and TiO_2–Cr_2O_3. These results enable us to establish likely criteria for the development of homologous series in oxide systems. The kinetic consequences of the existence of disordered shear planes (Wadsley defects) are further examined in the light of these developments.

Structures and chemical bond problems in vanadium oxides, P. Hagenmuller, *SP364*, pp. 205-218 (July 1972).

Key words: Covalence parameters; insulator-metal transitions; perovskite like structures; relations between structures and physical properties; vanadium oxides.

In the transition metal oxides the d-electrons may be either in a localized or a collective state depending essentially on the structure, the transition element and its oxidation state. Some significant examples will be given resulting from recent investigations in the field of the vanadium oxy compounds:

1. A study of the magnetic and electrical properties of the phase $K_{2-x}V_{3+2x}O_{8+2x\pm\kappa}$ ϕ in the system V_2O_5-VO_2-K_2O shows that it can be written formally as

$$K_{2-x}V^{4+}V^{5+}_{2-3x\pm2\kappa}\,(V^{4+}_{3x\pm2\kappa})_{subst.}\,(V^{4+}_{2x})_{ins.}\,O_8(O_{2x\pm\kappa})_{ins.}$$

$K_2V_3O_8$ is actually an insulator in which the V^{5+} and V^{4+} ions occupy well defined sites ($K_2V^{4+}(V^{5+})_2O_8$). It does not become a conductor until the progressive appearance of d-electrons in the V^{5+} sites as a result of a hopping mechanism. The variation with x of the Curie constant shows that the vanadium, inserted in the form of chain links (O)-V-O-V-(O) in the tunnels emptied by the potassium, also occupies a particular site. These properties were confirmed by the determination of the structure: the phase ϕ, which is isostructural with $Ba_2TiSi_2O_8$, is actually made up of three types of cationic sites.

2. VO_2 has an allotropic transformation at 340 K of the type homopolar bonding ⇆ metal. This transformation is characterized by a change of symmetry from monoclinic to tetragonal of the rutile type. The replacement of vanadium 4+ by cationic substitution of the type $2V^{4+} = M^{5+}$ (Nb^{5+} f.e.) + V^{3+} or by anionic substitution $V^{4+} + O^{2-} = V^{3+} + F^-$ results in the lowering of the transition temperature. It seems to be the result of the progressive occupancy of a π band. On the other hand the transformation temperature is raised by a substitution of the type $2V^{4+} = M^{3+}$(Cr^{3+} f.e.) = V^{5+}, and there appears an intermediate semi-conducting phase of orthorhombic symmetry. The existence of this phase can be explained by the ferroelectric distortions due to vanadium 5+. The change of the physical properties with the substitution rate is analyzed on the basis of the obtained structures.

3. The phase $La_{1-x}Sr_xVO_3$ ($0 \leq x \leq 0.40$) with a structure derived from $GdFeO_3$ is characterized by an evolution from semi-conductor to metal with increasing x. This latter results from the strengthening of the π (B–0) bond which is a consequence of the weakening of the σ (A–0) bond and the partial replacement of vanadium 3+ by vanadium 4+. This change is less sensitive for the phase $Gd_{1-x}Sr_xVO_3$, Gd^{3+} being more acidic than La^{3+} and hence σ (A–0) stronger and π (B–0) weaker.

These results are compared with those obtained for the homologous $LnTO_3$ phases, Ln being a lanthanide and T a 3d-transition element, on the basis of Goodenough's covalent mixing parameters λ_π and λ_σ. The influence of various factors on the physical properties is discussed.

Preparation and structure of a pyrochlore and perovskite in the $BiRhO_{3+x}$ system, J. M. Longo, P. M. Raccah, J. A. Kafalas, and J. W. Pierce, *SP364*, pp. 219–226 (July 1972).

Key words: $BiRhO_3$; defect structures; perovskite; pressure-synthesis; pyrochlore.

The pyrochlore structure with general formula $A_2B_2O_7$ is formed with a wide variety of ions and tolerates a high degree of nonstoichiometry on the anion and A cation sites, e.g., $Pb_{1.5}Nb_2O_{6.5}$. We have found that the reaction of Bi_2O_3 with either Rh metal or Rh_2O_3 (Bi/Rh = 1:1) at 600-1000 °C in air or oxygen forms a compound with a face-centered cubic unit cell ($a = 10.238 \pm .008$ Å) and the pyrochlore structure. X-ray fluorescence for the Bi/Rh ratio and

thermogravimetric analysis for the oxygen content gave $Bi_{2.0}Rh_{2.0}O_{6.8}$.

In the pyrochlore structure the cations are in fixed positions, and there are two types of oxygen. Six oxygen atoms are of one type (O_1) with one position parameter and form the octahedra around the B cations. The last oxygen (O_2) is fixed and coordinated only to the A cations. It is not essential to the B_2O_6-octahedra network. Taking the origin at the B cation, we have refined the position parameter for O_1, the occupancy factor (OF) for O_2 and atomic temperature factors (B) by R-factor minimization of integrated powder diffraction intensity data. The results are as follows:

$B_{Bi} = 0.7$, $B_{Rh} = 0.1$, $B_{O_1} = 0.1$,

$B_{O_2} = 0.0$, $x_{O_1} = 0.326$, $OF_{O_2} = 0.7$.

The position parameter for O_1 is in agreement with those found in other pyrochlores, and the occupancy factor (OF) is consistent with the chemical analysis. Resistivity measurements on sintered samples at room temperature gave $\rho = 3.2 \times 10^{-3}$ Ω-cm. We will discuss the stability of the defect structure in terms of the availability of the "inert pair" of electrons of the A cation.

When Bi_2O_3 and Rh_2O_3 were reacted in sealed, evacuated quartz tubes at 750-1100 °C, the product could not be identified. When the same reactants were placed in platinum capsules and subjected to over 65 kbar pressure at 1000-1300 °C for 1/2 hour, the perovskite $BiRhO_3$ was formed. Its unit cell is orthorhombic ($a = 5.354 \pm .005$ Å, $b = 5.813 \pm .005$ Å, $c = 7.776 \pm .005$ Å) as in $GdFeO_3$ or the series of $LnRhO_3$. The relationship between the defect pyrochlore and perovskite structures will be discussed.

Precious metal pyrochlores, A. W. Sleight and R. J. Bouchard, *SP364*, pp. 227-232 (July 1972).

Key words: Metallic conductivity; oxides; pyrochlore structure; semiconductivity.

Rare earth pyrochlores of the type $A_2M_2O_7$ where A is a rare earth and M is Ru, Ir, Pd, or Pt have been reported, but little is known of their physical properties. We have grown crystals of the rare earth ruthenate and iridate pyrochlores. Four-probe electrical resistivity measurements on single crystals show that both rare earth ruthenates and iridates are semiconducting with an activation energy of about 0.1 eV for the ruthenates and about 0.08 eV for the iridates. Very different behavior is found for the iridate and ruthenate pyrochlores when the A cation is a post-transition metal. Although $Tl_2Ru_2O_7$ is also semiconducting, it has an activation energy of only about 0.01 eV. Metallic conduction is found for $Tl_2Ir_2O_7$, $Tl_2Os_2O_7$, $Bi_2Ru_2O_7$, and $Bi_2Ir_2O_7$. Magnetic susceptibility measurements confirm the localized electron behavior for the semiconductors and delocalized electron behavior for the metallic compounds. Structural refinements have been carried out for $Nd_2Ru_2O_7$, $Yb_2Ru_2O_7$, and $Bi_2Ru_2O_7$. The Ru-O distance is $2.00 \pm .01$ Å for all three compounds; however, an anomalously high temperature coefficient was found for Bi.

Phases in the systems BaO-NiO-O-CO_2 and BaO-CoO-O-CO_2, T. Negas and R. S. Roth, *SP364*, pp. 233-263 (July 1972).

Key words: Ba/Co-oxide phases; Ba/Ni-oxide phases; crystal structure; phase equilibria; transition-metal oxides.

Several new materials apparently related to the aragonite form of $BaCO_3$ and to the 2H form of "$BaNiO_3$" were prepared at elevated temperature *in air*. The phases $Ba_3NiC_xO_{9-y}$ and $Ba_3Ni_2C_xO_{9-y}$ ($[Ni + C] \leq 3$) were prepared in powder and single crystal form. Both phases are hexagonal with *a*-axes related to the 2H "$BaNiO_3$" by $a \approx a_{2H}\sqrt{3}$. Single crystal x-ray and electron diffraction patterns of the Ba:Ni = 3:1 phase reveal $c \approx 2c_{2H}$. The structure was refined in space group P6 to R = 5.9% using 639 x-ray reflections. $BaCO_3$ - 3:2 (Ba:Ni) phase composite crystals were prepared by decomposition of 3:1 phase crystals in air at 800 °C. The structure for these composites is discussed. A similar 3:2 compound, $Ba_3Co_2C_xO_{9-y}$, containing low-spin octahedral Co^{4+}, was prepared in powder form.

Although 2H "$BaNiO_3$" is not stable in air, single crystals of two phases near Ba:Ni = 1:1 were obtained. Both are rhombohedral with hexagonal $a \approx a_{2H}\sqrt{3}$ and large *c*-axis multiplicities but exact stoichiometries are unknown. Two-layer-like forms of $BaCoO_{3-x}$ can be prepared in air, however, below 890 °C. Similar phases exist at compositions slightly deficient in cobalt. A 12-layer form of $BaCoO_{3-x}$ exists from 890 to 925 °C. It transforms to a phase of unknown structure above 925 °C. The compound Ba_2CoO_4, related to Ba_2TiO_4, can be prepared above 825 °C. Ba_2CoO_4 has a reversible, nonquenchable, monoclinic ⇄ orthorhombic inversion at 145 °C. The Co^{4+} is in a high-spin, tetrahedral, configuration.

Preparation of $SrFe_xMn_{1-x}O_{3-y}$ and $CaFe_xMn_{1-x}O_{3-y}$ crystals and some of their properties, E. Banks, O. Berkooz, and T. Nakagawa, *SP364*, pp. 265-273 (July 1972).

Key words: Antiferromagnetism; $CaFe_xMn_{1-x}O_{3-y}$; defect structure; mixed metal oxides; Mössbauer effect; oxygen vacancies; perovskite; semiconductivity; $SrFe_xMn_{1-x}O_{3-y}$.

Single crystals of $SrFe_xMn_{1-x}O_{3-y}$ and $CaFe_xMn_{1-x}O_{3-y}$ were grown by the usual technique from fluxes of excess $SrCl_2$ and $CaCl_2$, respectively. Apparently cubic perovskites were obtained in the $SrFe_xMn_{1-x}O_{3-y}$ system where x is in the range $0.4 \leq x \leq 0.7$ and in the $CaFe_xMn_{1-x}O_{3-y}$ where x is $0.2 \leq x \leq 0.4$. Hexagonal crystals, isostructural with the reported high temperature phase of $BaMnO_3$, were obtained in the $SrFe_xMn_{1-x}O_{3-y}$ where x is 0.1 and 0. Chemical analysis showed that the values of Fe:Mn ratio in these crystals were very close to the expected ones. From the density and x-ray measurements the existence of substantial amounts of oxygen vacancies ($0.26 \leq y \leq 0.44$) in the perovskite crystals was observed. For the hexagonal crystals, lower concentrations of oxygen vacancies ($y \sim 0.11$) were observed. The Mössbauer spectra of crystals having $x = 0.4 - 0.7$ in the $SrFe_xMn_{1-x}O_{3-y}$ system were found to consist of two kinds of quadrupole-split lines of Fe^{3+} ions, Fe^{3+} (I) which are present in regular oxygen octahedra and Fe^{3+} (II) which are associated with oxygen vacancies. From the magnetic measurements, Neél temperatures in the $SrFe_xMn_{1-x}O_{3-y}$ were found to be $T_N = 130$, 35 and 20 K for x - 0.7, 0.5 and 0.4, respectively. Using the experimental data of the densities, the Mössbauer effect and effective magnetic moments, discussions concerning the amount of oxygen vacancies in the perovskite compounds are given.

The perovskite-like phases exhibited semiconducting behavior with activation energies of about 0.16 eV, which was almost independent of composition.

$La_xSr_{1-x}RuO_3$: A new perovskite series, R. J. Bouchard and J. F. Weiher, *SP364*, pp. 275-284 (July 1972).

Key words: Antiferromagnetism; Curie-Weiss paramagnetism; ferromagnetism; metallic conductivity; oxide; perovskite; solid solution.

The compound $LaRuO_3$ was prepared for the first time. It appears to be metallic and antiferromagnetic. Solid solutions with ferromagnetic $SrRuO_3$ of the type $La_xSr_{1-x}RuO_3$ exist for all values of x. All compounds have the orthorhombic $GdFeO_3$-type perovskite structure. The ferromagnetism ob-

served for $SrRuO_3$ ($x = 0$) diminishes rapidly with increasing La content, and antiferromagnetism or parasitic ferromagnetism sets in at approximately 35% La. All compounds show Curie-Weiss behavior at fairly low temperatures. The properties of $LaRhO_3$ are also discussed.

High pressure synthesis and crystal structure of cobalt sesquioxide and its low-spin → high-spin transition, M. Marezio, P. D. Dernier, J. Chenavas, and J.-C. Joubert, *SP364*, pp. 285-286 (July 1972).

Key words: Cobalt sesquioxide; crystal structure; high pressure synthesis; low-spin → high-spin transition.

Influence of madelung energy and covalency on the structure of $A^+B^{5+}O_3$ compounds, J. A. Kafalas, *SP364*, pp. 287-293 (July 1972).

Key words: $A^+B^{5+}O_3$ compounds; ferroelectricity; perovskites; phase stability.

The large Goldschmidt tolerance factor $t = 1.06$ in $BaTiO_3$ appears to be related to its ferroelectric properties and also suggests that relatively large effective charge at a Ti^{4+} ion inhibits formation of the hexagonal-perovskite polytypes generally associated with $t > 1.0$. In order to test these ideas, $RbNbO_3$ and $RbTaO_3$ ($t = 1.08$) were prepared under very high pressures. $RbNbO_3$ is an orthorhombic perovskite isostructural with ferroelectric $BaTiO_3$, and it decomposes on heating without formation of an hexagonal-perovskite polytype. Only at 90 kbar and 900 °C did $RbTaO_3$ form a cubic, or nearly cubic, perovskite. Unlike the transition-metal ions, Sb^{5+} and Bi^{5+} have never been stabilized in a cubic perovskite structure. $AgSbO_3$ forms a defect pyrochlore, $NaSbO_3$ and $KSbO_3$ have ilmenite structures, although a cubic (Pn3) form of $KSbO_3$ is stabilized by prolonged annealing above 1000 °C. A body-centered-cubic, disordered form of the cubic $KSbO_3$ having space group I23 was prepared in five minutes at 20 kbar and 800 °C. Preparation of $RbSbO_3$ at 20 kbar and 1000 °C yielded a phase with the same structure. These results are interpreted to mean that strong covalent bonding inhibits the formation of 180° Sb^{5+}-O^{2-}-Sb^{5+} linkages.

Defects in oxides, J. S. Anderson, *SP364*, pp. 295-317 (July 1972).

Key words: Block structures; crystallographic shear; defect clusters; defect models; high resolution electron microscopy; oxide defects; rutile structure; Wadsley defects.

Defects in ionic crystals, such as the metallic oxides, are so intimately involved in diffusion, reactivity and electronic properties, that an understanding of defect structure is a necessary background for a variety of problems in the chemistry, physics and technology of materials. In the present context consideration will be restricted primarily to thermodynamic defects: the inner equilibrium of oxide structures, stoichiometric changes that displace that equilibrium, and solid solutions in which replacement of one cation by another of different valence involves an analogous change in the ratio of cations to anions in the crystal structure. This paper is largely concerned with structural matters and has two purposes: the first is to draw together what is known about highly defective oxide structures (stoichiometrically variable and solid solution phases); the second is to consider, in more detail, one or two systems that exhibit a remarkable capacity for organizing their defect structures.

It has been customary to treat these problems within the framework of point defect theory. This viewpoint, well rooted in statistical thermodynamics, is certainly applicable to highly ionic uni-univalent crystals (alkali halides) and, perhaps generally to highly dilute defect systems, e.g., 10^{19} cm^{-3} or less. We are concerned with concentrations two orders of magnitude greater, with ions of greater formal charge, and (in the important transition metal oxides) with a considerable measure of orbital overlap between cations and anions and, in some cases, direct cation-cation bonding. These last considerations raise questions about the effects exerted by defects, such as anion vacancies, on charge screening and cation repulsions, and about the preservation of cation coordination so as to maximize charge screening and optimize the covalent component of the bonding.

We shall try to trace a progression in our classification of defect structures, and in doing so we shall find effects both of chemical specificity— the electronic configuration, as well as the size of cations—and of influences exerted non-specifically, by crystal structure type.

Oxygen dissociation pressures and phase behavior in the transplutonium oxides, T. D. Chikalla and R. P. Turcotte, *SP364*, pp. 319-330 (July 1972).

Key words: Actinide oxides; actinide sesquioxides; americium oxides; berkelium oxides; curium oxides; melting points of actinide oxides; nonstoichiometry; oxides; thermodynamics.

The results of recent oxygen vapor pressure measurements over nonstoichiometric AmO_x, CmO_x, and BkO_x are presented. These include derived information concerning the phase relations and partial thermodynamics of oxygen solution over the range $1.5 < x < 2.0$ and $300 < T < 1200$ °C.

The americium-oxygen system has been examined by thermogravimetric techniques in the single phase α region for $1.80 < x < 2.00$ to yield relative partial molar heat and entropy data. Supporting information obtained by quench methods and x-ray diffraction analysis extend the results to lower compositions and, additionally, demonstrate the existence of a bcc σ phase over a wide composition range. Phase relations in the curium-oxygen system have been defined by a series of isobars in the pressure range $2 < p_{O_2}$ (mm) < 730. In addition to α and σ phase, compounds of more narrow compositional width are seen at $CmO_{1.72}$ and $CmO_{1.82}$, and a plausible phase diagram is constructed. Differences obtained on two curium isotopes of greatly different radioactivity are discussed. The berkelium-oxygen system has been examined using a novel capacitance manometer system and a 1.2 mg sample. A set of five isotherms was obtained over the range $852 < T$ (°C) < 1150. The isotherms show a regular variation across α and σ regions separated by a diphasic field at $x \sim 1.79$. In addition, a narrow two-phase region exists between $BkO_{1.91}$ and $BkO_{1.93}$. Certain similarities are shown to exist between this and certain other fluorite related ternary oxide systems.

In addition, melting behavior of the di- and sesquioxides and polymorphism in the sesquioxide is described over the entire actinide series.

Binary solid solutions of PaO_2 and other actinide dioxides and their exchange equilibria with molten salt reactor fluorides, C. E. Bamberger, R. G. Ross, and C. F. Baes, Jr., *SP364*, pp. 331-341 (July 1972).

Key words: Activity coefficients in solid solutions; equilibria with molten fluorides; equilibrium of actinide oxides and molten fluorides; heat of mixing in solid solutions; ion exchange between solid oxides and molten fluorides; lattice parameter of actinide oxides; molten fluorides; molten salt reactor; oxide solid solutions; plutonium dioxide; protactinium dioxide; thorium dioxide; uranium dioxide.

The dioxides of thorium, protactinium, uranium and plutonium all are relatively insoluble in molten mixtures—containing LiF, BeF_2, ThF_4, PaF_4, and UF_4 or UF_3—which serve as the fuel of the molten salt nuclear power reactors (MSR's). Since these dioxides can form substitutional solid solutions, exchange reactions of the type

$$ThO_2(ss) + MF_4(d) \rightleftarrows ThF_4(d) + MO_2(ss);\ Q_{Th}^{M} = \frac{X_{MO_2}}{X_{ThO_2}} \frac{X_{ThF_4}}{X_{MF_4}}$$

involving the solid solution (ss) and the molten fluoride phase (d) become possible. It is of interest to study such exchange equilibria not only because the inadvertent precipitation of fissile oxide solids from an MSR fuel should be avoided, but also because such reactions might provide a means of separating and recycling the fissile and fertile elements.

A study of the exchange reaction involving Pa^{4+} and Th^{4+} has been carried out in which PaO_2-ThO_2 solid solutions ($X_{PaO_2} \leq 0.33$) were formed by equilibration of ThO_2 with molten LiF-BeF_2-ThF_4-PaF_4 (72-16-12-0.05 mol %) in the temperature range 570-730 °C. The resulting values of the distribution quotient Q_{Th}^{Pa}, along with previously measured values of Q_{Th}^{U} and a value of Q_{Th}^{Pu} derived indirectly from other previous measurements, are consistent with the following expressions

$$\ln \gamma_{MO_2} = 10^6 \left(\frac{1.228 \pm .15}{T}\right)\left(\frac{\Delta a}{a_{ThO_2}}\right)^2 X_{ThO_2}^2;$$

$$\ln \gamma_{ThO_2} = 10^6 \left(\frac{1.228 \pm .15}{T}\right)\left(\frac{\Delta a}{a_{ThO_2}}\right)^2 X_{MO_2}^2$$

$$\ln Q_{Th}^{M} = 10^6 \left(\frac{1.318 \pm .03}{T}\right)\left(\frac{\Delta a}{a_{MO_2} a_{ThO_2}}\right)$$

$$+ 10^6 \left(\frac{1.228 \pm .15}{T}\right)\left(\frac{\Delta a}{a_{ThO_2}}\right)^2 (2X_{MO_2} - 1)$$

wherein the activity coefficients in the solid solution are related to the difference in the lattice parameters ($\Delta a = a_{ThO_2} - a_{MO_2}$) as suggested by Hietala's model.

Growth and x-ray studies of single crystals of higher oxides of praseodymium and terbium, M. Z. Lowenstein, L. Kihlborg, K. H. Lau, J. M. Haschke, and L. Eyring, *SP364*, pp. 343-351 (July 1972).

Key words: Higher oxides; hydrothermal crystal growth; oxide structures; praseodymium oxide; single crystal; terbium oxide.

Single crystals of higher oxides of praseodymium and terbium have been grown successfully using hydrothermal techniques. Cold seal reactors were utilized to study the crystallization process over a temperature range of 600-900 °C and at pressures up to 3.1 kilobar. Crystal growth conditions were optimized using controlled pressure and temperature cycling. Any oxide of praseodymium may be used as starting material. Nitric acid served both as a mineralizer to promote solubility and as a source of oxygen. Two predominant crystal habits are observed; octahedra and trigonal prisms. Faces are smooth and well defined.

Single crystals of praseodymium dioxide have been reduced to $PrO_{1.833}$ in the homologous series Pr_nO_{2n-2} with crystal integrity maintained. X-ray data have been obtained on these crystals using Weissenberg and Hägg-Guinier cameras. The phase has a fluorite-type sublattice with a superstructure of monoclinic symmetry (space group $P2_1/n, C_2^5h$) and a unit cell having $a = 6.6874$ Å, $b = 11.602$ Å, $c = 15.470$ Å, $\beta = 125.257°$ and $V = 979.6$ Å^3. Indexing of the powder pattern of this phase has been completed on the basis of this cell. The relationship to the fluorite subcell is shown.

Defects and mass transport in reduced CeO_2 single crystals, Y. Ban and A. S. Nowick, *SP364*, pp. 353-365 (July 1972).

Key words: Ceria; crystal defects; diffusion; mass transport; nonstoichiometry; oxides.

A study is made of reduced CeO_2 in the form of large single crystals grown by arc fusion. It is shown that, so long as $y \geq 1.67$ in the formula CeO_y, all structural changes on reducing CeO_2 occur without loss of coherency of the original fluorite lattice. Comparison of length and lattice parameter changes shows that only oxygen vacancies (and no detectable Ce interstitials) are present in the reduced state. For $y > 1.67$, it is shown that oxidation (in air or in O_2) takes place at reasonable rates just above room temperature. The kinetics of this anomalously rapid mass transport are studied in some detail, including the effects of sample thickness and of oxygen partial pressure. The results show that the kinetics are neither diffusion nor surface controlled. A model of the process is developed which explains the major results. The low temperature oxidation process does not terminate in the pure α (CeO_2) phase, but in a metastable structure, here called α', for which y is very close to 2.0. The properties of α' are discussed.

Anion centered coordination polyhedra and related physical properties in rare earth oxides and oxysalts, P. E. Caro, *SP364*, pp. 367-383 (July 1972).

Key words: Complex ions; coordination polyhedra; nonstoichiometry; polymolecular frameworks; rare earth optical spectra; rare earth oxide; refractory materials; thin films; 4 f^n configurations.

The structures of rare earth oxides and oxysalts can be conveniently described in terms of linkages of anion centered coordination polyhedra, namely tetrahedra, yielding two-dimensional or three-dimensional frameworks. A complex "lanthanyl" cation $(LnO)_n^{n+}$ can be recognized. It has two different arrangements of tetrahedra, one of them being identical with the well known "bismuthyl" cation $(BiO)_n^{n+}$. The structural elements are similar to the classical SiO_2 and Si_xO_y ones; SiO_4 tetrahedra frameworks, used for silicates structures classification. Other anions than oxygen (sulfur and halides) yield isomorphous networks.

Such types of structures imply some sort of covalent bonding. The covalence of the bond can be shown from optical measurements on solids. For (OLn_4) compounds the absorption spectrum is displaced to the red (nephelauxetic effect), a phenomenon which corresponds to the lowering of the Racah's parameters of the 4 f^n configuration. The mixing of the $|\,4\,f^n>$ wave functions with ligand wave functions also yields larger transition probabilities and the $(LnO)_n^{n+}$ materials are very effective phosphors.

The layered oxide structures also yield textured thin films which exhibit epitaxial continuity and intergrowth between the rare earth oxides phases.

The layered polymolecular complex cation concept can be applied to rare earth extended non-stoichiometric systems. It can be shown that the chemical composition of all the known phases of those systems can be accounted for in terms of the succession along a main crystallographic axis of four planar chemical units ABCD. Non-stoichiometry occurs because a layered structure AB is able to be interleaved

through another layered structure ADCD. A general chemical formula for the ordered phases was derived, for the bastnaesite family of compound (AB = bastnaesite, ADCD = synchisite), the Ln_2O_3-LnF_3 systems (AB = tysonite, ADCD = trigonal EuOF), the LnO_x systems (AB = Ln_6O_{10}, ADCD = $Ln_{12}O_{22}$) and the $LnCl_3$-$LnCl_2$ system (AB = $LnCl_3$, ADCD = $LnCl_2$). All of the compounds contain layered polymolecular complex cations.

Plasma-synthesized substoichiometric scandium oxide, J. E. Young, Jr., and M. J. Sienko, *SP364*, pp. 385-395 (July 1972).

Key words: Crystal growth; F centers; flame fusion; magnetic susceptibility; nonstoichiometry; scandium oxide.

Crystals of substoichiometric scandium oxide have been grown in high frequency, induction-coupled, argon plasmas. The composition of the crystals could be varied by addition of small percentages of hydrogen or oxygen to the argon stream. Chemical analysis by reoxidation indicated an oxygen deficiency that could attain 4% before metallic films appeared, concentrated at grain boundaries. The chemical composition of the films could not be established. X-ray studies of the bulk crystals indicated retention of the C-type rare earth structure of Sc_2O_3 with but slight shrinkage of the cubic cell parameter. Transmission electron microscopy showed no evidence for shear plane formation. Attempts to measure Hall voltage and conductivity by a van der Pauw technique gave conductivity values, both a.c. and d.c., too small to measure. Faraday susceptibility measurements from 1.6 to 300 K indicated a very small effective magnetic moment, which decreased below 10 K. Possible models are F and F′ centers in thermal equilibrium or Sc^{+1} ions with thermal equilibrium between ^3D and ^1D or ^3D and ^1S states.

Crystal chemistry and compound formation in the systems rare earth sesquioxide-WO_3, G. J. McCarthy, R. D. Fischer, G. G. Johnson, Jr., and C. E. Gooden, *SP364*, pp. 397-411 (July 1972).

Key words: Fluorite-related structures; rare earth tungstates; rare earth tungsten oxides; RE_2O_3-WO_3 compounds; RE-W-O systems.

Compounds with the following stoichiometries have been prepared in the rare earth sesquioxide-tungsten trioxide systems: RE_6WO_{12}, $RE_{10}W_2O_{21}$, $RE_{14}W_4O_{33}$, RE_2WO_6, $RE_2W_2O_9$. Compounds of the first three stoichiometries prepared at 1400 °C have structures apparently related to that of fluorite. RE_6WO_{12} has three structural classes whose symmetries are dependent on the rare earth ionic radius: La-Pr, cubic or pseudocubic; Nd-Gd, pseudotetragonal; Tb-Lu, Y, rhombohedral. $RE_{10}W_2O_{21}$ is stable only for RE = Gd-Ho, Y and has the same pseudotetragonal symmetry as the intermediate RE_6WO_{12} compounds. $RE_{14}W_4O_{33}$ has a pseudorhombohedral structure related to the third RE_6WO_{12} structure. The rhombohedral RE_6WO_{12} compounds are known to be isostructural with RE_7O_{12} oxides and it is suggested that $RE_{10}W_2O_{21}$ and $RE_{14}W_4O_{33}$ may be structurally related to RE_4O_7 and RE_6O_{11} respectively. RE_2WO_6 compounds with RE = Pr-Dy have a monoclinic scheelite-related structure. The $RE_2W_2O_9$ compounds, also with a complex monoclinic structure, are stable only for RE = Ce-Gd (or Tb). Compounds of the stoichiometries $RE_4W_3O_{12}$ and $RE_2W_3O_{12}$ were not studied, but the literature information on them is noted. A discussion of the probable subsolidus phase relations in RE-W-O systems is also included.

Preparation of oxides and related compounds by chemical transport, H. Schäfer, *SP364*, pp. 413-436 (July 1972).

Key words: Chemical Vapor Transport; crystal growth; oxides; synthesis.

In a temperature gradient it is possible for solids to migrate by sublimation, by catalytic sublimation (P_{red}/I_2), dissociative sublimation and by chemical transport.

Reversible heterogeneous reactions are utilized in chemical transport. The phenomenon is complex but can normally be treated as gaseous diffusion between spaces in which thermodynamic equilibrium has been established between solid and gaseous phases. The partial pressure drop between these spaces is the quantity which determines the suitability of a chemical reaction for transport processes.

Information is given regarding working techniques and transport agents which have been employed hitherto.

In further chapters there is an account of the binary oxides which have been chemically transported up to now and there is also an account of the types of reaction used for transport.

Using zinc oxide transport as an example, a demonstration is given of the selection of transport reactions on the basis of thermodynamic considerations.

There is a discussion of syntheses in a temperature gradient and of "solid/solid reactions," with regard to the preparative employment of chemical transport processes. This discussion is illustrated with several examples. There is in addition a review of the transport of ternary compounds and of the decomposition of ternary compounds which can occur under the influence of the transport agent.

Examples are given of the crystallization of metastable modifications out of the gas phase.

Precision parameters of the ferroelectric rare earth molybdates $Ln_2(MoO_4)_3$, L. H. Brixner, P. E. Bierstedt, A. W. Sleight, and M. S. Licis, *SP364*, pp. 437-443 (July 1972).

Key words: Ferroelectric molybdates of rare earths; lattice parameters; phase transitions.

Lattice parameters to an accuracy of better than ±0.001 Å have been determined for the ferroelectric $Ln_2(MoO_4)_3$ compounds with Ln = Pr, Nd, Sm, Eu, Gd, Tb, Dy and Ho. X-ray patterns were obtained with a Hägg-Guinier camera and the data was refined by a least-squares method using selected reflections. Parameters obtained this way exhibited a systematic trend of the *b-a* dimension as a function of the cation size for the orthorhombic Pba2 room temperature structure. A linear relationship between the cell volume and the cube of the ionic radius of the rare earths has been observed. The first seven compounds are metastable at room temperature and transform from the ferroelectric/ferroelastic Pba2 structure to the parent $P42_1m$ structure between 140 and 235 °C. Only $Ho_2(MoO_4)_3$ is stable in the Pba2 phase at room temperature and transforms into the tetragonal structure at 121 °C. The high temperature structure for this compound is orthorhombic, space group Pnca. The transition temperatures have been accurately determined by differential scanning calorimetry, differential thermal analysis, dielectric measurements and hot-stage optical techniques and are discussed in relationship with the degree of *b-a* distortion. Lattice parameters have also been determined for the stable monoclinic modification of Sm, Eu, Gd, Tb and Dy-molybdate and their transition temperatures ranging from 800 to 1000 °C, as reported.

Structural and phase relationships among trivalent tungstates and molybdates, K. Nassau and J. W. Shiever, *SP364*, pp. 445-456 (July 1972).

Key words: Crystal structure; lanthanide compounds; molybdates; tungstates.

The trivalent tungstates $L_2(WO_4)_3$, molybdates $L_2(MoO_4)_3$, and mixed systems, $L_2(W_{1-x}Mo_xO_4)_3$ have been studied between room temperature and the melting points (up to 1650 °C). Single crystal and powder x-ray diffraction at room and elevated temperatures, differential thermal analysis, and crystal growth were among the techniques used to characterize phases and determine relationships.

Among the molybdates of the lanthanides, In, Sc, Fe, Cr, and Al, at least five structures were observed: the tungstates show at least three. Particular attention was devoted to $Tb_2(MoO_4)_3$, which, like $Gd_2(MoO_4)_3$, shows transitions at 800, 1040 and melting at 1155 °C and a ferroelectric transition at 163 °C in the metastable phase region; not all of these transitions are easily reversible.

Pseudo-binary tungstate-molybdate phase diagrams and structural parameters were determined for the La, Nd, Sm, Gd, Ho, and In systems. Based on structural determinations together with phase diagram interpretations and crystal growth evidence of the nature of various transitions (destructive or nondestructive), structural relationships were used to organize the many structures into three groupings and relate the results to the radii of the trivalent atoms:

(i) The small size tungstates and molybdates, the $Sc_2(WO_4)_3$ type family, with at least two members, form 6-coordinated structures with unit cell or subcell based on *Pnca*; with rising temperature this family extends to larger size atoms.

(ii) The large size tungstates and molybdates form 8-coordination structures with scheelite related subcells; this α-$Eu_2(WO_4)_3$ type family includes at least 4 structures.

(iii) The β-$Gd_2(MoO_4)_3$ type family of structures, occurring only in the intermediate size molybdates, have 7-coordinated trivalent atoms; except for $Y_2(MoO_4)_3$ they are stable only above 800 °C, although extensive metastability does occur with ferroelectric transitions in the metastable form near room temperature.

Crystal chemistry of tetrahedrally-coordinated oxides: Li_3PO_4 derivatives, A. R. West and F. P. Glasser, *SP364*, pp. 457-469 (July 1972).

Key words: Crystal chemistry; kinetics; lithium arsenate; lithium phosphates; lithium vanadate; phase transformation; polymorphism.

The high and low polymorphs of Li_3PO_4 are type structures for a large family of tetrahedrally-coordinated oxides. These are readily synthesized by direct solid state reaction of the constituent oxides or by hydrothermal reaction. The simplest substances which are Li_3PO_4-type include Li_3VO_4 and Li_3AsO_4, although the high-low inversion in the latter two proceeds reversibly through one or more intermediate phases which are thermodynamically stable over a short range of temperatures.

The intermediate phases often undergo further structural distortion during quenching to ambient. Li_3PO_4 itself forms an intermediate phase in the conversion low → high Li_3PO_4. This intermediate phase is readily retained to ambient but is believed to be metastable at all temperatures. More complex Li_3PO_4 derivatives include substances of the general formula Li_2MXO_4, where M = Mg, Zn, Co^{2+} and X = Si, Ge^{4+}. Each compound usually has at least two polymorphs. These fall into three classes: one which is either high or low Li_3PO_4 type, one which includes the distortional derivatives of both high and low Li_3PO_4, and lastly, phases of related but unknown structures. A full explanation of the polymorphism of an individual phase is only possible if effects due to solid solution are taken into account. For example, the stoichiometry of "Li_2ZnSiO_4" varies within the system Li_4SiO_4-Zn_2SiO_4; the solubilities of excess Li^+ and Zn^{2+} have been measured as a function of temperature. Inversion temperatures, and especially, the occurrence and stability of many of the distortional derivative structures, are closely related to the stoichiometry.

The possibilities of making other substitutions, such as replacing $(Li^+ + M^{2+})$ by A^{3+}, where A = Al, Ga^{3+}, etc., are discussed.

This family of phases is probably of widespread occurrence. We have encountered these phases in glass-ceramic systems, such as Li_2O-MgO-ZnO-SiO_2, where they are an important crystallization product of *all* glass composition.

On the solidification temperature and the nonstoichiometry of cobaltous oxide in an oxidizing atmosphere, J. P. Coutures and M. Foex, *SP364*, pp. 471-481 (July 1972).

Key words: CoO-O_2 system; melting point depression; nonstoichiometry in liquid CoO; solar furnace; thermal analysis.

Liquid cobaltous oxide can dissolve a large amount of oxygen depending on temperature oxygen partial pressure and time. Therefore, the solidification temperature decreases when the amount of oxygen in the liquid phases increases. During solidification, a "spitting" phenomena occurs. The behavior (spitting phenomena for example) and the properties of this oxide (solidification temperature, melt composition, solid composition) are studied by high temperature techniques.

The system FeO-SiO_2-TiO_2 at high temperatures and high pressures, E. Woermann and A. Lamprecht, *SP364*, p. 483 (July 1972).

Key words: FeO-SiO_2-TiO_2 system; high pressure; high temperature; ternary system.

The investigations of liquidus and solidus relationships in the system FeO-SiO_2-TiO_2 in equilibrium with metallic iron at one atmosphere total pressure revealed four ternary invariant points:

(1) L = wüstite + fayalite + ulvöspinel (1169° C); (2) L = fayalite + tridymite + ulvöspinel (1145 °C); (3) L + ilmenite = tridymite + ulvöspinel (1180 °C); and (4) L + ferropseudobrookite = tridymite + ilmenite (1254 °C).

In the system ferropseudobrookite-tridymite-*rutile* in equilibrium with metallic iron considerable amounts of trivalent titanium are observed at solidus and liquidus temperatures. The titanium bearing phases thus are located outside of the ternary system FeO-SiO_2-TiO_2 toward the oxygen deficient side.

At elevated pressures the following reactions occur:

(1) Ferropseudobrookite = rutile + ilmenite; (2) ulvöspinel + quartz = fayalite + ilmenite; (3) fayalite + quartz = ferrosilite; and (4) ulvöspinel = wüstite + ilmenite.

Depending on temperature and pressure the iron titanium phases form limited solid solutions in the system FeO-SiO_2, due to the occurrence of defect structures.

Carbides and silicides, H. Nowotny, H. Boller, and G. Zwilling, *SP364*, pp. 487-504 (July 1972).

Key words: Carbides; chemical bonding; defect structures; interstitial compounds; ordering; silicides.

A brief survey of the structural chemistry of transition element carbides will be presented with emphasis on the problem of carbon-void ordering. The scandium carbides including $Sc_{15}C_{19}$ are to be discussed. Complex carbides which derive from octahedral and trigonal prismatic building

elements will be classified. Metal-metal carbides such as VCr_2C_2 and metal-nonmetal carbides such as Ti_3SiC_2, V_4P_2C, Nb_2SC or Ta_2S_2C will be interrelated. The role of nitrogen and hydrogen on the stabilization of complex carbides such as $Cr_3(C,N)_2$ or $Zr_2CH_{0.5}$ will also be treated. Besides the class of typical interstitial carbides, some examples of metal boro-carbides displaying a two-dimensional boron-carbon network will be given (YB_2C). In compounds such as $Cr_2(P,C)$ carbon plays an intermediate role. The present state of the problem of chemical bonding in carbides will be discussed.

Binary metal silicides are numerous and occur almost at any composition. They are commonly classified as valence compounds (electronegative), metal-like silicides (electropositive) and clathrate silicides (mainly electroneutral). Disilicides and related compounds exhibit a particularly wide occurrence. The continuous change of structural elements and properties of this group will be discussed. So-called defect disilicides of formula T_nSi_{2n-m} (T = transition element) which are derived from the $TiSi_2$ type structure belong to a uniform building principle, where n presents the number of subcells and m the deviation from the disilicide composition. In many cases a relation of the electronic concentration with m can be observed. In general, lowering of the overall electron concentration diminishes the defect m. Single crystal work on $Mn_{27}Si_{47}$ will be described. This phase, a fifth variety having a composition in the vicinity of $MnSi_{\sim 1.7}$, presents the problem of pseudo-homogenous domains. Some ternary silicides such as E-phases will be discussed from the viewpoint of ordered structures.

Investigations in the ternary system—boron-carbon-silicon, E. Gugel, R. Kieffer, G. Leimer, and P. Ettmayer, *SP364*, pp. 505-513 (July 1972).

Key words: Binary system; boron; carbon; chemical analysis; melting-point determination; metallography; phase-field division; silicon; solubilities; ternary system; x-ray investigations.

Viewing the literature one will notice that the available knowledge about the nonmetallic inorganic systems are rather insufficient and sometimes do not agree with each other. These systems yield a number of attractive high temperature materials and therefore it is essential to improve available information.

The Institut für chemische Technologie anorganischer Stoffe (Institute for Chemical Technology of Inorganic Materials), Technical University of Vienna, and the Research Institute of the Cremer-Group, Rödental-Germany, have systematically worked in this area for several years. This paper will deal with the system Boron-Carbon-Silicon.

In contradiction, some publications confirmed the existence of B_4C only in the enclosing system Boron-Carbon. However, Boron Carbide is able to incorporate excess Boron up to the composition $B_{6.5}$ (in solid solution) clearly showing a lattice expansion. Within the enclosing system Silicon-Boron there are the chemical compounds SiB_{4-x} ($x \leq 1$) and SiB_{12+x} ($x \geq 8$). According to our investigations the ternary system itself, in contrast to some other scientists, does not contain ternary phases as well as no solid solution between enclosing binary systems. Limited solid solutions exist around B_4C (+ Si) and around SiB_{4-x} (+ C). The x-ray investigations permit the presentation of phase distributions. By means of a new method for determination the melting temperatures of high temperature materials the liquidus areas (melting isotherms) of this system were investigated.

Valence bonding in some refractory transition metal compounds with high coordination, F. L. Carter, *SP364*, pp. 515-559 (July 1972).

Key words: Aluminum diboride—cadmium diiodide structure; bidirectional orbitals; effective charge; ESCA; Fermi surface distortion; Madelung constant; Madelung potential; metallic single bond radii; refractory transition metal compounds; tungsten carbide; valence bonding; Voronoi polyhedra.

Bond formation in transition metal compounds isomorphous with WC and AlB_2 is formulated using the bidirectional orbital approximation (BOA) to establish orbital hybridization and a simple but self-consistent application of Pauling's metallic radii with charge transfer to obtain the bond orders. For tungsten carbide seven mutually orthogonal bidirectional bonding orbitals for the negative W atom permit it to simultaneously bond its fourteen neighbors with up to 6.5 electrons. However, bond polarization results in an effective negative charge for carbon of 0.0 to $-0.3e$. For the diborides the metallic radii results indicate that the group IV diborides have a slightly positive boron which becomes negative with increasing group number but remains below a charge of $-1e$. Four arguments are given for the pleating of the boron layer were it to be heavily charged as has been proposed earlier in the isoelectronic analogy to graphite. One of these involves a new definition of atomic volume based on the Voronoi polyhedron. Bond formation by the boron and carbon atoms in these compounds is discussed using the nonpaired spin-orbital [NPSO] approach of Linnett.

Madelung constant and Madelung potentials calculations via the method of Bertaut have been made for both the tungsten carbide and the $AlB_2(CdI_2)$ structure. These were computed in order to both estimate the magnitude of the electrostatic stability as a function of atomic parameters and to provide a basis for the comparison of ESCA chemical shift data with the calculated effective charge.

The effect of bond formation in distorting the surfaces of constant energy in k space is also considered in these compounds with the aid of a simple square well potential model. The principle directions of these distortions of the unreduced Fermi surface are indicated for the WC structure and as a function of the boron position parameter for the AlB_2 structures.

Finally, we note that in both of these structures almost all the electrons outside the rare gas cores are involved in bond formation; this is in contrast to the refractory chalcogenides.

Crystal chemistry of refractory carbides, A. L. Bowman, *SP364*, pp. 561-566 (July 1972).

Key words: Carbide; crystal structure; molybdenum carbide; niobium carbide; reaction mechanism; solid state; tantalum carbide; tungsten carbide; vanadium carbide.

The crystal structures of most of the refractory metal carbides may be described generally on the basis of a close-packed metal sublattice, with the carbon atoms occupying all or part of the octahedral sites. Close-packed carbide structures have been observed with composition MC and packing type c, M_4C_3 and hhcc, M_3C_2 and hcc or hhc, and M_2C and h or c. All of these structures have one octahedral site per metal atom, and thus an apparent possible composition MC. This is reached however, only with the c-type packing, and it has been suggested that only one half of the sites adjacent to an h layer can be filled. This is found to be an upper limit that is not always reached. These carbide structures thus have carbon vacancy concentrations ranging from ~ 0 up to $\sim 70\%$, with a possibility of vacancy order-

ing. Neutron and electron diffraction studies have shown ordering to exist in the M_2C compounds and in carbon-deficient VC.

The order-disorder transformation of the carbon vacancies in Mo_2C has been studied in detail with high-temperature neutron diffraction. The kinetics data are consistent with a nucleation-growth mechanism involving nucleation on grain boundaries and linear growth across the interface. The reaction between Mo_2C and Mo_3C_2, involving the transformation of the close-packed metal lattice ($h \rightleftharpoons hcc$) has been studied less thoroughly, but the kinetics data also appear to be consistent with a nucleation-growth mechanism.

A simple model for the stability of transition metal carbides, R. G. Lye, *SP364*, pp. 567-582 (July 1972).

Key words: Bonding; carbides; cohesive energy; density of states; electronic structure; heat of formation; $L_{II,III}$ spectra; refractory hardmetals; Ti; TiC; transition metal compounds.

The origins of the unusual and complex combination of physical properties exhibited by the transition metal carbides remain somewhat obscure despite extensive studies of the problem in recent years. Even the qualitative nature of the bonding has not yet been described in a manner that accounts satisfactorily for the diverse and sometimes apparently contradictory experimental observations made on these compounds.

One theme, however, recurring through the years of study, draws attention to the similarity of these compounds to the parent transition metals. This characteristic of the carbides is considered briefly in the present study in an attempt to provide a qualitative explanation for the manner in which the stability of the carbide phases varies with the position of the parent metal in the periodic chart of the elements. A simple model for the d band bonding in the transition metals, discussed by Cyrot-Lackmann, is modified for this purpose. In particular, it is assumed that a major component of the bonding in the carbides arises from crystalline electronic energy bands derived for the d states of the metal atoms. Because of changes in crystal structure, these bands are modified somewhat from the shape of the corresponding bands in the parent metal. Of greater importance for the stability of the carbides, however, is the increase in the width of the band, discussed by Costa and Conte, that results from the presence of the carbon atoms within the interstitial positions in the metal sublattice.

As for the parent metals, the cohesion of the carbides is determined by the number of electrons in the d band. In the carbides, however, it is assumed that some of these electrons are provided by transfer from the 2p states of the carbon atoms. Thus, the stability, as measured by the heat of formation, results from the combined effects of the increase in the width of the d band and in the number of electrons it contains.

Despite the considerable simplifications employed, an analytical formulation of this model yields estimates for the heats of formation of the carbides that agree remarkably well with the experimental data presently available.

Ordering effects in NbC and TaC, J. D. Venables and M. H. Meyerhoff, *SP364*, pp. 583-590 (July 1972).

Key words: Carbides; electron diffraction; interpretation of ordering effects; niobium carbide; ordering effects; superlattice; tantalum carbide; transition metal compounds; vanadium carbide.

Studies of the phase equilibria in the MC transition metal carbides have shown that they retain their nominal NaCl structure over a relatively wide phase field. Although it is well known that this wide latitude in composition is accomplished through the incorporation of carbon vacancies in the carbon sublattice, there is considerable uncertainty regarding the degree of order exhibited in most of the carbides by the remaining carbon atoms. In this investigation, an attempt has been made to resolve this question for NbC and TaC using some of the techniques applied previously in a study of ordering in the vanadium-carbon system.

By means of transmission electron microscopy and electron diffraction, evidence has been obtained for the existence of long range carbon atom ordering in single-crystal niobium carbide that has a carbon-to-metal ratio close to the integral composition Nb_6C_5. The ordering, which gives rise to superlattice and domain structures similar to those observed in V_6C_5, appears, however, only in samples that have been cooled slowly (~ 8 °C/h) through the order-disorder temperature of 1025 C. In TaC of similar composition, the ordering, although present, remains very imperfect even after the crystals are subjected to the same thermal treatment.

The results are interpreted in terms of the electronic structure of the transition metal carbides as it is currently understood, and their relevance to the mechanical properties of NbC and TaC are discussed.

The CdP_2-Ge system and the growth of crystals of $CdGeP_2$, E. Buehler and J. H. Wernick, *SP364*, pp. 591-595 (July 1972).

Key words: $CdGeP_2$; CdP_2-Ge system; Ge; phase diagram; single crystals.

The macroscopic features of the phase relationships in the CdP_2-Ge system have been determined. The tetragonal $CdGeP_2$ phase melts congruently at 790 ± 5 °C. Two eutectics are present: one between CdP_2 and $CdGeP_2$ at ~ 700 °C and 20 mol % Ge, and the other, between $CdGeP_2$ and Ge at ~ 750 °C and 65 mol % Ge. Techniques and results for the growth of crystals from stoichiometric melts, by chemical transport, and from liquid Cd and Sn are presented.

High boron content rare-earth borides, K. E. Spear and G. I. Solovyev, *SP364*, pp. 597-604 (July 1972).

Key words: Borides; lattice constants; LnB_{66} compounds; melting temperatures; microhardness; rare-earth borides.

Investigations were performed to determine which rare-earth metals form LnB_{66} phases, and to measure some of the properties of these compounds. Similar rare-earth borides have been recently reported with B:Ln ratios of 50 to 100 for metals Y, Gd, Tb, Ho, and Yb. A single crystal structure analysis published on the yttrium compound shows the structure to be face-centered cubic with an ideal stoichiometry YB_{66}. In the present studies, ten representative metals were used: Y, La, Ce, Pr, Nd, Sm, Gd, Dy, Er, and Yb. Boron-rich compositions were prepared by arc-melting mixtures of the elements. Identification of the phases in each sample was performed with the use of x-ray and metallographic techniques. All of the investigated systems except La, Ce, and Pr formed the LnB_{66} phase, and it is predicted that all rare-earth metals from Nd through Lu will form this phase. Lattice parameters were measured and show a general, but not regular decrease with atomic number. The LnB_{66} phases are extremely hard, with Vickers microhardness values ranging from about 3600 to 4000 kp/mm^2. Melting temperatures for the LnB_{66} phases were essentially the same for all metals, and equal to approximately 2150 °C.

Preparation and characterization of boron suboxide, D. R. Petrak, R. Ruh, and B. F. Goosey, *SP364*, pp. 605-611 (July 1972).

Key words: Amorphous boron; anhydrous boric acid; boric oxide; boron carbide structure type; boron suboxide; crystal structure; decompose; electron microbeam probe; infrared spectrum; lattice parameters; pycnometer; reaction-hot pressing; rhombohedral boron; x-ray diffraction.

Fabrication techniques have been developed to produce specimens of near theoretical density by reaction hot pressing of boron and boric acid in vacuum at temperatures of 1900-2000 °C and pressures of 0.41 kbars. The composition range 80 to 89 atomic % boron was investigated by chemical analysis, lattice parameter studies, pycnometric density determinations, electron probe analysis and infrared analysis. Results support the $B_{12}O_2$ chemical formula and the R3m space group with twelve boron atoms in the 18h positions and two oxygen atoms in the 6c positions. Thus, on the basis of the experimentally determined hexagonal lattice parameters of $a = 5.386 \pm 0.003$ Å and $c = 12.326 \pm 0.004$ Å, the calculated density is 2.602 $g \cdot cm^{-3}$ and this is in good agreement with the experimentally determined value of 2.600 ± 0.007 $g \cdot cm^{-3}$. The occupancy of the 3b position by either boron or oxygen (to allow the B_4O or $B_{13}O_2$ stoichiometry) is ruled out since this would require increases in density and/or lattice parameters and none were observed. Also these configurations do not satisfy the Longuet-Higgins and Roberts counting rule. The boron suboxide phase has been studied by electron probe and infrared analyses. The oxygen K emission spectra as well as the infrared reflection spectra are presented. Boron suboxide has been studied by mass spectrometric analysis and found to decompose to rhombohedral boron and B_2O_2.

Ternary transition metal silicides and germanides: Ordering and metal-metal bonding in Ni_2In-related phases, V. Johnson and W. Jeitschko, *SP364*, pp. 613-622 (July 1972).

Key words: Fe_2P and Mn_5Si_3; metal-metal bonding; metal-site occupancies; Ni_2In; ordered ternary silicides and germanides; silicides and germanides; ternary Ni_2In-related phases; TiNiSi.

Ternary transition metal silicides and germanides with structures related to Ni_2In ("filled" NiAs) are reviewed. For compositions TT'Si and TT'Ge, where T is a transition metal from groups IV, V and VII and T' is from the iron group, the structures adopted are TiNiSi (ordered anti-$PbCl_2$), ordered Fe_2P, TiFeSi or Ni_2In. We describe and illustrate how these as well as the hexagonal Mn_5Si_3 structure are related.

Metal site occupancies in ternary TiNiSi and Fe_2P-type silicides and germanides and pseudobinaries with Ni_2In and Mn_5Si_3 structures are also reviewed. We discuss the importance of the relative size and electronegativity of the transition metal atoms and their d-electron configurations in determining site preferences.

Bonding in these Ni_2In-related phases, $(TT')_{2-x}Si(Ge)$, is discussed. The structures differ principally in the strengths of the respective T-T, T-T', and T'-T' metal-metal interactions. Questions as to how these are determined by electronegativities, size and d-electron configuration, and how they in turn affect phase stability and metal-site occupancies are raised.

Structural transitions of some transition-metal chalcogenides, F. Jellinek, *SP364*, pp. 625-635 (July 1972).

Key words: Dichalcogenides; intercalation compounds; layer structures; modulated structures; occupation waves; selenides; semiconductor-to-metal transitions; structure transitions; sulfides; tellurides; transition-metal chalcogenides; trigonal-prismatic coordination.

A survey is given of some recent investigations on transition-metal chalcogenides (sulfides, selenides, tellurides) carried out in the author's laboratory; particular attention is paid to compounds undergoing structural transitions at elevated temperatures. Examples are given of transitions involving a change of the coordination of the metal ($NbSe_2$, TaS_2, $TaSe_2$, $MoTe_2$, Ni_3Se_2), of order-disorder transitions ($AgCrSe_2$ and related compounds; chromium sulfides, $Ni_{3\pm x}Te_2$), and of transitions involving distortions of the structure (CrS, VS, $Nb_{1-x}S$). The occurrence of trigonal-prismatic coordination in several transition-metal chalcogenides is ascribed to d-covalency which stabilizes trigonal-prismatic with respect to octahedral coordination for ions with a d^0, d^1 or spin-paired d^2 configuration. The effect of the metal coordination on the physical properties of the compound is also described. The distributions of occupied and vacant metal sites in transition-metal chalcogenides $M_{1+p}X_2$ are discussed (chromium sulfides, zirconium selenides), as is the concept of "occupation waves" (titanium sulfides). In $Ni_{3\pm x}Te_2$ occupation waves lead to a phase lacking three-dimensional periodicity; the intervention of this phase allows smooth transitions from the disordered high-temperature form to the ordered low-temperature forms (two-step second-order transition).

Solid solubility in the face centered cubic Gd_xSe_{1-x} system, F. Holtzberg, D. C. Cronemeyer, T. R. McGuire, and S. von Molnar, *SP364*, pp. 637-644 (July 1972).

Key words: Color-concentration dependence; gadolinium monoselenide; Hall effect; homogeneity range; magnetic ordering; reflectivity; resistivity; single crystal growth.

The range of homogeneity has been studied in the face-centered cubic Gd_xSe_{1-x} system. The solid solution field is bounded by the composition $x = 0.443$ for excess Se and extends through the stoichiometric composition to at least 0.512 for excess Gd. The lattice constant decreases linearly with decreasing Gd concentration except at lowest values of x. The materials have been characterized by resistivity, reflectivity and magnetic measurements. The results of the transport and reflectivity measurements are explained on the basis of a simple single rigid band model. Magnetization measurements show that all compositions order antiferromagnetically with the Neél temperature, T_N, varying from ~ 20 to ~ 60 K and θ from -25 to -135 K with increasing Gd or electron concentration.

Ternary chalcogenides of light rare earth elements with transition elements, G. Collin, H. D. Nguyen, O. Gorochov, M. Guittard, P. Laruelle, and J. Flahaut, *SP364*, pp. 645-65(
(July 1972).

Key words: Crystal structure; magnetic properties; rare earth; ternary chalcogenides; transition metals.

Description of three new crystal families. Crystal structures. Magnetic properties. (1) $La_2Fe_2S_5$-type – orthorhombic $A2_1am$; (2) $La_8Fe_3S_{15}$-type – monoclinic Bm. These two structures have similarities. The rare earth atoms are 7-8 coordinated. The Fe atoms have two kinds of environments: 4-coordinated in a distorted tetrahedron of S atoms, 6-coordinated in a distorted octahedron of S atoms. In both cases 2 neighboring Fe atoms are associated by 2 intermediate S atoms. These 4 atoms form a distorted quadrilateral with Fe-S-Fe angles not far from 90°; (3) $CeCrSe_2$ type – orthorhombic Pnam. The rare earth atoms are 9-coordinated, and the Cr atoms are 6-coordinated, inside nearly regular octahedron of selenium. As in the preceding structures, 2 neighboring Cr atoms form with 2 intermediate Se atoms a nearly regular square.

These compounds are antiferromagnetic at low temperature (Neél temperature for $LaCrSe_3$: 165 K). Weak ferromagnetism appears at lower temperature.

Crystal chemistry of metal-rich refractory sulfides, H. Chen and H. F. Franzen, *SP364*, pp. 651-662 (July 1972).

Key words: Crystal structure; intermetallic; phosphides; refractory; sulfides; transition metal; coordination polyhedra.

Systematization of the crystal structures of metal-rich chalcogenides was attempted with emphasis on the coordinations of a few key metal atoms. This approach gave a more complete interpretation of many chalcogenide structures, notably those of Ta_2S, Ta_6S and Nb_2Se, than did the conventional descriptions using the packing of the coordinations of the chalcogen atoms. The pursuit of this approach led to the recognition of a polyhedron, which, owing to its repeated presence in many metal-rich compounds, appeared to be of great importance in crystal chemistry. It is a two-centered polyhedron formed by the interpenetration of two C. N. 14 Kasper polyhedra in such a way that the center of one of the Kasper polyhedra is the apex of another. The presence of a very short interatomic distance between the two centers is one of the important features of this polyhedron. With the help of this polyhedron as the building block, the structures of Zr_9S_2, α-V_3S and β-V_3S were satisfactorily described and correlated; the short interatomic distances in the structures could be explained semi-quantitatively; and the structural differences expressed by the different packing schemes of the polyhedra and the different positions the sulfur atoms occupied in the polyhedra. The description using the two-centered polyhedra as the basic units was extended to the structures in phosphide systems and provided new structural evidences to the similarities and distinctions among the Zr_9S_2-, α-V_3S-, β-V_3S-, Fe_3P- and Ti_3P-type structures, and to the correlation that the Fe_3P structure is the high temperature form of the Ti_3P structure. The smooth correlation between the sulfides, Zr_9S_2, α-V_3S and β-V_3S, and the phosphides and related compounds renders further support to the speculation that these sulfides possess the nature of intermetallic compounds.

Mixed cation disulfides of titanium, vanadium, and chromium, L. E. Conroy and K. R. Pisharody, *SP364*, pp. 663-671 (July 1972).

Key words: Disulfides; electrical conductivity; magnetic properties; sulfides; titanium disulfide; titanium-vanadium disulfides; vanadium disulfide.

Mixed cation disulfides of the types $Ti_{1-x}V_xS_2$ and $Ti_{1-x}Cr_xS_2$ have been prepared with compositions in the range $0 < x < 1$ in the Ti-V system and $0 < x < 0.4$ in the Ti-Cr system. Polycrystalline materials were prepared by direct reaction of the elements in vacuo at 950°. Single crystals of the Ti-V compounds were prepared by chemical transport reactions, employing iodine as the transport agent. The Ti-Cr disulfides failed to transport by this technique. The chemical properties of the mixed cation materials were found to be very similar to those of TiS_2. X-ray diffraction data indicated a random substitution of V or Cr for Ti in the normal Ti sites in the TiS_2 structure. A regular variation of lattice parameter with the vanadium content was observed in the Ti-V system. The magnetic properties of both the Ti-V and Ti-Cr compounds were characteristic of ferrimagnetic materials, with magnetic susceptibilities in the range of 3×10^{-11} m³/g to 12×10^{-11} m³/g (corrected) at room temperature. All of the mixed cation materials exhibited metallic electrical conductivity in contrast with the degenerate semiconductor behavior of TiS_2, with resistivities of the order of 10^{-5} ohm-m at room temperature. No superconductivity was observed at temperatures above 1.3 K. A band model for the description of the electronic properties of these materials is discussed.

Crystal growth and properties of some I-III-VI_2 compounds, H. M. Kasper, *SP364*, pp. 671-679 (July 1972).

Key words: $AgGaS_2$; chalcogenides; chalcopyrite; I-III-VI_2 compounds; crystal growth; $CuGaS_2$; $CuInS_2$; d-bands; direct bandgap semiconductors; nonlinear optical materials; semiconductor materials.

The I-III-VI_2 compounds are ternary analogues to the II-VI semiconductors and are interesting both as possible nonlinear optical materials and as semiconductors. They usually crystallize in the chalcopyrite structure which belongs to the uniaxial acentric crystal class 42m. In order to study their optical and semiconductor properties, single crystals of $AgGaS_2$, $CuGaS_2$ and $CuInS_2$ have been grown by slowly cooling melts of stoichiometric composition, and the conditions of growth by directional freezing are reported. $AgGaS_2$ crystallizes as yellow and green crystals. The yellow crystals seem to be gallium rich. $CuGaS_2$ does not melt congruently. Stoichiometric melts first crystallize a composition near $Cu_{0.88}Ga_{1.04}S_2$ as light orange crystals. Later darker, nearly stoichiometric crystals are obtained. $CuInS_2$ crystallizes between 1050 and 1000 °C with all crystals transparent to beyond 10 μ. There is a strong absorption in $CuGaS_2$ near 1.8 μ, which extends toward the visible and causes the darker color. The bandgaps are 2.72 eV for $AgGaS_2$, 2.53 eV for $CuGaS_2$ and 1.55 eV for $CuInS_2$ at 2 K. Both the light and dark crystals of $CuGaS_2$ as well as $CuInS_2$ and $AgCuS_2$ show sharp line luminescence. The linear and nonlinear optical properties of $AgGaS_2$, $Cu_{0.88}Ga_{1.04}S_2$ and $CuInS_2$ have been investigated. Unfortunately in both $Cu_{0.88}Ga_{1.04}S_2$ and $CuInS_2$ the birefringence is not large enough to permit three frequency phase matching, but $AgGaS_2$ can be phase matched in the infrared for both parametric oscillation and second harmonic generation. With both $CuGaS_2$ and $CuInS_2$ a pronounced structure has been observed in electroreflectance near the bandgap and at higher energies. From this structure is concluded that the crystal field splitting of the d bands is about 0.7 eV and that the d bands lie about 2 eV below the valence band edge in both compounds. Stimulated emission has been observed in $AgGaS_2$, $CuGaS_2$ and $CuInS_2$. $AgGaS_2$ is usually of high resistivity, whereas $CuGaS_2$ is p-type and $CuInS_2$ can be made both p- and n-type.

Crystal chemistry and magnetic properties of phases in the Ba-Fe-S(Se) systems, H. Steinfink, H. Hong, and I. Grey, *SP364*, pp. 681-694 (July 1972).

Key words: Crystal structures of Ba_2FeS_3, Ba_2FeSe_3, $BaFe_2S_3$, $BaFe_2Se_3$, $Ba_7Fe_6S_{14}$, $Ba_6Fe_8S_{15}$, $Ba_3Fe_3Se_7$; magnetic characteristics of Ba_2FeS_3, $Ba_7Fe_6S_{14}$ and $Ba_6Fe_8S_{15}$.

The crystal structures of a number of new phases synthesized in the Ba-Fe-S and Se systems were investigated by x-ray diffraction techniques. Ba_2FeS_3 is orthorhombic, Pnma, $a = 12.087(5)$ A, $b = 4.246(2)$ A, $c = 12.359(5)$ A, $\rho_{meas} = 4.0$ g/cc, $\rho_{calc} = 4.47$ g/cc, $Z = 4$, m.p. > 1300 °C. The compound is isostructural with Ba_2ZnS_3 and the structure consists of FeS_4 tetrahedra sharing corners to form an infinite linear chain. Ba_2FeSe_3 is isostructural with the sulfide and its parameters are $a = 12.350(7)$ A, $b = 4.439(2)$ A, $c = 12.921(5)$ A. $BaFe_2S_3$ is orthorhombic, Cmcm, $a = 8.7835(9)$ A, $b = 11.219(1)$ A, $c = 5.2860(5)$ A, $\rho_{meas} = 4.0$

g/cc, ρ_{calc} = 4.40 g/cc, Z = 4, m.p. = 765 ± 10 °C. Three dimensional x-ray diffraction data was used to refine the structure which consists of two FeS_4 tetrahedra sharing edges and this binuclear unit in turn shares edges with others to form an infinite chain. The structure of $BaFe_2Se_3$ is essentially the same as that of the sulfide but they are not isostructural. The selenide is orthorhombic, Pnma, a = 11.878(3) A, b = 5.447(2) A, c = 9.160(2) A, ρ_{calc} = 5.44 g/cc, Z = 4; decomposes above 750 °C. $Ba_6Fe_8S_{15}$ is tetragonal, I4/m, a = 11.408(2) A, c = 10.256(2) A, ρ_{meas} = 4.30 g/cc, ρ_{calc} = 4.36 g/cc, Z = 2, m.p. 880 ± 10 °C. The structure was determined from three dimensional x-ray diffraction data and consists of a tetranuclear unit formed by 4 FeS_4 tetrahedra sharing corners and these units then share edges to form an infinite column. $Ba_3Fe_3Se_7$ is hexagonal, $P6_3mc$, a = 10.843(3) A, c = 7.384(2) A, ρ_{calc} = 5.00 g/cc, Z = 2. The structure was determined using three dimensional single crystal x-ray diffraction data and consists of isolated trinuclear units formed by edge sharing of three FeS_4 tetrahedra. The Fe-Fe distances between chains are 6 A, and vary from 2.6 A to 4.2 A within the chains. The Fe-S distances are 2.3—2.4 A, the S-Fe-S angles are tetrahedral and the Ba-S distances are essentially equal to the sum of the ionic radii. The corresponding distances in the selenides reflect the larger size of the anion.

The magnetic characteristics of Ba_2FeS_3, $Ba_7Fe_6S_{14}$ and $Ba_6Fe_8S_{15}$ were investigated; all three compounds are antiferromagnets. The values of the exchange forces, J/k, correlate with the observed Fe-Fe distances.

Study of sulfospinels, R. E. Tressler and V. S. Stubican, *SP364*, pp. 695-702 (July 1972).

Key words: Flash evaporation; high pressure phases; sulfospinels; thin films.

Several new compounds with the formula AB_2S_4 were synthesized. Pressure-induced polymorphism of the sulfospinels was investigated. Sulfospinels which produced new high-pressure phases were $NiRh_2S_4$, $FeYb_2S_4$, In_2S_3, $CrIn_2S_4$, $NiIn_2S_4$, $CoIn_2S_4$ and $MnIn_2S_4$. The only sulfospinels which transformed to the NiAs derivatives were those in which A and B atoms had unfilled d-orbitals. P-T phase relations were investigated for a series of sulfochromites.

Thin films of several ACr_2S_4 (A = Mn, Fe, Co, Cu and Zn) sulfospinels were prepared by a flash evaporization technique on the (111) and (100) planes of NaCl and on the (100) plane of MgO.

Phase changes in Cu_2S as a function of temperature, W. R. Cook, Jr., *SP364*, pp. 703-712 (July 1972).

Key words: Chalcocite; Cu_2S; digenite; djurleite; nonstoichiometry; phase relations.

The high-copper phase boundary of Cu_2S deviates from stoichiometry above 300 °C, first becoming copper deficient, then above ~ 1075 °C becoming copper rich. The maximum copper content occurs at the monotectic temperature of 1104 °C. The strong effect of oxygen on the hexagonal-cubic transition in Cu_2S was confirmed; the transition was also found to be sensitive to the type of pretreatment of the material. The high temperature tetragonal "$Cu_{1.96}S$" phase is stable between $Cu_{1.95}S$ and Cu_2S, at temperatures of ~ 90 to ~ 140 °C. The transition to the tetragonal phase is extremely sluggish. The true composition of djurleite has been shown to be approximately $Cu_{1.93}S$.

The phases near the chalcocite-digenite region of the diagram may be grouped into those with hexagonal close packing of sulfur atoms and those with cubic close packing of sulfurs. This is important in understanding rates of transformation among the various phases that occur in this area of the diagram.

Preparation and properties of the systems $CuFeS_{2-x}$ and $Cu_{1-x}Fe_{1+x}S_{2-y}$, R. L. Adams, P. Russo, R. J. Arnott, and A. Wold, *SP 364*, pp. 713-719 (July 1972).

Key words: Chalcopyrite; $CuFeS_2$, $CuFeS_{2-x}$, $Cu_{1-x}Fe_{1+x}S_{2-y}$; Cu-Fe-S system; $CuFeS_2$ crystal growth.

Stoichiometric samples of $CuFeS_2$ were prepared by direct combination of the elements in sealed evacuated silica tubes. The products were characterized by x-ray diffraction, density determination, magnetic susceptibility and Mössbauer spectroscopy. Homogeneous single phase products gave a density of 4.18 ± 1 g/cc and cell parameters of a_o = 5.292 ± (5) Å and c_o = 10.407 ± (5) Å. In addition, all of the iron was found to be trivalent and located on tetrahedral sites. The plot of inverse susceptibility versus temperature was nearly temperature independent from 77 to 300 K, and the magnetic susceptibility measurements gave a $\chi_M = 9.8 \times 10^{-4}$ emu/mole. Single crystals of $CuFeS_2$ were grown from the melt by means of a modified Bridgman technique.

Samples having the composition $CuFeS_{2-x}$ were also prepared by the direct combination of the elements. X-ray diffraction studies indicated that existence of a single phase, tetragonal γ-form, when x was varied from 0.17 to 0.24. The compound $CuFeS_{1.8}$ had cell dimensions of a_o = 10.598 ± (5) Å and c_o = 5.380 ± (5) Å. Contrary to previous reports, this phase was found to be stable from room temperature to 800 °C. In addition, this phase was stable at room temperature for a period of time in excess of 250 days. It was concluded from density measurements that the structure is best represented as a close packing of sulfur with excess metal ions occupying additional lattice sites.

Compounds having the composition $Cu_{1-x}Fe_{1+x}S_{1.80}$ ($0.25 > x > 0.08$) were prepared and found to be cubic with an average cell size of a_o = 5.32 Å. However, attempts to prepare single phase products with a composition of $Cu_{1+x}Fe_{1-x}S_{2-y}$ were unsuccessful.

Laser Raman spectra of polycrystalline ZnS and $Zn_xCd_{1-x}S$ solid solutions, J. Shamir and S. Larach, *SP364*, p. 721 (July 1972).

Key words: Laser Raman spectra; polycrystalline; ZnS; $Zn_xCd_{1-x}S$.

Raman spectra of polycrystalline ZnS and of CdS have been recorded. The instrument consisted mainly of a He-Ne laser, Spectra-Physics, model 125 and a 1400 Spex double monochromator. The lines observed were in good agreement with those observed before in a single crystal. Some of these lines are not as sharp and intense as in a single crystal; however, the LO frequency of ZnS at 351 cm^{-1} is a very sharp and intense line.

In addition we studied the spectra of $Zn_xCd_{1-x}S$ solid solutions. These materials have been prepared by firing mixtures of pure ZnS and CdS, in the proper compositions, at 1100 °C, in an atmosphere of purified Argon. It has been observed that the LO frequency of CdS at 306 cm^{-1} shifts toward higher frequencies as the concentration of zinc increases. This behavior indicates a type I change as discussed by Pershan and Lacina, namely a linear shift of the frequency as the concentration varies from zero to one in the $Zn_xCd_{1-x}S$. These results resemble the ones obtained in a Vegard plot of lattice constants as determined by x rays.

Novel method for the synthesis of rare earth chalcogenides, C. Paparoditis and R. Suryanarayanan, *SP364,* p. 723 (July 1972).

Key words: Coevaporation of elements; rare earth chalcogenides; synthesis.

A description is given of an all-metal vacuum system for the synthesis of rare earth tellurides and selenides by the coevaporation of the elements. The evaporation chamber is provided with three crucibles so that ternary compounds can also be prepared. Forty or more deposits can be obtained in a single operation. A wide range of compositions can thus be obtained if desired. The substrates, amorphous or crystalline, can be heated up to 600 °C. The following compounds have been obtained as polycrystalline, highly textured or single crystal films: EuTe, EuSe, YbTe, YbSe, $YbSe_{1+\delta}$, SmTe, SmSe, $SmSe_{1+\delta}$ (Th_3P_4 structure), $Eu_{1-x}Pb_xTe$, $Eu_{1-x}Gd_xSe$, $Eu_{1-x}Yb_xTe$. Evidence of high quality is given by x-ray, electron microscopy, electron diffraction and electron microprobe analysis. Optical absorption spectra up to 6 eV, reflection spectra up to 10 eV, magnetic circular dichroism spectra in the visible have been obtained. Transition assignments have been proposed for the first time in the case of Yb and Sm monochalcogenides.

Results of optical and magneto optical investigations have been presented for the ferromagnetic EuS obtained by coevaporation and for EuO obtained by reactive evaporation. Finally, electrical and other transport properties of stoichiometric EuO have also been presented.

P365. **Metric conversion card,** J. V. Odom, Nat. Bur. Stand. (U.S.), Spec. Publ. 355, 2 pages (Revised Nov. 1972).

Key words: Metric units, conversion customary to metric; metric units, conversion metric to customary.

A pocket card for convenient appropriate conversion of the ustomary units of physical measurement to metric units and ietric units to customary units.

P366. **Bibliography on atomic line shapes and shifts (1889 through March 1972),** J. R. Fuhr, W. L. Wiese, and L. J. Roszman, Nat. Bur. Stand. (U.S.), Spec. Publ. 366, 165 pages (Sept. 1972).

Key words: Atomic; instrumental broadening; line shapes; line shifts; pressure broadening; resonance broadening; Stark broadening; Van der Waals broadening.

This is the first general, annotated bibliography on atomic line hapes and shifts. It covers exhaustively the atomic spectral line roadening literature in about 1400 separate references extend- ng from 1889 through March 1972. The bibliography contains our major parts: (1) All general interest papers are catalogued ccording to the broadening mechanisms (and, further, according o special topics under several of the mechanisms), and as to hether the work is a general theory, a general review, a table of rofiles or parameters, a comment on existing work, a study of eneral experimental measurement techniques, or an experimen- al effort of general importance. Also included are selected apers on important applications of line broadening and on iscellaneous topics relating to atomic spectral line shapes and hifts. (2) In Part 2, all papers containing numerical data are or- ered as to element, ionization stage, broadening mechanism (in he case of foreign gas broadening the perturbing species are sted), and it is indicated whether the data are experimentally or eoretically derived. (3) While in the two preceding parts of the ibliography the references are listed for brevity by identification umbers only, in Part 3 all references are listed completely by ournal, authors, and title and are arranged chronologically and lphabetically within each year according to the principal

SP366. Supplement 1. **Bibliography on atomic line shapes and shifts (April 1972 through June 1973),** J. R. Fuhr, L. J. Roszman, and W. L. Wiese, Nat. Bur. Stand. (U.S.), Spec. Publ. 366 Suppl. 1, 73 pages (Jan. 1974) SD Catalog No. C13.10:366, Suppl. 1.

Key words: atomic; instrumental broadening; line shapes; line shifts; pressure broadening; resonance broadening; Stark broadening; Van der Waals broadening.

This is the first supplement to the NBS Special Publication 366, "Bibliography on Atomic Line Shapes and Shifts (1889 through March 1972)." It contains about 350 references and covers the literature from April 1972 through June 1973. The bibliography contains five major parts: (1) All general interest papers are cataloged according to the broadening mechanisms (and, further, according to special topics under several of the mechanisms) and as to whether the work is a general theory, a general review, a table of profiles or parameters, a comment on existing work, a study of general experimental measurement techniques, or an experimental effort of general importance. Also included are selected papers on important applications of line broadening and on miscellaneous topics relating to atomic spectral line shapes and shifts. (2) In Part 2, all papers containing numerical data are ordered as to element, ionization stage, broadening mechanism (in the case of foreign gas broadening the perturbing species are listed), and it is indicated whether the data are experimentally or theoretically derived. (3) While in the two preceding parts of the bibliography the references are listed for brevity by identification numbers only, in Part 3 all references are listed completely by journal, authors, and title and are arranged chronologically and alphabetically within each year according to the principal author. (4) This section contains a list of all authors and their papers. (5) A final section provides corrections or additions to our first bibliography.

SP366-2. **Bibliography on atomic line shapes and shifts (July 1973 through May 1975),** J. R. Fuhr, G. A. Martin, and B. J. Specht, Nat. Bur. Stand. (U.S.), Spec. Publ. 366 Suppl. 2, 75 pages (Nov. 1975) SD Catalog No. C13.10:366/Suppl. 2.

Key words: atomic; instrumental broadening; line shapes; line shifts; pressure broadening; resonance broadening; Stark broadening; van der Waals broadening.

This is the second supplement to the NBS Special Publication 366, "Bibliography on Atomic Line Shapes and Shifts (1889 through March 1972)." It contains about 400 references and covers the literature from July 1973 through May 1975. As before, the bibliography contains five major parts: (1) All general interest papers are catalogued according to the broadening mechanisms (and, further, according to special topics under several of the mechanisms) and as to whether the work is a general theory, a general review, a table of profiles or parameters, a comment on existing work, a study of general experimental measurement techniques, or an experimental effort of general importance. Also included are selected papers on important applications of line broadening and on miscellaneous topics relating to atomic spectral line shapes and shifts. (2) In Part 2, all papers containing numerical data are ordered as to element, ionization stage, and broadening mechanism (in the case of foreign gas broadening the perturbing species are listed), and it is indicated whether the data are experimentally or theoretically derived. (3) While in the two preceding parts of the bibliography the references are listed for brevity by identification numbers only, in Part 3 all references are listed completely by journal, authors, and title and are generally arranged chronologically and alphabetically within each year according to the principal author. (4) This section contains a list of all authors and their papers. (5) A final section provides corrections or additions to the first bibliography and supplement.

SP367. **National Bureau of Standards Brochure, 1972,** W. E. Small, Editor, Nat. Bur. Stand. (U.S.), SP367, 66 pages (Dec. 1972).

Key words: National Bureau of Standards; organization; overview; program descriptions.

This publication presents an in-depth look at the National Bureau of Standards. An overview of the Bureau's history, programs, and major contributions precedes individual chapters detailing the programs of each of the four NBS Institutes: Institute for Basic Standards; Institute for Materials Research; Institute for Applied Technology; and Institute for Computer Sciences and Technology. Supersedes NBS Miscellaneous Publication 282 and Special Publication 360.

SP-368, Superseded by Special Publication 368, 1976 Edition.

SP369. **Soft x-ray emission spectra of metallic solids: Critical review of selected systems and annotated spectral index,** A. J. McAlister, R. C. Dobbyn, J. R. Cuthill, and M. L. Williams, Nat. Bur. Stand. (U.S.), Spec. Publ. 369, 176 pages (Jan. 1974) SD Catalog No. C13.10:369.

Key words: alloys; critical review; emission spectra; intermetallic compounds; metals; soft x ray; spectra.

Theory and experimental practice in the field of soft x-ray emission from metallic solids are briefly reviewed, and measurements on a number of systems are critically evaluated and compared with the results of other techniques and theory, with a view to establishing the pertinence of the soft x-ray measurements and indicating specific guidelines for further enhancing their value. In addition, an exhaustive annotated index of measured spectra is provided. Supersedes NBS Monograph 52 in part, for emission spectra only.

SP370. **Research and testing facilities of the Engineering Mechanics Section, National Bureau of Standards, Washington,** D.C., by the Staff of the NBS Engineering Mechanics Section, D. J. Chwirut, Coordinator, Nat. Bur. Stand. (U.S.), Spec. Publ. 370, 23 pages (Jan. 1973) 55 cents, SD Catalog No. C13.10:370.

Key words: Engineering Mechanics Section; force generating equipment; research facilities; testing machines.

The principal characteristics of the force measuring and generating equipment and related research facilities available in the Engineering Mechanics Section of the National Bureau of Standards are described.

SP371. **A supplementary bibliography of kinetic data on gas phase reactions of nitrogen, oxygen, and nitrogen oxides,** F. Westley, Nat. Bur. Stand. (U.S.), Spec. Publ. 371, 92 pages (Feb. 1973) $1.25, SD Catalog No. C13.10:371.

Key words: Bibliography; chemical kinetics; excited state; gas phase; nitrogen atom; nitrogen molecule; nitrogen oxides; oxygen atom; oxygen molecule; ozone.

A bibliography, a reaction-oriented list of references supplementing NBS publication COM-71-00841 (NBS-OSRDB-71-2, August 1971), is provided for published papers and reports containing rate data for reactions of N, N_2, N_3, N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5, NO, NO_2, NO_3, NO_4, O, O_2 and O_3 with each other. It includes an extensive list of papers dealing with production and reactions of molecular oxygen in excited singlet state ($a^1\Delta_g$, $b^1\Sigma_g^+$, $c^1\Sigma_u$). In addition, two lists of critical reviews dealing with the above reactions are included. About 500 papers are listed. The period covered extends from 1900 through January 1972.

SP371-1. **Supplementary bibliography of kinetic data on gas phase reactions of nitrogen, oxygen, and nitrogen oxides (1972-1973),** F. Westley, Nat. Bur. Stand. (U.S.), Spec. Publ. 371-1, 88 pages (June 1975) SD Catalog No. C13.10:371-1.

Key words: bibliography; chemical kinetics; excited state; gas phase; nitrogen atom; nitrogen molecule; nitrogen oxides; oxygen atom; oxygen molecule; ozone.

A reaction-oriented list of references is provided for papers and reports published in 1972 and 1973, containing rate data for reactions of N, N_2, N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5, NO, NO_2, NO_3, NO_4, O, O_2 and O_3 with each other. Some reactions of species in excited states are included. This bibliography, covering about 500 papers, extends the coverage of two previous bibliographies on the same subject, COM-71-00941, NBS-OSRDB-71-2, August 1971 and NBS Special Publication 371, February 1973. Some work published prior to 1972 omitted in the previous publications has been included here.

SP372. **Laser induced damage in optical materials: 1972.** Proceedings of a Symposium Sponsored by the American Society for Testing and Materials and by the National Bureau of Standards, June 14-15, 1972, NBS, Boulder, Colo., A. J. Glass and A. H. Guenther, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 372, 215 pages (Oct. 1972).

Key words: IR windows and mirrors; laser damage; laser materials; self-focusing; thin films.

The fourth ASTM Symposium on Laser Induced Damage in Optical Materials was held at the National Bureau of Standards in Boulder, Colo., on June 14-15, 1972. This symposium is held as part of the activity of Subcommittee II on Lasers and Laser Materials, of the ASTM. Subcommittee II is charged with the responsibility of formulating standards for laser materials, components, and devices. The chairman of Subcommittee II is Haynes Lee of Owen-Illinois, Inc. Co-chairmen for the damage symposia are Dr. Arthur H. Guenther of the Air Force Weapons Laboratory, and Professor Alexander J. Glass, Chairman of the Department of Electrical Engineering at Wayne State University.

Approximately 125 attendees at the symposium heard 21 papers on topics relating to laser induced damage in glass, crystalline materials, nonlinear optical materials, thin film dielectric coatings, and infrared components. Particular attention was given to the process of plasma formation at dielectric surfaces, the role played by self-focusing in bulk damage in solids, damage morphology of thin film coatings, and the role of absorption in IR component failure.

The proceedings of these Symposia represent the major source of information in the field of laser induced damage in optical materials. The Symposia themselves, along with the periodic meetings of Subcommittee II, provide a unique forum for the exchange of information regarding laser materials specifications among the manufacturers and users of laser devices, components, and systems. The Symposium also serves as a mechanism of information gathering, to enable the Subcommittee to write informed and realistic specifications. *These proceedings include the following papers* (*indented*):

Laser damage of HOYA Laser Glass, LCG-11, T. Izumitani, K. Hosaka, and C. Yamanaka, *SP372,* pp. 3-10 (Oct. 1972).

Key words: HF treatment; inclusion damage; passive and active testing; platinum inclusion; surface damage; thin film coating.

In HOYA Glass Works we have developed a Barium Crown Laser Glass, LCG-11. It has a stimulated emission cross section (σ) of 2.0×10^{-20} cm^2 and a loss coefficient (γ) of 0.001 cm^{-1}.

In this report we show that, while platinum lowers the damage threshold of laser glass, by controlling the number and size of the platinum inclusion, the damage threshold of platinum crucible melts of LCG-11 laser glass does not go below 400 J/cm² in the passive test, nor below 28 J/cm² in the active test. This compares favorably with the damage threshold of melts in SiO_2 and ceramic crucibles. The ceramic melted glass showed a higher lasing threshold, a lower slope efficiency in normal oscillation and an output saturation tendency in Q-switched oscillation.

We find that surface damage is independent of glass strength, glass thermal expansion, and adsorption of water in glass surface. We find that LCG-11 glass, upon treatment with hydrofluoric acid, was improved from 28 J/cm² to 40 J/cm², a higher damage threshold in passive test, yet we were unable to find a change in glass surface composition due to hydrofluoric acid treatment by using electron microprobe. We assume that surface damage is dependent upon the multi-photon ionization tendency of a glass surface. This assumption is based upon our observation of silica glass which has no single-bond oxygen and a high damage threshold.

Interaction gradients, concurrent light scattering experiments and bulk laser damage in solids, C. Y. She and D. F. Edwards, *SP372*, pp. 11-14 (Oct. 1972).

Key words: Bulk; crystalline quartz; fused quartz; interaction gradient; laser glass; laser induced damage; light scattering; stimulated Brillouin scattering.

The concept of interaction gradient and its role on bulk laser damage is discussed. Results of light scattering experiments concurrent with damaging laser pulses on crystalline quartz, fused quartz and laser glass samples are compared to substantiate the role of interaction gradient and stimulated Brillouin scattering on bulk laser damage in solids.

Optical index damage in electrooptic crystals, A. M. Glass, G. E. Peterson, and T. J. Negran, *SP372*, pp. 15-26 (Oct. 1972).

Key words: Holographic measurements; laser induced index change; optical memories; reversible low power damage.

Optically induced refractive index changes which occur at low incident power densities (< 1 KW/cm²) in many electrooptic crystals have severely limited the application of these materials in the visible spectrum. Following a brief historical review of the subject, we discuss the recent advances in the understanding of the physical mechanisms involved, progress in reducing the damage susceptibility, and in enhancing the effect for holographic applications.

Particular attention is paid to $LiNbO_3$ and $LiTaO_3$ crystals. Optical and EPR studies of these materials have demonstrated that Fe^{2+} impurity ions present in nominally pure material are responsible for the index damage. The effects of stoichiometry variation, heat treatment, impurity and color center content, X-irradiation of crystals and the kinetics of the index damage process are accounted for by Fe^{2+}-Fe^{3+} reactions.

By careful control of crystal growth and stabilization of the Fe^{3+} impurity ion state, $LiNbO_3$ and $LiTaO_3$ crystals with greatly improved damage resistance have been prepared.

Comparison of laser induced bulk damage in alkali-halides at 0.6, 1.06, and 0.69 microns, D. W. Fradin, E. Yablonovitch, and M. Bass, *SP372*, pp. 27-39 (Oct. 1972).

Key words: Alkali halides; avalanche breakdown; bulk damage; self-focusing; surface damage.

It has long been recognized that catastrophic self-focusing cannot occur below a critical power P_c and that perturbations from self-focusing become progressively less important as the power of a probe optical beam is lowered below P_c. Using this fact, we have designed and conducted a number of experiments to study bulk damage in alkali-halides in which self-focusing was eliminated and unequivocal measurements of damaging fields obtained. Strongly focusing optical systems were used so that damage could be achieved while probe powers could be restricted to between one and two orders-of-magnitude below theoretical critical powers for electrostrictive self-focusing. Experimental evidence confirms the absence of self-focusing.

By observing the absolute magnitude of breakdown strengths and relative values among the alkali-halides, striking similarities between 10.6, 1.06, and 0.69 μm and d.c. avalanche breakdown were found. The results also showed no frequency dispersion over the wavelength range of 10.6 to 0.69 microns. The implications of this work for surface damage studies are explored and, in addition, the effects of inclusions on bulk optical strength are considered.

Laser induced damage to glass surfaces, N. L. Boling and G. Dube', *SP372*, pp. 40-45 (Oct. 1972).

Key words: Chemically strengthened glass; glass damage; glass lasers; laser damage; Q-switched; surface damage.

Entrance and exit surface damage thresholds for Owens-Illinois ED-2 laser glass are measured at Brewster's angle and near normal incidence. A theory that accounts for the observed asymmetry in exit/entrance face damage thresholds is presented. The nature of the damage at both surfaces is described for both untreated and chemically strengthened ED-2 laser glass.

The relation between surface damage and surface plasma formation, C. R. Giuliano, *SP372*, pp. 46-54 (Oct. 1972).

Key words: Entrance and exit surface damage; sapphire; spatial and temporal plasma resolution; streak camera experiments; surface plasmas.

A number of experiments are described in which entrance and exit surface laser-induced damage on sapphire samples are studied. Damage thresholds are measured as a function of beam size and divergence at the surfaces. Temporal evolution of surface plasmas is studied using a streaking camera, and spatial differentiation of surface plasmas is accomplished by allowing the light to strike the surfaces away from normal incidence. It is found that the entrance surface has two plasma components, an air plasma which is directed along the light beam and an "explosion" plasma which is directed normal to the surface. The exit surface has only the explosion plasma. It is concluded that surface plasmas are a result of rather than a cause of surface damage.

Ion beam polishing as a means of increasing surface damage thresholds in sapphire, C. R. Giuliano, *SP372*, pp. 55-57 (Oct. 1972).

Key words: Ion beam polishing; sapphire; surface damage; threshold increase; threshold measurement.

Polishing of sapphire surfaces with energetic Ar^+ ion beams is shown to result in a substantial increase in laser damage threshold over that for conventionally polished surfaces. Data for both entrance and exit damage are presented. The results are interpreted in terms of an increase in surface strength with ion beam polishing.

Laser-induced damage probability at 1.06 and 0.69 μm, M. Bass and H. H. Barrett, *SP372*, pp. 58-69 (Oct. 1972).

Key words: Breakdown starting time; electron avalanche; probabilistic nature of damage; surface damage; wavelength dependence of damage.

Measurements of the laser-induced surface damage process at both ruby and Nd:YAG laser wavelengths are reported in which the laser pulse and beam parameters were carefully held constant for both sources. This resulted in the first directly comparable measurements of laser damage at two different wavelengths. The most striking feature of the data is that all the materials studied are harder to damage at 0.69 μm than at 1.06 μm. In addition, the relationship between the damage probability and the optical electric field strength at 0.69 μm, though similar to that at 1.06 μm, suggests that more than one damage mechanism may be operative.

The probabilistic nature of the laser-induced damage process at 1.06 μm was explored further by measuring the distribution of breakdown starting times with the image-converter streak camera. For a particular laser pulse a threshold-like damage process would result in a very sharp distribution of breakdown starting times. Instead, a large spread is found, with the most likely starting time occurring before the laser intensity reaches its maximum. The observed distribution is described by the compound probability that breakdown occurs at a particular time, given that it has not occurred before that time.

In addition, several possible connections between the probabilistic and threshold-like interpretations of laser-induced damage are discussed. It is shown that these points of view are not totally incompatible.

Damage to GaAs surfaces from ruby- and Nd-glass laser illumination, J. L. Smith, *SP372*, pp. 70-74 (Oct. 1972).

Key words: Doping; GaAs; laser induced damage; photoconductivity; surface; surface finish.

Surface damage of GaAs due to 0.694- and 1.06-micron beams from ruby and Nd-glass lasers has been investigated. The wavelengths employed represent photon energies above and below the bandgap of GaAs. For laser operation in the conventional mode, Ga-rich material developed on the surface to a greater extent than for Q-switched operation. Surface damage from Q-switched beams did not appear to depend on the absence, presence, or type of doping, although the nature of the surface preparation was important. The damage threshold for Nd-glass laser illumination was approximately 10^7 W/cm^2, only a little higher than that for ruby laser illumination. For Q-switched, Nd-glass laser beam exposure, the damage occurred in highly localized regions and appears to be connected with material flaws near the surface.

Surface science and surface damage, J. M. Khan, *SP372*, pp. 75-83 (Oct. 1972).

Key words: Laser damage; surface science; thin films.

The relatively new field of Surface Science is concerned with the measurement of physical and chemical properties of well characterized surfaces. The ability to characterize these surfaces has been steadily increasing due to the development of new tools, or the application of older techniques to surface interrogation. The overwhelming result of surface investigation is to draw attention to the difficulty of obtaining such well-characterized surfaces. With this realization in mind, it is highly instructive to review the conventional methods of creating surface conditions. The assumptions involving the conditions at prepared surfaces or interfaces must be reexamined. New procedures may have to be evolved to control conditions to even assure reproducibility. Only when this has been accomplished can measurements of surface damage thresholds be taken as intrinsic characteristics of prepared surfaces.

Self-focusing with elliptical beams, J. Marburger, *SP372*, pp. 84-91 (Oct. 1972).

Key words: Bulk damage; damage threshold; elliptical beams; enhancement; self-focusing.

The time independent self-focusing of beams whose constant intensity contours are ellipses has been studied in the paraxial ray-constant shape approximation. This approximation leads to equations for the principal $1/e$ intensity diameters versus axial distance which have been analysed previously by Vorob'yev by a different method. Our method allows the treatment of non-gaussian intensity profiles. The solutions are employed to find expressions for the critical powers and self-focal lengths of nonaxially symmetric beams under a variety of initial conditions. The critical power can be greatly enhanced by astigmatic focusing, even if the beam shape is initially axially symmetric. This theory implies that bulk damage thresholds arising from self-focusing depend strongly on beam shape, in agreement with experimental results of Giuliano.

Relative contribution of Kerr effect and electrostriction to self-focusing, A. Feldman, D. Horowitz, and R. M. Waxler, *SP372*, pp. 92-99 (Oct. 1972).

Key words: Damage threshold; electrostriction; Kerr-effect; laser damage in glasses; optical glasses; self-focusing.

The ratio of damage thresholds for circularly polarized radiation to linearly polarized radiation was found to be > 1 in borosilicate crown glass, fused silica, and dense flint glass. A Q-switched Nd:glass laser operating in the TEM_{00} mode was used. The damage was assumed to result from self-focusing. The fractional contributions of electrostriction and the Kerr effect to the nonlinear index n_2 are estimated from the threshold ratios calculated for each mechanism in the absence of the other and assuming no other self-focusing mechanism. The high damage threshold of fused silica is attributed to its relatively small Kerr effect. Measurements of self-focusing lengths as a function of peak power give qualitatively good agreement with theory.

Damage measurements with subnanosecond pulses, J. M. McMahon, *SP372*, pp. 100-103 (Oct. 1972).

Key words: Damage mechanisms in laser systems; disc amplifiers; Nd: YAG laser; self-focusing; subnanosecond pulses.

The realization of high energy subnanosecond pulse lasers has been limited by self-focusing damage in laser rods. In this paper measurements on n_2 for laser glasses with subnanosecond pulses are described. The system aspects of using such glasses are also discussed since in practice this can have a dominant effect on the performance of a high energy short pulse device.

Time resolved damage studies of thin films and substrate surfaces, J. H. Parks and N. Alyassini, *SP372*, pp. 104-107 (Oct. 1972).

Key words: Damage induced reflectivity change; laser induced damage; laser induced surface acoustic waves; surface; surface breakdown plasma; thin film; time resolved damage.

The time evolution of damage to thin films and substrate surfaces was observed by monitoring the intensity variation of a He-Ne beam reflected from the film or surface during irradiation by a Q-switched ruby laser. Monolayered films including ZnS, CaF_2 and NaCl on fused silica substrates were studied, as well as uncoated fused silica and LiF substrates. When the probe beam is reflected from the exit surface of a substrate sample, the reflected intensity was observed to decrease within the time-scale range of 20-200 nanoseconds to a final value significantly less than that prior to damage. When the probe is spatially offset from the damage region, the reflected intensity decreases and then returns to approximately the predamage value within 0.2-0.3μ sec. This reversible effect was observed to be associated with a propagating disturbance on the substrate surface moving with approximately the speed characteristic of a Rayleigh surface wave. The risetime and duration of the plasma which accompanies surface damage was also measured.

The reflected intensity from thin films was observed to increase or decrease depending on the film index of refraction. The monolayer film samples exhibited reflectance changes on the timescale of the ruby pulse, however an offset probe position indicates this change can occur after a time delay of $\sim$ 0.1-0.2μ sec.

Laser induced damage to mirrors at two pulse durations, E. . Bliss and D. Milam, *SP372*, pp. 108-122 (Oct. 1972).

Key words: Dielectric mirror; electron avalanche; laser damage mechanisms; laser induced damage; laser monitoring; plasma production; scattering sites.

The damage thresholds of eight, multiple layer dielectric, 95% reflecting mirrors have been measured for single pulses of 20 nanoseconds and 20 picoseconds duration. In both sets of measurements the pulse energy, an oscilloscope trace of the pulse, and the beam's transverse energy density profile at the surface being damaged are recorded for each shot. The variation of the threshold from mirror to mirror and as a function of pulse duration, beam radius, and appearance under microscopic examination is discussed in the context of possible damage mechanisms.

Study of laser-irradiated thin films, B. E. Newnam and L. G. DeShazer, *SP372*, pp. 123-134 (Oct. 1972).

Key words: Damage morphology; damage thresholds; laser-induced scatter; ruby; spark thresholds; thin films; truncated Gaussian optics.

Laser damage to thin-film coatings was studied using a TEM_{oo} Q-switched ruby laser. Our study included mono-, bi- and multi-layered coatings of the materials TiO_2, SiO_2, ZrO_2, MgF_2 and ZnS on substrates of glass, rocksalt and spinel. The samples included coatings for antireflection and reflection at the ruby wavelength, and were produced either at USC or by a commercial vendor. Damage threshold energy and power densities were measured with attention paid to dependences on laser beam spot-size, film material and thickness, substrate condition and incipient scattering of the film. Particular attention was given to the establishment of a threshold criterion for laser damage to thin films. Several effects attendant to damage were investigated, with the conclusion that film scattering induced by the laser was the most sensitive detector of film breakup. The laser induced scatter was observed prior to or at the threshold of spark formation at the film, depending on the film material.

Influence of structural effects on laser damage thresholds of discrete and inhomogeneous thin films and multilayers, R. R. Austin, R. C. Michaud, A. H. Guenther, J. M. Putman, and R. Harniman, *SP372*, pp. 135-164 (Oct. 1972).

Key words: Laser damage; inhomogeneous films; microscopy; optical coatings; thin film stress.

The dependence of single shot damage threshold on certain film properties is discussed. Variable stress films are produced by mixing components with approximately equal damage thresholds but opposite stress characteristics a definite stress dependence is shown. Films formed from mixtures of high and low threshold components are investigated and found to have damage thresholds between the high and low component values. The damage threshold and damage mode of multilayer and periodic inhomogeneous film systems is compared. The results confirm that the damage threshold is almost entirely material dependent.

Fundamental absorption mechanisms in high-power laser window materials, R. Hellwarth, *SP372*, pp. 165-171 (Oct. 1972).

Key words: Absorption limit; extrinsic absorption; high-power laser window materials; intrinsic absorption; optical absorption mechanisms; thermal damage.

The thermal deformation and damage to windows and lenses caused by their optical absorption poses serious limitations on the operation of high-power CW and long-pulse lasers. For example, no known materials have both low enough absorption coefficients and good enough mechanical and chemical properties to perform satisfactorily as windows in the large 10.6 μm lasers being developed today. However, very many crystals and glasses would be good candidates for high-power IR windows, if their linear absorption coefficients could be made lower by at least an order of magnitude. Here we review what is known of the physical mechanisms that are responsible for, or may limit, the small residual absorption in the "transparent" wavelength regions of the best candidate window materials. From the primitive state of present knowledge, it seems likely that uncontrolled impurity effects are presently limiting performance in the best window materials, and that therefore their high-power performance can be improved further. We identify theoretical gaps whose filling would greatly improve our understanding of the mechanisms and limits of laser-window absorption.

Recent developments in high-power infrared-window research, M. Sparks, *SP372*, pp. 172–175 (Oct. 1972).

Key words: Infrared absorption; infrared laser systems; thermal fracture; window materials.

The problem of failure of high-power infrared laser-system windows involves low intensities (a few hundred to a few thousand W/cm^2). Thermally induced distortion of the optical beam by a heated window and thermal fracture have been considered previously. Pressure-induced optical distortion is discussed. For large-diameter windows of weak materials, the minimum window thickness is determined by pressure-induced optical distortion, rather than by pressure-induced fracture. Previous figures of merit for rating candidate window materials assumed a constant thickness of 1 cm for all materials. New figures of merit, based on the minimum thickness required to withstand a given pressure, indicate a different preference for materials than that of the previous figures of merit.

It is not known if the measured values of the optical absorption coefficient β for candidate materials are extrinsic or intrinsic. The intrinsic value of β is needed in order to determine if material-improvement programs could produce materials with sufficiently low values of β. Information on extrinsic processes is needed in order to identify the sources of the extrinsic contributions to β so that they may be

removed. Measurements of β over ranges of frequency and temperature should be invaluable in obtaining this information. Feasibility studies indicate that emissivity measurements should yield the required values of β, which cannot be obtained by current transmission or calorimetric measurements.

Low emittance and absorption measurements of windows and mirrors, G. Wijntjes, N. J. E. Johnson, and J. M. Weinberg, *SP372,* pp. 176-182 (Oct. 1972).

Key words: Absorptance measurement; bulk scattering; coating measurement; emittance measurement; infrared absorptance; laser damage.

A cryogenic interferometric spectrometer has been developed which can achieve a noise equivalent spectral radiance (NESR) of 1.2×10^{-11} watts/cm^2-ster-cm^{-1} at 10 μm in 10 seconds of integration, with spectral resolution of 1 cm^{-1}.

The application of this instrument to the measurement of low level emittance or absorptance in optical elements is described. In such measurements, the specimen is kept at 300 K and its surroundings at 77 K. The measurement is limited by the sensitivity of the instrument, the accuracy of the specimen temperature measurement, and the dynamic range of the measurement. The first limitation is expressed by the noise equivalent spectral emittance.

$$(NE\Delta\epsilon)_\nu = \frac{NESR}{R^o_\nu(T)}$$

where $R\nu^o$ (T) is the blackbody radiance at temperature T. With reasonable integration times the determination of emittance is feasible to a precision approaching a part in 10^7, which represents the fundamental limitation to such measurement. The other limitations are proportional to the average emittance over the spectral range considered, and for average emittances below 0.01, permit absolute emittance measurements to a few parts in 10^6. The high spectral resolution of this instrument permits examination of absorption band structure in substrate and coating materials, and the identification of contaminant organic materials. The measurement of bulk scattering in transmissive materials is also possible.

Investigation of pulsed CO_2 laser damage of metal and dielectric-coated mirrors, V. Wang, A. I. Braunstein, M. Braunstein, and J. Y. Wada, *SP372,* pp. 183-193 (Oct. 1972).

Key words: Damage mechanisms; inclusions in dielectrics; multilayer dielectric mirrors; pulsed CO_2 laser damage; thin film coated metal; uncoated metal mirrors.

Recent progress made in pulsed high power CO_2 lasers has increased the power handling capabilities of mirrors and mirror coatings. Discussed in this paper are surface damage mechanisms based upon simple physical models (i.e., surface heating, thermally induced stress, absorption centers, etc.) and the experimental results obtained using a pulsed CO_2 laser. Various substrates (Mo, Cu, Ni, quartz, graphite, etc.), metal films (Au, Ag, and Cu), and dielectric coatings (Ge, ThF_4, CdTe) were exposed to 10.6 μm pulses of 1 to 10 μsec duration with energy fluxes of up to 200 J/cm^2. The measured threshold values (> 140 J/cm^2 for 10 μsec pulses) of polished metal mirrors were generally in agreement with the predicted values based on the simple model. Thin film coated mirrors exhibited slightly lower threshold values (≃ 75 to 140 J/cm^2 for 10 μsec pulses) than that of simple metal metals. The thresholds for those limited numbers of dielectric mirrors tested were even lower (≃ 10 J/cm^2 for pulses of 1 to 10 μsec lengths); this low performance is attributed to inclusions which act as local absorption centers within the dielectric.

SP373. **Bibliography of temperature measurement, January 1953 to December 1969,** P. D. Freeze and L. P. Parker, Nat. Bur. Stand. (U.S.), Spec. Publ. 373, 140 pages (Nov. 1972).

Key words: Fluidic thermometers; pyrometry; radiation pyrometry; temperature measurement; thermistors; thermocouple; thermometry.

This bibliography consolidates into a single publication National Bureau of Standards Monograph 27 (January 1953 to June 1960) and its two supplements (September 13, 1963 and April 28, 1967, respectively) together with 1800 new references covering essentially the period from January 1966 to December 1969, but including some earlier citations previously omitted. The consolidated publication, which supersedes the earlier bibliographies, thus covers literature of temperature measurement published between January 1953 and December 1969.

In general, the arrangement of material in this new edition is the same as in Monograph 27, and the journal abbreviations are those employed in Chemical Abstracts. However, starting with 1963, and in the new material, scope of coverage in Part 1 was broadened to include theory, calibration, and temperature scales in addition to the previous categories of thermoelectric theory and calibration.

SP374. **Method for determining the resolving power of photographic lenses,** F. E. Washer and I. C. Gardner. Appendix added by C. E. Kuyatt, Nat. Bur. Stand. (U.S.), Spec. Publ. 374, 32 pages (June 1973) $3.00. SD Catalog No. C13.10:374.

Key words: Photographic lenses; resolution test charts; resolving power.

This publication supersedes NBS Circular 533, issued May 20, 1953. It contains the original data and a new appendix describing the NBS Microcopy Resolution Test Charts No. 1010a. It provides the photographer with two sets of charts by which the resolving power of a photographic lens may be numerically measured with respect to a definite scale of values. A detailed description is given of the procedure and technique to be followed in order that comparable values may be obtained by different observers. The test provides an objective method of testing a photographic lens. The six charts of one set are printed in black on a white background to form a high-contrast chart. The six charts of the other set are printed with gray ink on a gray background to form a low-contrast chart. Additional uses of these charts are also described. These uses include the testing of goggle lenses for definition and prismatic power and the testing of telescopes and binoculars for definition. Supersedes NBS Circular 533, issued May 1953.

SP375. **An index of State specifications and standards, covering those standards and specifications issued by State Purchasing Offices of the United States,** L. L. Grossnickle, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 375, 394 pages (Sept. 1972). $3.70, SD Catalog No. C13.10:375.

Key words: Index of State specifications and standards; Key-Word-In-Context index of State specifications and standards; purchase specifications and standards, State specifications, State; standards, State; State specifications and standards.

This computer-produced Index contains the permuted titles of more than 6,000 State purchasing specifications and standards issued by 37 State Purchasing Offices thru 1971. The title of each specification and standard can be found under all the signifi-

nt key words which it contains. These key words are arranged phabetically down the center of each page together with their rrounding context. The date of publication or latest revision, e specification or standard number, and an abbreviation for ch State appear as part of each entry. A list of these abbrevia- ns and the names and addresses of the State Purchasing Offi- als are found at the beginning of the Index.

P376. **Ruler: 15 cm/6 in, with metric-customary units and equivalents,** Nat. Bur. Stand. (U.S.), SP367, Both Sides (Dec. 1972).

Key words: Centimeter; conversion; customary units; inch; metric units.

This ruler provides metric linear measure (15 cm) and custo- ary-unit linear equivalents (approximately 6 inches) plus con- rsion formula for effecting changes from customary to metric its.

P377. **Index to the reports of the National Conference on Weights and Measures. From the First to the Fifty-sixth 1905 to 1971,** F. C. Bell, Nat. Bur. Stand. (U.S.), Spec. Publ. 377, 46 pages (Feb. 1973) 75 cents, SD Catalog No. C13.10:377.

Key words: Index; measures; National Conference; reports; weights.

This publication comprises a subject index and a speaker dex for the Reports of the National Conference on Weights d Measures from the First (1905) through the Fifty-Sixth 971). Supersedes Miscellaneous Publication 243.

P378. **Accuracy in spectrophotometry and luminescence measurements,** Proc. Conf. held at the National Bureau of Standards, Gaithersburg, Md., Mar. 22-24, 1972, R. Mavrodineanu, J. I. Shultz, and O. Menis, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 378, 268 pages (May 1973) $4.85, SD Catalog No. C13.10:378.

Key words: Accuracy; critical parameters; instrumentation; linearity; quantum efficiency; spectrofluorometry; spectrophotometry; standards.

This volume contains the 18 papers presented at the Con- rence on Accuracy in Spectrophotometry and Luminescence easurements organized by the Analytical Chemistry Division the National Bureau of Standards and held from March 22 to 4, 1972.

These papers discuss the problems encountered in accurate pectrophotometry and luminescence measurements of materi- s. They also define the status of these competences from the andpoint of basic principles, critical factors involved in the easurements, and the instrumental conditions which must be lfilled to assure accurate measurements. Particular attention is ven to the selection, production and use of Standard Reference laterials in spectrophotometry and spectrofluorometry. roblems related to health are also covered in six of the papers, vo of which include original contributions to the application of minescence techniques to specific biochemical problems.

Reprinted from the National Bureau of Standards Journal of esearch, Section A. Physics and Chemistry, Vol. 76A, Nos. 5 nd 6, Sept.-Oct., and Nov.-Dec. 1972. *These proceedings in- lude the following papers (indented):*

High accuracy spectrophotometry at the National Physical Laboratory, F. J. J. Clarke, *SP378,* pp. 1-29 (May 1973).

Key words: High accuracy spectrophotometry; photoelectronic linearity; reflectance; transmittance.

The techniques and equipment used at the National Physical Laboratory (NPL) to achieve high accuracy spectrophotometric measurements are described and discussed. The emphasis at NPL has always been on the determination of systematic components of error and their elimination or correction rather than on the attainment of mere precision, which is largely a matter of variance and resolution. The scales of regular transmittance, diffuse transmittance, total transmittance of scattering samples, regular reflectance, diffuse reflectance, total reflectance and radiance factor are determined, maintained, and made available in practical form to industry by combined use of a reference NPL manual spectrophotometer and commercial recording spectrophotometers.

The presentation will concentrate on transmittance measurements made with the reference instrument, which is designed specifically to allow separate investigation of the various possible sources of systematic error, processes that are not practicable with commercial spectrophotometers. The investigation of the linearity of the complete photoelectronic system has always been a key factor, and double-aperture devices have been used consistently at NPL for over 40 years to monitor the performance of this instrument and its predecessors. Besides instrumentation, the procurement of material standards of suitable quality is a major limitation of the art, and the types in use at NPL are described, including the recently developed Ceramic Colour Standards.

An accurate spectrophotometer for measuring the transmittance of solid and liquid materials, R. Mavrodineanu, *SP378,* pp. 31-51 (May 1973).

Key words: Absorbance; automation of accurate spectrophotometer; instrumentation, spectrophotometric; spectrophotometry, high accuracy; standard reference material in spectrophotometry; transmittance.

The optical transmittance of solids and liquids as well as the molar absorptivity of various chemical species are parameters of fundamental significance in characterizing these materials. Meaningful transmittance data can be obtained only when the measurements are performed with well-known accuracy and precision. To perform such measurements, a high accuracy spectrophotometer was designed and assembled at NBS, Analytical Chemistry Division, and will be described in this paper. This single-beam instrument is composed of a constant radiation source, a monochromator, a sample carriage, an integrating sphere-photomultiplier assembly followed by appropriate electronics, and a read out system consisting of a digital voltmeter and a computer data acquisition and handling provision. The accuracy of transmittance measurements is determined by the light-addition principle used in conjunction with a two-aperture arrangement. The spectrophotometer can be used in manual or automatic modes of operation. A detailed discussion of the data obtained with this instrument, used in both modes, will be presented together with its application to the certification of solid and liquid Standard Reference Materials for checking the photometric scales of conventional spectrophotometers.

Absolute spectroradiometric measurements, G. A. W. Rutgers, *SP378,* pp. 53-62 (May 1973).

Key words: Absolute spectroradiometry; absolute standard source of radiation; calibrated photodetector.

There are two general methods for measuring a quantity of radiation emitted by a source. One can compare it with the radiation emitted by a standard source or one can measure the radiation with a detector calibrated in absolute units. When using the latter method, one must know the

spectral transmittance factor of the optical components between source and detector.

In the present paper, a survey will be given of the standard sources available for spectroradiometry: cavity radiator, tungsten strip lamp, anode of the carbon arc, xenon arc and cascade arc. Several types of detectors such as the absolute bolometer and thermopile, with their properties, will be discussed.

Accurate measurements of and corrections for nonlinearities in radiometers, C. L. Sanders, *SP378,* pp. 63-79 (May 1973).

Key words: Nonlinearity; photocell linearity; photometric accuracy; radiation addition method.

The methods described in the literature for accurately measuring photocell linearity are surveyed and assessed. The effect of not measuring photocell linearity under the conditions used in the final apparatus are considered. Some of the conditions necessary for accurate assessment of the nonlinearity under working conditions are specified. The use of the NRC "Photocell Linearity Tester" to measure and correct for the nonlinearity of various receivers is described.

Physical parameters in high-accuracy spectrophotometry, K. D. Mielenz, *SP378,* pp. 81-93 (May 1973).

Key words: High accuracy spectrophotometry, physical parameters; linearity test of photodetector; spectrophotometry, high accuracy.

The measured apparent transmittance T_A of a filter or liquid sample depends on the beam geometry in the spectrophotometer. For focused light incident upon the sample, T_A is different for systems having different f-numbers, and also depends on the state of polarization of the light. These effects are eliminated when the incident light is collimated; in this case T_A approaches the "true" transmittance τ of the sample. Both modes of operation suffer from stray light and interference effects. The former may be reduced significantly by using mirror rather than lens optics, and the latter by suitable choice of the monochromator slit width. A new spectrophotometer based upon the above-mentioned design principles is described. The photometric precision of this instrument is shot-noise limited, permitting measurements to better than 10^{-4} transmittance units.

The double-aperture method of testing detector linearity to this level of precision is discussed. The conventional method of finding the nonlinearity correction can be replaced by a curve-fitting procedure giving better precision. Data on detector nonlinearity, and its dependence on wavelength, are presented.

Liquid absorbance standards, R. W. Burke, E. R. Deardorff, and O. Menis, *SP378,* pp. 95-108 (May 1973).

Key words: Absorptivity data; accuracy; liquid absorbance standards; Standard Reference Materials.

Errors in the measurement of the absorbances of liquid filters result from instrumental and chemical uncertainties. This paper presents a systematic study of these variables on the absorbances of selected filters. Three types of liquid filters are discussed. These are (1) individual solutions of high purity compounds, (2) composite mixtures, and (3) aqueous solutions of organic dyes. The accuracy of the absorptivity data is established using NBS-calibrated glass filters. The magnitude of the errors arising from spectral bandpass, beam geometry, stray light, internal multiple reflections, and refractive index are delineated. Finally, as a practical outgrowth of this study, the development and issuance of NBS Standard Reference Material 931, Liquid Absorbance Star dards for Ultraviolet and Visible Spectrophotometry, i described.

Accurate measurement of molar absorptivities, R. W. Bu nett, *SP378,* pp. 109-115 (May 1973).

Key words: Molar absorptivity in clinical chemistry; ran dom errors in molar absorptivity; systematic errors in mol absorptivity.

The key to accurate measurement of molar absorptivitie is a thorough understanding of the sources of error whic appear throughout the measurement procedure. Sources determinant error will be listed with comments on estima ing their magnitude and eliminating them where possibl Sources of random error will be discussed as well as th propagation of both random and determinant errors. The is discussion of the need for accurate values of molar ab sorptivities using examples from clinical chemistry. Finall the proper use of accurate absorptivity values in the clinic chemistry laboratory will be considered. Here, emphasis on the need for a quality assurance system which includ routine checks on such things as wavelength calibration ar photometric accuracy of spectrophotometers, calibration analytical balances, and quality of incoming reagents.

Problems associated with the need for standardization in clin cal spectrophotometric and fluorometeric measurements, J. Penton, G. M. Widdowson, and G. Z. Williams, *SP378,* p 117-124 (May 1973).

Key words: Clinical standards; standard reference mate als; standardization, spectrofluorometric; standardizatio spectrophotometric.

There is a growing demand in clinical chemistry f analyses to be performed in a manner allowing compariso of results among laboratories and, from time to time, in t same laboratory. Reliable comparability requires adequa procedures of standardization for spectrophotometric a fluorometric instruments and methods. Problems wi chemical and instrumental standardization are discussed.

For assays where the substance to be measured is avai ble in suitable form, primary chemical standardization justifiably popular. Relatively unsophisticated instrumen tion can be used to compare measurements of unkno samples with such standards. Because primary standar meeting all necessary criteria are not available for many says of clinical significance, standardization must depend precision and accuracy of the instrumentation used, and accurately compiled values of chemical-optical propert for the materials of interest. The task of compilation is o side the capability of the routine laboratory and should provided by a reliable central agency. If an individ laboratory is to use the agency's compiled values, t laboratory must have available precise, accurate a reasonably inexpensive instrumentation along with relia absorbance, fluorescence, and wavelength calibration st dards.

The role of spectrophotometric standards in the clini chemistry laboratory, R. N. Rand, *SP378,* pp. 125-134 (M 1973).

Key words: Clinical spectrophotometry, accuracy, pre sion; optical cuvettes; spectrophotometric standards, cl cal.

It is obvious that erroneous data reported to a physic may adversely affect patient welfare. Currently, accepta limits of accuracy and precision are poorly defined.

should be recognized, however, that the spectrophotometric measurement step in an appropriate analytical procedure is critical and inapparent error may occur. Spectrophotometric measurements, both manual and automated, are extensively used in the clinical chemistry laboratory. At least 1,000,000 such measurements per day on rather diverse equipment are made in this country; yet, few standards exist. Results of intra-lab surveys suggests that performance could be improved. The various ways in which spectrophotometry is used will be illustrated and a discussion of possible errors resulting from nonstandardized instrumentation will follow. There is pressing need for well defined and easily usable standards for wavelength, photometric accuracy, photometric linearity, stray light, as well as NBS specifications for optical cuvettes.

Spectrophotometric standards, W. H. Venable, Jr., *SP378,* p. 135-136 (May 1973).

Key words: Photometric accuracy; standards, spectrophotometric.

To be useful, spectrophotometric measurements must be believable and practical. The basic standard for any believable spectrophotometric measurement is the ability to accurately compare fluxes of radiation within the framework of a well-defined geometry. The emphasis in the program proposed for the Institute for Basic Standards is to develop such ability over the broadest range of spectrophotometric measurements. Establishing such a basis will enable the National Bureau of Standards to render real assistance to those who deal with the problem of making practical measurements.

Absolute spectrofluorometry, W. H. Melhuish, *SP378,* pp. 137-150 (May 1973).

Key words: Actinometers; calibration of spectrofluorometers; detectors, absolute; fluorescence spectra, corrected; quantum counters; spectrofluorometers, design; spectrofluorometry, absolute; standard lamps; standards, fluorescence; thermopiles.

The last 10 years has seen the increasing publication of the emission spectra of organic, inorganic and metal-chelate compounds, but there is no agreed method of presentation of such spectra. In the few cases where corrected emission spectra have been published, there is often no mention of the units used for the intensity coordinate or the method used for correcting spectra. A method of reporting absolute fluorescence spectra originally put forward in 1962 will be reexamined and improved. The two best known methods for calibrating spectrometers for absolute spectrofluorometry: (a) standard tungsten lamp, (b) quantum counter method, will be critically examined, and the limitations and possible improvements in accuracy will be proposed. The criteria for an emission standard will be examined and the use of emission standards for calibrating spectrofluorometers discussed. It is suggested that the distribution of emission standards to laboratories measuring corrected fluorescence spectra and the analysis and publication of the results should be done in the near future.

Absolute quantum efficiencies, G. A. Crosby, J. N. Demas, and J. B. Callis, *SP378,* pp. 151-167 (May 1973).

Key words: Calorimetry in quantum yields; laser, use in quantum yields; photodetectors in quantum yields; quantum efficiencies.

Recent developments in several areas of chemistry, laser technology, photodetector instrumentation, and calorimetry are surveyed, and their probable impact on the measurement of quantum yields is assessed. Chemical developments include: (a) synthesis and design of new luminescent molecules that could possibly serve as standards, (b) application of improved separation techniques to provide samples of extreme purity, and (c) advances in photochemistry that portend the development of wide-range chemical actinometers. The potential use of lasers in quantum-yield measurements and their advantages over conventional sources for application in both optical and calorimetric techniques are pointed out. New methods of quantum-yield measurements, based on the novel characteristics of laser pump sources, are suggested, including the feasibility of measuring yields under time-resolved conditions and of employing internal standards. The possible lifting of wavelength restrictions on both laser sources and detector devices and the implications of these developments for extending the spectral range of quantum-yield measurements are discussed. The current status of calorimetry for determining yields is surveyed, and the impact of recent technology on the feasibility of developing calorimetric methods competitive with optical methods is assessed.

Phosphorimetry, J. D. Winefordner, *SP378,* pp. 169-182 (May 1973).

Key words: Aqueous solvents in phosphorimetry; phosphorimetry; rotating capillary cell; solvents for phosphorimetry.

Phosphorimetry in the past has received limited use because the precision of reproducibility was inadequate, there were solvent limitations, and preparation of test specimens was difficult and time consuming. Detection limits have now been lowered by more than two orders of magnitude by using a rotating capillary sample cell, a more stable excitation-source power supply, and aqueous solvents. These steps have also increased precision by more than an order of magnitude. Considerable reduction in time and effort of sampling and measurement has been effected compared to phosphorimetric measurements made with standard procedures and commercial equipment. Twenty microliters of aqueous solution is all that is required to fill a quartz capillary cell by capillary action. Capillary cells filled with aqueous solutions do not crack when cooled to 77 K or when returned to room temperature. Rotation of the sample cell minimizes effects due to cell orientation and thus improves precision. Reduction of background phosphorescence results in improved accuracy of analysis. A study was made of the influence of methanol-water mixtures and of sodium-halide aqueous solutions on the magnitude of phosphorescence signals from several substances and of the effect on signal-to-noise ratios. The optimum solvent system for many phosphorimetric measurements is discussed. Analytical results are given for several organic substances measured by phosphorimetry at 77 K. These results are compared with those from previous studies by older methods.

Measurements of absolute values in biochemical fluorescence spectroscopy, R. F. Chen, *SP378,* pp. 183-196 (May 1973).

Key words: Absolute fluorometry; absolute fluorometry in biochemistry; standard reference materials in fluorometry.

Fluorescence spectroscopy is an important tool of the biochemist studying the structure and interactions of proteins and nucleic acids. The four basic quantities to measure accurately are: 1. spectra (corrected excitation and emission), 2. quantum yields (Q), 3. fluorescence decay

characteristics, and 4. polarization. Commercially available instruments, with little modification, can be used to obtain these measurements, but the biochemist in this field is very dependent on the accuracy of measurements of substances he uses as standards. Confusion arises from disagreement between reported values for standards which may be used to calibrate a detector system to obtain quantum yields, or to set up lifetime and polarization photometers. For instance, the protein chemist is fond of using tryptophan and quinine as quantum yield standards, but Q for tryptophan has been variously reported as 0.13 and 0.20, and Q values for quinine bisulfate range from 0.4 to 0.7. The biochemist should also be aware of the problems inherent in the use of commercially available instruments in absolute measurements, as well as the special complications arising in complex biochemical systems where the fluorescence is heterogeneous.

Newer fluorometric methods for the analysis of biologically important compounds, G. G. Guilbault, *SP378*, pp. 197-202 (May 1973).

Key words: Enzymes, fluorometric analysis; fluorometry of enzymes; fluorometry of substrates; silicone pad; solid surface fluorometry.

Newer fluorometric methods for the analysis of biologically important compounds will be discussed: enzymes such as LDH, alkaline phosphatase, lipase and cholinesterase, and substrates such as glucose, urea and uric acid. These methods are based on the production of fluorescence initiated by an enzymic reaction.

New reagentless fluorescence methods will be described for enzymes and substrates. These methods are highly precise (1%), fast (less than 1 minute) and involve no preparation of reagents. These methods, as adapted to clinical laboratory procedures, will be discussed.

Inorganic ions in glasses and polycrystalline pellets as fluorescence standard reference materials, R. Reisfeld, *SP378*, pp. 203-225 (May 1973).

Key words: Fluorescence standards, inorganic ions; glass standards in fluorescence; rare-earth-doped glasses.

The absorption and fluorescence of inorganic ions; glass polycrystalline disks doped by heavy metal ions is discussed, and their use as fluorescence standards is evaluated. The advantages of the glass standards over other media is summarized.

The glass standards are divided into two groups (1) glasses doped by trivalent earths such as Gd^{3+}, Tb^{3+}, Eu^{3+}, Sm^{3+}, and Tm^{3+} which have narrow band optical spectra as a result of intraconfigurational transitions, and (2) glasses and polycrystalline disks doped by ions such as Tl^{+}, Pb^{2+}, Ce^{3+}, and Cu^{+} which have broad spectral bands since the optical spectra originate from interconfigurationally allowed transitions. Optical and physical parameters, including matrix effects, quantum efficiencies, decay characteristics, Stokes' shifts and spin-orbit versus orbit-lattice interactions due to the different transitions will be discussed.

Group (1) glasses are suitable for use as standards where a narrow well-defined fluorescence range is required, and group (2) glasses are suitable for use as standards whenever a substance with a wide range of fluorescence is measured. Special emphasis will be placed on energy transfer between donor and acceptor ions.

Development of a new fluorescent reagent and its application to the automated assay of amino acids and peptides at the picomole level, S. Udenfriend, *SP378*, pp. 227-230 (M 1973).

Key words: Fluorometry, amino acids; fluorometry, pe tides; picomole fluorometry.

Methods for the assay of amino acids and peptides a most important in elucidating the structure of proteins a peptides. In many important areas of research such as in e docrinology, neurobiology, and genetics, methods a needed with sensitivity higher than is available with t widely used colorimetric ninhydrin procedure. A short wh ago, we noted that all primary amines react with ninhydi and phenylacetaldehyde to give a ternary product which highly fluorescent. The chemistry of that reaction has n been elucidated and the conditions have been modified a improved so that essentially quantitative yields fluorescent products are formed with all primary amin The reaction has been automated and is being used as t detecting system for chromatography of amino acids, pe tides and amines in the 10 to 100 picomole range. Proble concerning the fluorescence instrumentation and the iso tion and chromatography of these compounds in t picomole range will be discussed.

Considerations on organic compounds in solution and in ganic ions in glasses as fluorescent standard reference materi R. A. Velapoldi, *SP378*, pp. 231-244 (May 1973).

Key words: Emission spectra; excitation spect fluorescence; fluorescence standards; glass standards; qu ine derivatives; rare earths; relative quantum efficienci solution standards.

The use of various organic compounds in solution and organic ions in glasses has been investigated as possi fluorescence Standard Reference Materials. Emphasis placed on measuring physical and chemical parameters s as stability, reproducibilities of absorbance and fluoresce measurements, relative quantum efficiencies as a funct of excitation wavelength, etc., for quinine derivatives selected organic compounds. A brief discussion is inclu on the use of rare earth and non-rare earth inorganic ion glasses as standards.

SP379. **Report of the 57th National Conference on Weights Measures 1972,** F. C. Bell and H. F. Wollin, Report Edit Nat. Bur. Stand. (U.S.), Spec. Publ. 379, 216 pages (M 1973) $1.85, SD Catalog No. C13.6/3:379.

Key words: Administration; Conference; laws; procedu regulations; requirements; technology; weights and n sures.

This is a report of the proceedings (edited) of the 57th tional Conference on Weights and Measures, sponsored by National Bureau of Standards, held in Washington, D.C., 10-14, 1972, and attended by state, county, and city weights measures officials, the Federal Government, business, indus and consumer organizations.

SP380. **Photonuclear reaction data, 1973,** E. G. Fuller, H. Gerstenberg, H. Vander Molen, and T. C. Dunn, Nat. Stand. (U.S.), Spec. Publ. 380, 131 pages (Mar. 1973) $2 SD Catalog No. C13.10:380.

Key words: Bibliography; data index; data summary; ments; isotopes; nuclear physics; photonuclear g resonance; photonuclear reaction.

A brief summary is given of the available data on the gross tures of the photonuclear giant resonance. Data are presente tabular form for all nuclei where measurements have been m

In addition, a comprehensive, annotated data index and bibliography are given which cover experimental data for the field of photonuclear reactions published in scientific and technical journals in the period from 1955 through 1972. Organized by element and isotope, each entry in the index is for a specific reaction reported in a given reference. Information is given on the type of measurement, excitation energies studied, source type and energies, detector type and angular ranges covered for each reaction entry. This publication supersedes NBS Miscellaneous Publication 277 and NBS Special Publication 322 which also embraced Supplement 1 to Misc. Publ. 277. All information contained in these publications has been combined and merged with new data to form the Photonuclear Data Index and Bibliography contained in this publication.

SP381. **Bibliography of ion-molecule reaction rate data (January 1950-October 1971),** G. A. Sinnott, Nat. Bur. Stand. (U.S.), Spec. Publ. 381, 73 pages (Oct. 1973) $1.00, SD Catalog No. C13.10:381.

Key words: Atoms; bibliography; cross-sections; ions; molecules; rate coefficients; reactions.

A bibliography is presented of papers in the open literature that contain original experimental data on ion-molecule reaction rates or cross sections. Positive and negative ion-molecule and ion-ion reactions are included but not electron impact processes. For papers to be included, the reactants must have been identified and data for kinetic energies below 10 electron volts must have been presented.

SP382. **Hydraulic research in the United States and Canada, 1972,** G. Kulin and P. H. Gurewitz, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 382, 340 pages (Jan. 1974) SD Catalog No. C13.10:382.

Key words: fluid mechanics; hydraulic engineering; hydraulic research; hydraulics; hydrodynamics; model studies; research summaries.

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1971-1972 are summarized. Projects from more than 250 university, industrial, state and federal government laboratories in the United States and Canada are reported.

SP383. **The creative partnership: Government and the professional services,** Proceedings of the Fourth Users-Producers Conference Sponsored by the Technical Analysis Division, Institute for Applied Technology, National Bureau of Standards, in Cooperation with the Center for the Study of Private Enterprise, The American University, held at the National Bureau of Standards, Gaithersburg, Md., January 23, 1973, J. D. Johnson, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 383, 142 pages (Aug. 1973) $2.10, SD Catalog No. C13.10:383.

Key words: Creative-partnership; management; operating; procurement; services; Users-Producers.

These proceedings are written for the 4th Users-Producers Conference held at the National Bureau of Standards on January 23, 1973. The Conference was designed to highlight the problems and advantages in our present procurement system when Government utilizes the services of professional and professions Service firms.

The speakers addressed themselves to the many facets of the procurement process. They represent both the private and Government side and bring their views forward in a clear and concise manner. Speakers are grouped into three panels. The first panel describes the development of the problem, the second panel considers the procurement process, and the third panel discusses managing the project. At the end of each group of panel speeches, there is a general discussion with comments and questions by all attendees.

There is also a separate presentation given by the Honorable James C. Corman, United States Congressman (Calif.), Chairman, Sub-Committee on Government Procurement of Professional Services. *These proceedings include the following papers (indented):*

Management information and computer systems, R. M. Davis, *SP383,* pp. 21-28 (Aug. 1973).

Management consulting, W. P. Sommers, *SP383,* pp. 29-41 (Aug. 1973).

Architecture and engineering, J. R. Dunn, *SP383,* pp. 42-45 (Aug. 1973).

Operating level problems in procurement, W. E. Cushen, *SP383,* pp. 46-56 (Aug. 1973).

Government procurement policy, P. Waterman, *SP383,* pp. 69-73 (Aug. 1973).

The relationship of private enterprise to Government procurement, R. W. Kreuger, *SP383,* pp. 74-78 (Aug. 1973).

Legal aspects of Government procurement, G. P. Bond, *SP383,* pp. 79-86 (Aug. 1973).

A proposed Government system for professional services, J. E. Moriarty, *SP383,* pp. 87-93 (Aug. 1973).

Government project management, T. F. Noble, *SP383,* pp. 107-109 (Aug. 1973).

Managing the private contractor, R. A. Walbrecker, *SP383,* pp. 110-114 (Aug. 1973).

Managing the university research team, R. P. Boynton, *SP383,* pp. 115-122 (Aug. 1973).

SP384. **Annotated bibliography of the literature on resource sharing computer networks. Revised 1976,** H. M. Wood, S. W. Watkins, and I. W. Cotton, *Nat. Bur. Stand. (U.S.), Spec. Publ. 384 (revised),* 179 pages (Sept. 1976) SD Catalog No. C13.10:384/rev..

Key words: bibliography; computer network; data communications; resource sharing.

This bibliography consists of over 1,000 references with critical annotations to the literature on computer networks. A classification scheme has been developed to make each citation more accessible by general topic. Five indexes to the bibliography are included: author index, corporate author index, network index, title word index, and report number index.

SP385. **Transfer of radiation in spectral lines,** V. V. Ivanov, English language edition of *Radiative Transfer and the Spectra of Celestial Bodies.* Prepared in collaboration with D. G. Hummer from a draft translation by Eileen Weppner, Nat. Bur. Stand. (U.S.), Spec. Publ. 385, 480 pages (Nov. 1973) $7.45, SD Catalog No. C13.10:385.

Key words: Astrophysics; energy loss; photons; radiative transfer; spectral line profiles; stellar atmospheres.

This book is a revised and somewhat extended version of V. V. Ivanov's *Radiative Transfer and the Spectra of Celestial Bodies,* published in Moscow in 1969. The principal subject is

the transfer of radiant energy through gas composed of atoms with two discrete levels. Although the emphasis of the book is on analytical methods, extensive numerical and graphical results are presented.

SP386, 1976 Edition. **Standards on noise measurements, rating schemes, and definitions: A compilation,** T. L. Quindry, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 386, 1976 Edition,* 84 pages (Apr. 1976) SD Catalog No. C13.10:386.

Key words: acoustics; noise; rating scheme; sound; standards organization.

This compilation deals with material assembled from the various standards, industrial and trade organizations, or technical and scientific societies concerned with acoustics. There has been no attempt to review or evaluate the standards, but rather just to list documents covering measurement techniques, calibration methods, definitions, rating schemes, and equipment and product specifications concerned with noise. Those standards dealing solely with ultrasonics, audio equipment, or shock and vibration have not generally been included. The paragraphs describing the standards give a brief summary of intent and/or scope of the standard. In some cases the paragraph is the official description of the standard as issued by the organization or society promulgating the standard, while in others the paragraph merely describes the intent of the standard. Proposed standards are also listed where available. Not listed are proposed revisions of current standards and those which must be reapproved to remain in effect. For the convenience of those readers wishing to purchase copies of standards, names and addresses for the various organizations and/or societies are provided. Federal Regulations directly involving noise measurements are given in Appendix A. Appendix B lists active committees for each organization and names and addresses of appropriate committee chairmen or technical contacts. This compilation includes all information available as of January 1, 1976.

SP387. **Laser induced damage in optical materials: 1973.** Proceedings of a symposium sponsored by Office of Naval Research, The American Society for Testing and Materials and by the National Bureau of Standards, Boulder, Colo. May 15-16, 1973, A. J. Glass and A. H. Guenther, Editors, Nat. Bur. Stand. (U.S.), Spec. Publ. 387, 285 pages (Dec. 1973) $2.85, SD Catalog No. C13.10:387.

Key words: IR windows and mirrors; laser damage; laser materials; self-focusing; thin films.

The Fifth ASTM-ONR-NBS Symposium on Laser Induced Damage in Optical Materials was held at the National Bureau of Standards in Boulder, Colo. on May 15 and 16 of this year. These Symposia are held as part of the activities of Subcommittee II on Lasers and Laser Materials, of the ASTM. Subcommittee II is charged with the responsibilities of formulating standards and test procedures for laser materials, components, and devices. The chairman of Subcommittee II is Haynes Lee, of Owens-Illinois, Inc. Co-chairmen for the Damage Symposia are Dr. Arthur H. Guenther, Scientific Director, Technology Division of the Air Force Weapons Laboratory, and Dr. Alexander J. Glass, Head, Basic Studies, Y Division, Lawrence Livermore Laboratory.

Approximately 135 attendees at the Symposium heard 25 papers on topics relating to laser induced damage in crystalline and nonlinear optical materials, at dielectric surfaces, and in thin film coatings as well as discussions of damage problems in the infrared region due both to cw and pulsed irradiation. In addition, several reports on the theoretical analysis of laser-materials interaction, relative to the damage process were given, along with tabulations of fundamental materials properties of importance in evaluation of optical material response to high power laser radiation. Several papers presented by title only are included within the proceedings for completeness.

The proceedings of these Symposia represent the major sources of information in the field of laser induced damage in optical materials. The Symposia themselves, along with the periodic meetings of Subcommittee II, provide a unique forum for the exchange of information regarding laser materials specifications among the manufacturers and users of laser devices, components, and systems. The Symposia also serve as a mechanism of information gathering to enable the Subcommittee to write informed and realistic specifications. *These proceedings include the following papers (indented):*

The ARPA program on optical surface and coating science, C. M. Stickley, *SP387,* pp. 3-10 (Dec. 1973).

Nonlinear refractive index measurements in laser media, A. Owyoung, *SP387,* pp. 11-24 (Dec. 1973).

Key words: Ellipse rotation; glass; nonlinear index; nonlinear susceptibility; self focusing; yttrium aluminum garnet.

The ellipse rotation technique has been employed to measure nonlinear refractive index changes in YAG and several laser glasses using a Q-switched TEM_{00q} mode ruby oscillator-amplifier. By time resolving the 9 ns ellipse rotation signal, we obtain all of the information necessary to plot ellipse rotation vs. input power in a single shot, thereby also introducing the capability to detect transient contributions which would interfere with the measurement.

A small anisotropy is found in the third order nonlinear susceptibility of YAG and values for n_2 are inferred assuming electronic distortion to be the primary mechanism.

Self-focusing in yttrium aluminum garnet and optical glasses A. Feldman, D. Horowitz, and R. M. Waxler, *SP387,* pp. 26-35 (Dec. 1973).

Key words: Absorption coefficient; electrostriction; Kerr effect; laser damage; nonlinear refractive index; optical glasses; self-focusing; thermal self-focusing; yttrium aluminum garnet.

An analysis of damage threshold data in borosilicate crown glass, fused silica, and dense flint glass for linearly and circularly polarized radiation indicates that the Kerr effect is the dominant self-focusing measurement for 1.06 μm laser pulses with a 25 ns temporal width. The calculated thermal effect is found to be larger than the electrostrictive effect, which is small. Self-focusing length measurements in yttrium aluminum garnet (YAG) are found to agree with theory. In YAG, the Kerr effect also dominates.

A rational definition of index nonlinearity in self-focusing media, A. J. Glass, *SP387,* pp. 36-41 (Dec. 1973).

Key words: Critical power; laser damage; nonlinear index; self focusing.

It is proposed that the index nonlinearity in self-focusing media be reported in terms of a critical power for the medium, P_1, rather than in terms of n_2. The principal results of self-focusing theory are expressed in terms of the ratio (P/P_1), where P is the total power in a Gaussian beam. Using P_1 not only simplifies the expressions for quantities of physical interest, but also will remove some of the confusion now existing in the literature of self-focusing and laser damage.

Self focusing of very powerful laser beams, B. R. Suydam, *SP387,* pp. 42-48 (Dec. 1973).

Key words: Laser damage; nonlinear; self focusing.

Self focusing has heretofore been studied by assuming something equivalent to total collapse of the beam. Computer simulations at high power level show, however, that it is rather some small portion of the beam (e.g., a diffraction spike) which first collapses. We have therefore examined self focusing as a problem in stability theory. The method can be applied to divergent beams and to any medium in which gain is a known function of field strength. The theory agrees well with computer experiments. We find an absolute limit to the intensity available from a glass laser of order 10^{10} watts/cm^2.

Homogeneity requirements for minimizing self-focusing damage, J. Marburger, R. Jokipii, A. Glass, and J. Trenholme, *SP387*, pp. 49-56 (Dec. 1973).

Key words: Laser damage; nonlinear index; random index variation; self focusing.

The theory of wave propagation in random media is generalized in a straightforward way to include the effects of self focusing. Simple solutions are obtained which show how the intensity fluctuations which are induced by random inhomogeneities grow catastrophically. These solutions can be used to obtain conditions on the homogeneity of the medium, and on the fluctuations in the incident beam, for elimination or reduction of catastrophic self focusing in the medium.

Self focusing and saturation in disk amplifiers, K. A. Brueckner and J. E. Howard, *SP387*, pp. 57-62 (Dec. 1973).

Key words: Damage threshold; disk amplifiers; eikonal; saturation; self-focusing.

The methods of geometrical optics are used to investigate self focusing in arbitrarily spaced Nd glass disk amplifiers. Difference equations describing the growth of a localized ring or spot beam inhomogeneity are derived and solved numerically. The corresponding differential equations are solved in closed form for the case of equally spaced disks, yielding explicit constraints on the allowable amplitude and width of spikes in terms of the thickness and spacing of the disks. In a more refined calculation, the decrease in gain at large flux densities is taken into account. The analytic and numerical results are applied to a typical laser system, wherein a chain of slab amplifiers is used to produce a high energy pulse for CTR experiments.

Damage control in a 100 GW high power laser system, J. Tillson, B. Guscott, and K. Moncur, *SP387*, p. 63 (Dec. 1973).

Key words: Disc laser; laser damage; laser fusion; Nd-glass lasers.

With the development of high power Nd^{+++} lasers for CTR research, severe damage in laser glass and optical components can be expected from both the output energy and from reflected plasma energy. At KMS, laser operating procedures, system diagnostics, and several isolation devices have been developed in an effort to reduce damage effects and to maximize laser lifetime. Since December 1972, the KMS laser system has operated in the 50-100 GW power range (up to 300 J at 3 nsec pulse width) for a total of 310 shots on target. An additional 2,379 laser shots have been fired for purposes of laser beam diagnostics. Plasma experiments with f/1 and f/1.5 focusing lenses have been performed with plane targets of CD_2, CH_2 and aluminum. This paper will discuss the KMS laser system, with particular emphasis on damage control procedures and equipment necessary for conducting high energy plasma experiments.

Low scatter finishing of optical elements, W. P. Barnes, *SP387*, pp. 64-68 (Dec. 1973).

Key words: Low scatter; mirror; optical surfacing.

The adaptation of bowl-feed polishing techniques to the low-scatter finishing of large optical elements is described. Electron micrographs of the surface of a 27 inch diameter fused silica spherical mirror indicate promise for the successful superpolishing of large, high-precision, optical elements.

Laser surface damage studies on several glasses, N. L. Boling, G. Dubé, M. D. Crisp, *SP387*, pp. 69-79 (Dec. 1973).

Key words: Absorption; electron avalanche; laser damage; plasma formation; polishing compound.

Q-switched laser induced surface damage studies on several glasses and sapphire are reported. By measuring thresholds on these various glasses, investigating the effect of various polishing compounds on damage of laser glass, studying damage morphologies, and taking care to detect damage in its initial stages, several conclusions are reached. Initial damage in practical situations is probably due to absorption by isolated submicron inclusions, and not electron avalanche. Inclusion type damage is found to occur without formation of the bright plasma associated with electron avalanche. The damage threshold is found to depend strongly on polishing compound in some cases. It is found that increased smoothness of a surface does not necessarily lead to an increased threshold.

Some aspects of surface damage that can be explained with linear optics, M. D. Crisp, *SP387*, pp. 80-83 (Dec. 1973).

Key words: Laser damage; surface damage.

Quantitative predictions of the relative values of surface damage thresholds for various geometries are found to follow from linear optics and simple assumptions concerning the damage mechanism. It is assumed that, for a fixed pulse shape, a surface will damage when it experiences an oscillating field of amplitude greater than a threshold value. This assumption is consistent with both absorption by inclusions and avalanche breakdown as a damage mechanism. The ratios of damage thresholds for entrance and exit surfaces at normal incidence, surfaces at Brewsters angle and a total internal reflection surface are found to depend only on the index of refraction of the material. It follows from the analysis that the different threshold values obtained from measurements made with various geometries are simply related and contain information about only one intrinsic surface parameter.

Damage in lithium iodate with and without second harmonic generation, C. R. Giuliano and D. Y. Tseng, *SP387*, pp. 84-90 (Dec. 1973).

Key words: Bulk damage; lithium iodate; phase matching; second harmonic generation.

The purpose of this study has been to determine whether a significant difference exists between bulk damage thresholds under conditions of phase matching (PM) for second harmonic generation (SHG) compared with the condition where phase matching is absent. Bulk damage in lithium iodate was studied both at 1.06 μm and 0.694 μm using single mode Q-switched lasers. Under the conditions of the experiment no significant difference was observed in damage thresholds between PM and non-PM conditions for single shot damage at 0.694 μm and for both single pulse and 10 pps at 1.06 μm.

Laser surface damage studies at Bendix, P. Bräunlich, J. Carrico, B. Rosenblum, and A. Schmid, *SP387,* pp. 91-102 (Dec. 1973).

Key words: Exoelectron emission; laser surface damage.

A status report will be presented which describes the application of the exoelectron imaging technique as a nondestructive test method for laser surface damage. The mechanism of exoelectron emission from dielectrics will be discussed and an outline of a theory of laser induced exoelectron emission will be given. It will be shown that thermally or optically stimulated electron emission images represent a record of physical phenomena that are precursors of laser surface damage. Experimental techniques used to obtain exoelectron images after laser exposure of the sample will be described and recent results presented.

Effects of laser flux on GaAs, J. L. Smith, *SP387,* pp. 103-106 (Dec. 1973).

Key words: GaAs; laser-induced acoustical pulse; laser-induced damage; stimulated Brillouin scattering; threshold dependence on wavelength and doping.

Pulsed laser damage thresholds for surface damage of GaAs have previously been measured for 0.694 and 1.06 μm laser beams. Measurements have recently been made for a 10.6 μm laser beam. These wavelengths were obtained with ruby, Nd^{3+}-glass, and TEA CO_2 lasers with pulse half-widths of 20 nsec, 60 nsec, and 100 nsec, respectively. The first two lasers utilized dye Q-switched cells. Later work with the Nd^{3+}-glass laser incorporated a Pockels cell for Q-switching. Surface damage thresholds ranged from about 8 MW cm^{-2} for 0.694 μm radiation to 30 MW cm^{-2} for 10.6 μm radiation, and except for 10.6 μm radiation did not depend significantly on whether the GaAs was p-type, n-type, or undoped. For 10.6 μm radiation, the p-type GaAs was damaged at one third the value for the n-type GaAs and mostly exhibited bulk cracking rather than surface damage. The damage threshold of GaAs shows some dependence on the 1.06 μm laser pulse time, becoming lower as the pulse duration increases. Highly localized damage sites occurring at 1.06 μm cannot be accounted for by laser beam inhomogeneities. A study of the effects of surface trash on this localization revealed that, although visible trash does play a role, it need not be present for surface pits of approximately 2 μ size to occur. An arrangement utilizing a Pockels-switched Nd^{3+}-glass laser and quartz transducer was devised to determine whether the leading acoustical pulse induced in undoped GaAs bulk by the laser beam was rarefaction or compression. Rarefaction could result if the material were strongly electrostrictive, and this would bring out the question of the possibility of stimulated Brillouin scattering which depends on the effect. On the other hand, compression would result, for example, from thermal expansion. The study confirmed that the main effect of the 1.06 μm laser beam is to produce a compression in the leading pulse. The compression pulse amplitude was found to be proportional to the laser power up to the damage threshold.

Carrier effects observed in laser-induced damage in a silicon junction photodetector, J. F. Giuliani, *SP387,* pp 107-113 (Dec. 1973).

Key words: Laser damage; silicon photodetector; surface damage; surface recombination lifetimes.

Damage induced by a pulsed 1.06 μm laser was studied in a n-p-n silicon photodiode on the basis of measured surface changes using a technique of He-Ne beam probing of the photoconductive gain and excess minority carrier diffusion lengths as functions of increasing cumulative pulsed-laser energy.

These preliminary studies suggest that the pulsed laser produces significant changes in the surface recombination rates for the charge carriers and this in turn can be related to the measured changes in detector gain and dark current also as functions of increasing laser energy.

The role of coating defects in laser-induced damage to thin films, L. G. DeShazer, B. E. Newnam, and K. M. Leung, *SP387,* pp. 114-123 (Dec. 1973).

Key words: Coating defects; damage morphology; damage thresholds; laser-induced scatter; mean distance between defects; rutile crystal damage; thin-film damage.

Laser damage to dielectric thin-film coatings was investigated using a TEM_{00} Q-switched ruby laser. The laser-induced damage thresholds of several thin-film coatings increased with decreasing laser beam spot-size and were invariant for spot-sizes greater than 150 μm. A simple model has been suggested that the distribution and nature of coating defects have played an important role in this spot-size dependence, e.g., the probability of the laser beam striking a defect site will be greater for larger spot-sizes and that damage in materials can be distinguished as defect damage and intrinsic damage. This model can be also applied to surface damage.

The role of inclusions and linear absorption in laser damage to dielectric mirrors, D. Milam, R. A. Bradbury, and M. Bass, *SP387,* pp. 124-132 (Dec. 1973).

Key words: Dielectric mirror; inclusions; laser-induced damage; linear absorption.

By studying the morphology of threshold damage and observing the predicted "pulse duration-inclusion size" relationship we have found that laser damage to dielectric coatings is primarily determined by the presence of metallic or highly absorbing nonmetallic inclusions. It is also shown that linear absorption does not determine the damage resistance of coatings when they are properly prepared from materials which do not show bulk absorption.

Time resolution of laser-induced damage to thin films, N. Alyassini, J. H. Parks, and L. G. DeShazer, *SP387,* pp. 133-137 (Dec. 1973).

Key words: Laser induced film damage; optical probe; surface plasma; time resolved laser damage.

The time evolution of laser-induced damage to ZnS film was measured by monitoring the intensity of a He-Ne probe beam internally reflected from the films at the critical angle. The time behavior of the damage was measured with a resolution of 2 nsec, and was correlated to the ruby laser pulse and the spark emission, when present. This technique was used to compare the damage time evolution with the related damage site morphology observed in SEM photographs.

Investigation of pulsed CO laser damage in coated metal mirrors and dielectric-coated windows, S. Holmes and P. Kraatz, *SP387,* pp. 138-150 (Dec. 1973).

Key words: CaF_2 windows; CO laser damage; damage threshold; dielectric antireflection coatings; metal coatings; metal mirrors; protective overcoatings.

Results of some pulsed high power CO laser damage tests

of metal-coated metal mirrors and AR-coated CaF_2 windows are reported. The laser employed in these tests is an E-beam pumped, CO gas laser which produces a multimode output pulse of ~ 100 μsec duration at a wavelength of 5 μm. It was focused to a spot size of ~ 2-3mm, yielding maximum energy densities in excess of 700J/cm^2. The mirrors tested were polished beryllium copper substrates coated with either silver or gold; the windows were polished CaF_2 having multilayer AR-coatings comprising combinations of ThF_4, PbF_2, MgF_2, and MgO. Damage threshold measurements and effects of fabrication parameters on performance are discussed.

Pulsed CO_2 laser damage studies of windows and window coatings, A. I. Braunstein, V. Wang, M. Braunstein, J. E. Rudisill, and J. Wada, *SP387*, pp 151-156 (Dec. 1973).

Key words: CO_2 laser damage; damage thresholds; laser windows; window coatings; KCl; ZnSe; CdTe.

A study was made of damage thresholds and damage morphology for KCl, ZnSe, and CdTe windows subjected to a pulsed CO_2 TEA laser. Damage to KCl and CdTe was initiated at the surfaces while ZnSe windows were found to fail due to explosion of inclusions in the bulk. For As_2S_3 passivated KCl or ThF_4/As_2S_3 antireflection coated KCl, or BaF_2/ZnS antireflection coated ZnSe the damage morphology was the same as for uncoated windows—failure was not initiated by the coatings. For the two antireflection coating designs studied electric field distributions are shown, and their use in choosing between alternate designs is explained.

Pulsed CO_2 laser damage studies of metal and dielectric coated mirrors, V. Wang, A. Braunstein, M. Braunstein, J. E. Rudisill, J. Y. Wada, *SP387*, pp. 157-169 (Dec. 1973).

Key words: As_2S_3; CdTe; dielectric reflector; inclusions in dielectrics; KCl; pulsed CO_2 laser damage; thin film damage; ZnTe.

Damage thresholds measured using single transverse mode 10.6 μm radiation are reported for several metal and dielectric enhanced multilayer mirrors ($CdTe/ThF_4$, ZnTe/ZnS, As_2S_3/KCl). Typical values are in the range of several J/cm^2 for semiconductor thin films to over 30 J/cm^2 for wide bandgap dielectric thin films (pulse length 0.6 μsec). These single mode values are considerably lower than the corresponding multimode results. Scanning electron microscope, x-ray microprobe, and power dependent absorption measurements were performed in order to examine the nature of mirror surfaces before and after laser damage. Several models for potential damage mechanism (thermal, inclusion, dielectric, etc.) have been investigated. A comparison of the experimental and theoretical results has provided the basis for a possible damage model.

Damage threshold in 10.6 μm laser materials, J. Davit, *SP387*, pp. 170-174 (Dec. 1973).

Key words: Alkali halides; infrared windows; laser damage; TEA laser.

Q-switched laser damage thresholds have been determined for three materials: germanium (Ge), potassium chloride (KCl), and sodium chloride (NaCl). A TEM_{oo} mode CO_2 laser with output at 10.6 μm wavelength and a 75 nsec pulse length was employed. For the three materials, the damage observed was surface damage. In the case of potassium chloride and sodium chloride, while the surface damage threshold was about the same as with germanium, the surface breakdown threshold was much lower. Results on antireflection coated materials are also reported.

Radiation induced damage to NaCl by 10.6 μm fractional joule, nanosecond pulses, W. H. Reichelt and E. E. Stark, Jr., *SP387*, pp. 175-180 (Dec. 1973).

Key words: Damage threshold; exit damage; NaCl; surface damage.

Fractional joule nanosecond pulses from the Los Alamos pulsed CO_2 laser system have been used to obtain preliminary breakdown data for optical quality NaCl. Both surface and bulk damage have been observed. Surface damage in some samples takes the form of a rectangular craze pattern. This pattern is at the surface and similar to that observed by Bastow, et al., in TiC irradiated with light pulses from a Q-switched ruby laser. Estimated thresholds for breakdown and damage patterns are given.

A study of 10.6 μm laser induced damage in alkali halide crystals, H. Posen, J. Bruce, J. Comer, A. Armington, *SP387*, pp. 181-188 (Dec. 1973).

Key words: Alkali halides; ALQLOY; damage threshold; IR coatings; IR materials; laser damage.

Laser induced damage at 10.6 micrometers is observed in alloy alkali halide single crystals of the ALQLOY composition ($KCl_{0.33} - KBr_{0.67}$) and pure KCl, as a function of crystalline orientation. The effect of the stepwise increase in laser irradiation power is monitored by x-ray topographic techniques, Nomarski microscopy and electron microscopy of the replicated damage surface.

The relationship of the damage threshold to the crystalline orientation is explained by invoking the critical resolved shear stress law for the rock salt crystal structure of the alkali halides.

Surface and coating absorption measurement with an Alphaphone, E. L. Kerr, *SP387*, pp. 189-193 (Dec. 1973).

Key words: Absorption; coatings; high-power laser; measurements; surface; testing.

Optical elements and coatings for high power laser applications require low surface absorption. The Alphaphone provides an instrument for rapidly measuring surface absorption at laser wavelengths. Sensitivity is 10^{-5} absorption with 10 W input and a noise bandwith of 15 Hz. The total measuring time is a few minutes. Sensitivity down to 1.5×10^{-7} is achievable by decreasing the chopping frequency. In addition, sensitivity may be improved by signal averaging or by increasing the input power. Two surfaces of a window may be measured independently. Scattering has no significant effect.

The sample to be tested forms one wall of a thin cell filled with air. The air is heated by a small fraction of the energy absorbed at the sample surface when it is illuminated by the laser beam. The resulting pressure rise is measured by a capacitance microphone. In a demonstration we have recorded the absorption signals from two KRS-5 windows coated with antireflection coatings for 10.6 μm. The absorption was 1 percent, measured with a signal-to-noise ratio of 1000.

Photoelastic constants of infrared transmitting materials, B. Bendow and P. D. Gianino, *SP387*, pp. 194-201 (Dec. 1973).

Key words: IR transmitting materials; photoelasticity; stress-optics.

Stress-induced birefringence may severely degrade or limit the optical performance of IR transmitting materials, especially in high power laser applications. The birefringence in a given material is predictable once the photoelastic tensor has been determined. In this work we carry out a

first-principles calculation of the photoelastic constants p_{ij}, employing a recent theory of Humphreys and Maradudin. For ionic crystals, a Born-Mayer interatomic potential is employed, while for semiconductors a Morse potential is employed. The p_{ij} are calculated for a wide variety of rocksalt- and zinc blende-type crystals, including alkali-halides, II-VI's and III-V's. The electronic contribution to the p_{ij}'s is found to dominate in most semiconducting crystals, so that dispersion in the transparent frequency regime is generally negligible. For ionic materials, however, dispersion can be important; values at 10.6 μm, for example, may differ from those in the visible by as much as 25 to 50 percent, even for the better potential laser window materials.

Checks of multiphonon absorption theory, R. Hellwarth, *SP387*, pp. 202-207 (Dec. 1973).

Key words: Crystal absorption theory; frequency moments; infrared absorption; infrared susceptibility; infrared window materials; multiphonon absorption.

There is considerable uncertainty as to the accuracy of calcuations to date of multiphonon absorption in infrared window materials. Here we show that such uncertainties can be checked by calculating various weighted integrals over frequency ("frequency moments") of the imaginary part $\chi''(\omega)$ of the electrical susceptibility, to which the absorption coefficient $\beta(\omega)$ cm^{-1} is related. We obtain expressions for six moments, evaluating a moment of the 2-phonon contribution explicitly for an anharmonic pair-interaction model. This exact result reveals inaccuracies in the dependence of absorption on ion masses and temperature predicted by approximate theories.

Theory of material failure in crystals containing infrared absorbing inclusions, C. J. Duthler and M. Sparks, *SP387*, pp. 208-216 (Dec. 1973).

Key words: Dielectric particles; inclusions; laser damage; thermal damage.

Small amounts of macroscopic inclusions in or on the surface of infrared-transmitting materials (in some cases a fractional volume of 10^{-7} to 10^{-8}) increase the average value of the optical absorption coefficient β and cause localized heating that could lead to material failure at high-power levels. The frequency dependence of β ranges from increasing as ω^2, to independent of ω, to exponentially decreasing with ω. Temperature dependence ranges from independent of T, to increasing as T^p in the high-temperature limit, where $p \cong 1 - 4$ typically. Simple expressions for the absorption cross section are used to derive expressions for β for large inclusions of strong and weak absorbers and small inclusions of dielectric and metallic particles. Material failure resulting from local heating of inclusions is a far greater problem in high-intensity short-pulse systems than in low-intensity long-pulse or cw systems having the same average intensity. Microsecond pulses with energy densities as low as a few joules per square centimeter can cause material failure.

Surface damage by laser induced collective electron oscillations, R. A. Shatas, L. M. Narducci, J. L. Smith, H. C. Meyer, and S. S. Mitra, *SP387*, pp. 217-224 (Dec. 1973).

Key words: Electron avalanche; electron tunneling in alternating fields; laser damage of GaAs; laser damage processes; laser-induced surface damage; parametric plasma instability; resonant plasmon-photon interaction; solid state plasma.

Recent experiments with high pressure infrared molecular lasers demonstrate that the surface damage of ancillary optical components is the performance limiting factor. Intensities of a few tens of MW cm^{-2} in the pulse regime of fractional μsec are sufficient to damage the optical components; this performance is considerably less than what one would expect from the analysis of the intrinsic dielectric strength. It is proposed that the principal damage mechanism is associated with the damping of collective electron oscillations which have been driven beyond the linear regime by resonant photon-plasmon interaction. If the mobility of the carriers in a typical optical component is sufficiently high (such as for example in GaAs), one can adequately model the collective behavior of the carriers by a collisionless plasma. Thus the threshold for instabilities can be calculated on the basis of the Vlasov equation. In particular, the threshold for parametric instabilities in GaAs illuminated by 10.6 μm radiation is shown to be of the order of 10^5 V cm^{-1} which is in close agreement with recent experimental results. The mechanism responsible for producing the critical electron density is proposed to be field-assisted electron tunneling. The required tunneling probability for electric fields of the order of the instability threshold is attained if the energy separation of bound to free state is less than the crystalline bandgap. Adsorbed impurities and bending of the crystal bands at the surface account for the lowered value of the effective pseudo gap; hence the damage is seen first at the surface of the material.

Studies of intrinsic optical breakdown, D. W. Fradin and M. Bass, *SP387*, pp. 225-238 (Dec. 1973).

Key words: Alkali halides; avalanche breakdown; intrinsic breakdown.

Previous work demonstrated that intrinsic optical damage is caused by electron avalanche breakdown. We have conducted a number of recent studies of intrinsic damage which have reinforced the original identification of the damage process and which have probed various characteristics of avalanche breakdown.

By using a ruby laser to induce damage in the alkali halides, we have observed frequency dispersion in the relative breakdown fields. This dispersion, which was not apparent at 1.06 μm, provides insight into the development of the avalanche. A mode-locked Nd:YAG laser with output pulses of 300 to 15 ps duration was used to induce damage in NaCl, and the results were compared to Q-switched studies. It was found that the rms breakdown field increased by almost an order of magnitude to over 10^7 volts/cm as the pulse duration was reduced from 10 ns to 15 ps. This result agrees at least qualitatively with published dc breakdown measurements. A statistical character to bulk optical damage was observed in a number of materials including sapphire and fused quartz and found to be indistinguishable from statistics observed in surface damage. This observation and measurements of the ratio of surface to bulk breakdown fields show that the intrinsic mechanisms for surface and bulk breakdown are identical. Finally, the effect of crystalline disorder on the breakdown strength of solids was studied by measuring the intrinsic damage fields for a polycrystal, an alloy, and an amorphous insulator and comparing the results to the damage fields for the respective single crystals.

Laser-induced surface damage in proustite (Ag_3AsS_3) at 1. μm and 0.694 μm, G. R. Giuliano and D. Y. Tseng, *SP3* pp. 239-249 (Dec. 1973).

Key words: Ag_3AsS_3; proustite; pulse duration dep dence; repetition rate dependence; surface damage; 1. μm; 0.694 μm.

The results of a number of experiments on laser-induced entrance surface damage in proustite (Ag_3AsS_3) are presented. Morphology for pulsed and cw surface damage is discussed and illustrated. Damage at 1.06 μm where most of the work was done was studied with single pulse, repetitively pulsed, and continuous radiation; damage at 0.694 μm was studied with single pulses. It was found that the surface damage threshold at 1.06 μm is independent of pulse repetition rate from single pulse to 500 pps. Results of measurements taken for pulses of different duration are interpreted in terms of a thermal mechanism.

Spectral emittance measurements on several crystalline samples, D. L. Stierwalt, *SP387*, pp. 250-253 (Dec. 1973).

Key words: Absorption coefficient; emittance spectra; KBr; CdTe; ZnSe; $ZnSe_xTe_{1-x}$.

Emittance spectra were obtained at 273 and 373 K from 3 to 15 microns on several samples supplied by AFCRL. The specimens included KBr, CdTe, $ZnSe_xTe_{1-x}$, ZnSe, and four samples of Pb-doped KCl. Values of absorption coefficient were derived from the emittance data. Curves of absorption coefficient versus wavelength will be presented.

A sensitive interferometric null method for measuring stress-induced birefringence, G. Birnbaum and E. Cory, *SP387*, pp. 254-258 (Dec. 1973).

Key words: Birefringence; fused silica; optical spectrum analyzer; photoelastic effect; sapphire; scanning Fabry-Perot interferometer; YAG.

A sensitive apparatus for measuring induced birefringence utilizing a scanning Fabry-Perot interferometer excited by circularly polarized laser radiation has been developed. Because of birefringence in the sample located within the interferometer, its resonance wavelengths for radiation polarized parallel and perpendicular to the direction of applied stress are different. The voltage on a Kerr cell properly oriented within the interferometer is adjusted to cancel the sample birefringence. The wavelength difference is observed by using the scanning interferometer as a spectrum analyzer and comparing the resonance curves associated with each polarization. The stress-induced birefringence in YAG, sapphire and fused silica at 0.633 μ in the temperature range 26 to 75 °C has been measured.

P388. **The public need and the role of the inventor.** Proceedings of a Conference held in Monterey, Calif., June 11-14, 1973, F. Essers and J. Rabinow, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 388, 215 pages (May 1974) SD Catalog No. C13.10:388.

Key words: antitrust doctrine; employed inventors; entrepreneurship; innovation; invention; needs of society; new enterprises; Patent Office; patent system; technological policy making; technology.

This book presents the proceedings of the Conference on the ublic Need and the Role of the Inventor, held at Monterey, alif., on June 11-14, 1973. The conference, based on a recomendation of the National Inventors Council, was sponsored by e Office of Invention and Innovation, Institute for Applied echnology, under a grant from the Experimental Technology ıcentives Program, NBS. The purpose of the conference was to udy the climate for invention and how to make it one in which merica's inventors can flourish for the common good. Eighteen vited papers were presented. In addition, the proceedings inudes statements from the chairmen of the three sessions: harles S. Draper, Jacob Rabinow, and Myron Coler. The oceedings are divided into three sessions with an edited version of the floor discussions following the papers. Following the presentation of papers, the participants of the conference separated into six workshop panels. Their recommendations are presented at the end of this volume. *These proceedings include the following papers (indented):*

Inventions, innovations, and incentives, Betsy Ancker-Johnson, *SP388*, pp. 5-6 (May 1974).

Key words: government patent policy; government R. & D.; technology enhancement efforts; technological innovation; technology transfer programs.

The Government has a responsibility to transfer the results of its research and development activities to wider use in the private sector. Last year, in the President's Science and Technology Message, and this year, in his budget, a strategic approach to technology was adopted as a national policy. The strategy includes increased funding, new emphasis on critical problems of special, national concern, and an effort to provide incentives to inventors, entrepreneurs, and research managers. The Department of Commerce is taking steps to promote actively the licensing of Government-owned patents, and the Experimental Technology Incentives Program in the National Bureau of Standards is asking such questions as "What cost-effective Federal actions can be taken to facilitate the commercialization of the technical inventions of the individual and small R. & D. firms?"

An economist looks at the patent system, R. D. Tollison, *SP388*, pp. 11-14 (May 1974).

Key words: economic tradeoffs; monopolies; new information; patent reform; patent system.

This talk sketches the way an economist might view the tradeoffs involved in the social institution of a patent system. If the output that a patent is designed to protect can be loosely labeled as "information," then there will always be a tension between the need for patents to stimulate the production of new information and placing a short-run monopoly price on goods that, once produced, are inherently non-rival in consumption. A patent system is probably a socially efficient way to make this tradeoff, although the fact that societies impose different standards and procedures in the patent process suggests that study and discussion of patent reform may be worthwhile.

Trends in technological policy making, D. V. De Simone, *SP388*, pp. 17-20 (May 1974).

Key words: experimental incentives programs; Federal incentives; technological policy making; technology assessment program.

Federal programs and policies contribute to technological advances in numerous ways. Many Federal incentives for technological innovation have been proposed over the years, but none has been put into effect. We need to develop a better basis for choosing courses of action.

Three Federal programs recently begun are aimed at this deficiency: the systematic assessment of the state of industrial technology by the Department of Commerce, a study on the barriers to technological innovation by NSF, and the experimental incentives programs being conducted by NSF and NBS. These are small-scale pilot projects, but the experiments and studies will help us understand more about the factors influencing technological advance. As a result, decision makers will be better equipped to determine what should be the nature and extent of Federal encouragement of private investment in technological innovation.

New enterprise generation, R. S. Morse, *SP388*, pp. 23-28 (May 1974).

Key words: entrepreneurship; environment for innovation; government policy for innovation; industry R. & D.; new enterprises; university R. & D.

The national environment for innovations is examined: in government, industry, the university, and the public.

The administration is concerned for the environment of science and technology, but centralized leadership and responsibility for long-range analysis and planning are absent. New rules and policies, or new legislation by Congress are needed.

Industry has been trying new methods in the management of R. & D., both in establishing centers for entrepreneurship within the company, and providing venture capital to acquire new technology outside the company. The key to success in these enterprises is the entrepreneur who can judge the market and bring a new product into public use.

Universities should study the mechanisms that industry is using; there is need for research in these areas, and a need for a coupling of effort between the university and the industrial community. The university can also play an important role in teaching entrepreneurship.

The President should delegate authority either in the Executive Office or in the Department of Commerce to review the problems of invention, innovation, and entrepreneurship for the generation of new enterprises. New approaches should be tried to expedite the public use of technology and a closer relationship among government, industry, and the university.

Inventor-entrepreneurship and national priorities, N. S. Kapany, *SP388,* pp. 31-36 (May 1974).

Key words: business management; inventor-entrepreneur; national priorities; national problems; technological innovation.

Because he is capable in science, invention, management and business, the inventor-entrepreneur has a high potential for solving some of the urgent problems of mankind today.

The attributes of the inventor and of the entrepreneur are briefly examined: the inventor-entrepreneur combines these talents in a bold, imaginative way.

Although some national problems are of such a nature that they must be solved by massive, large-scale interdisciplinary effort, there are still many high-priority areas that can be attacked by the inventor-entrepreneur.

The optimum climate for nurturing his efforts must include: a strong technological and industrial base; a free-enterprise economic system; a healthy reception by the financial community and a sympathetic public attitude; and, a cooperative, benevolent government attitude.

The inventor-entrepreneur is a pioneer—a champion of innovation—and as such, he deserves attention, support, and a chance to share the responsibility for solving the problems of society today.

Invention and innovation in the university, J. Adams, *SP388,* pp. 37-43 (May 1974).

Key words: academic risk; business-Government-university relationship; faculty risk; time constraints; university entrepreneurial activities.

Universities are not fulfilling their potential as a source of public need-oriented invention and innovation. Their potential is inhibited by three constraints: risk, time, and business.

There is an academic risk to the student in undertaking projects where the outcome must be uncertain. The risk to the faculty lies in the fact that the academic rating procedure treats entrepreneurial activities as unusual and academic publication as usual.

Time is another constraint: there is insufficient time in the academic year to develop a product and market it.

The business constraint is a lack of knowledge as to how ideas could be carried to reality with a just division of the compensation among the students, faculty, university, Government, and commercial business interests involved.

Government funding might help to solve the risk and time constraints by forming peer groups and allowing employment of long-term professional support.

People in the educational community would appreciate help on solving the business-Government-university relationship problems. Frameworks must be found and publicized in which universities can put their intellectual resources to work in a more applied way and gain reasonable financial and intellectual rewards.

The invention of the transistor—"an example of creative-failure methodology," W. Shockley, SP388, pp. 47-88 (May 1974).

Key words: creative-failure methodology; invention of transistor; junction transistor; patents; semiconductor amplifiers; will-to-think.

Presents a general historical perspective on the invention of the transistor, from the standpoint of the patents issued and the men involved in the inventions.

Five applications for patents on transistor devices were filed prior to the first public announcement of the transistor on June 30, 1948. The development of the essential inventive ideas for these five patents is described.

Several attempts to make semiconductor amplifiers failed. These failures were used creatively by the team involved—an example of effective research, of which one of the principal elements is the "will to think." The day-to-day development of important ideas and the interaction between them are presented.

The story is continued through the invention and realization of the junction transistor.

Antitrust doctrine v. the individual inventor: Friend or foe? J. C. Stedman, *SP388,* pp. 93-98 (May 1974).

Key words: antitrust; Hart proposal; inventors; patent licenses; patents; Scott proposal.

The perennial conflict between antitrust and patents is currently reflected in the Scott (Patent Bar) and Hart proposals pending before the Senate. The Scott proposal would apply a "rule of reason," giving a patentee considerable freedom in imposing various restrictions upon licensees. The Hart proposal would apply a "reasonably ancillary" test, narrowly circumscribing the patentee's freedom in this respect. The question is: which is more advantageous to the inventor, independent or employed? Restrictions in patent licenses, while they may enable the patentee to maximize his return from the invention, may at the same time provide protection from competition and thus lessen the competitive fears and hopes of competitive advantage that provide the main economic force underlying inventive activity. Thus paradoxically, the short-range advantages of restrictive licensing may operate long-range to the detriment of the inventor. Deeper research into the subject is urgently needed, but tentatively one may suggest that enactment of a law enlarging a patentee's freedom to impose licensing restrictions may prove, in the long run, advantageous to institutions that seek to minimize the forces of competition (including competition in research and innovation), but disadvantageous to small concerns and individual inventors, independent or employed, whose welfare depends upon competitive achievement and innovative activity.

The inventor in a changing world of patents, A. R. Whal *SP388,* pp. 103-110 (May 1974).

Key words: adversary proceedings; antitrust; deferred examination; independent Patent Office; innovation; inventor patent system; useful arts.

It's time we overcome our collective hardening of the attitudes about changes in the patent system. The simple choice is whether the design of change will pass by default to those in the courts or Congress who march to different drummers, or whether those who use and understand the system will meet the challenge of change.

The patent system faces an identity crisis. Three positive approaches would help set thinking straight:

1. Emphasize the patent system's effectiveness in areas of its intended operation in the useful arts.

2. Foster understanding of the interdependence of invention and innovation in making the patent system work in the public interest.

3. Work for a no-fault divorce between patents and antitrust to rectify the subservient status now assigned to patents.

At the same time, we should move to reconstruct the patent system rather than repair it. Recognizing that the concept of patents remains sound, we should give consideration to carefully circumscribed adversary proceedings made practicable by deferred examination and maintenance fees and administered by an independent Patent Office. Thorough discussion of the possibilities and pitfalls of these approaches should lead to a patent system of increased vigor and the restoration of confidence in the patenting process without distress to the substantive aspects we seek to preserve.

The role of the patent office in the process of invention and innovation, E. J. Brenner, *SP388*, pp. 111-115 (May 1974).

Key words: advisers to inventors; deferred examinations; innovation; invention; mechanized searching; patent litigation; Patent Office; patent system reform; petty patents; satellite research centers.

Examines how well the U.S. Patent Office is doing its job now, and presents some suggestions that might enable it to do a better job in the future.

Within the financial limitations under which it must operate, the Patent Office performs an efficient screening operation, rather than a validity proceeding, which would take far more time and money.

Two general suggestions are given for future improvement: first, that an Assistant Secretary for Invention, Innovation, and Intellectual Property be appointed in the Department of Commerce, to serve as a focal point for these activities; and secondly, that a systems analysis approach be taken to weigh the merits of various ideas for reforming the patent system.

Specific suggestions are also made for consideration: adoption of deferred or selective examination; a system of petty patents; a greater role for the Patent Office in litigation; continued efforts to improve mechanized searching; the institution of satellite search centers and a system of advisers to inventors; and a review of the patent system to eliminate some of the technicalities that may invalidate patents.

United States patent system: Fraud on the inventor and the public (and what can be done about it), I. Kayton, *SP388*, pp. 119-126 (May 1974).

Key words: inventor; monopoly; patent system; property rights; validity of patents.

The inventor is the creator of progress, and our main hope to solve most of society's problems. In order for him to be motivated to continue inventing, he needs to have his property rights protected. By and large, the United States patent system no longer affords the protection.

There are some Federal circuits where, because of the rules of law enunciated by the United States Court of Appeals, a patent cannot be held valid, irrespective of the merit of the invention.

The law of expected return dictates which patents get litigated—there's no such thing as a *per se* good patent. The reason is the legally outrageous proposition which has been imposed on the public, the bar, and the bench, either fraudulently, through arrant ignorance or simple misconception, that all patents are monopolies. Monopolies are bad—therefore, patents are bad.

The truth is that practically no patents are monopolies. Patents are property—and where there is competition, either by product alternatives or by licensing, you cannot control price and you do not control a relevant market and you do not have a monopoly.

A revision of the patent statute is suggested which would reverse the alienation of the small inventor from the patent system and restore the system to its earlier effectiveness in promoting the useful arts.

NBS and the inventive process, R. W. Roberts, *SP388*, pp. 131-135 (May 1974).

Key words: Experimental Technology Incentives Program; inventors; National Bureau of Standards; Office of Invention and Innovation; technological innovation.

If we are to compete for international markets, we need more and better science, and we need a continuing supply of marketable inventions. The role of the inventor at the National Bureau of Standards, and the services offered to the outside inventor by the Bureau, are described. The aims of a major new NBS effort—the Experimental Technology Incentives Program—are explained, and suggestions are requested for additional experiments that ETIP could perform.

The inventive process—where does it need stimulation?, W. B. McLean, *SP388*, pp. 139-142 (May 1974).

Key words: government help to innovation; government ownership of patents; innovation; inventor; patent system.

The patent system is crucial for the development of our national economy. Its influence is exerted by providing a period in which risk capital needed for development can realize a return through production. The inventor and his returns are only incidental to this process.

Many areas of new development exist where the returns to the economy would be great but the Government is the only organization capable of starting the development. These include: (1) Satellite communications; (2) Two-way cable TV; (3) Floating cities; (4) Undersea cities and oil and mining operations; (5) Submarine tankers. Government ownership of patents is inconsistent with the purpose for which the patent system was created because it has no reasonable means to grant exclusive licenses.

The employed inventor and the corporation, C. E. Anagnostopoulos, *SP388*, pp. 145-149 (May 1974).

Key words: corporation; employed inventor; innovation; invention; research director; technological entrepreneur.

The idea that the goals of the employed inventor conflict with those of the corporation is an outmoded fallacy. The creative challenges of the modern corporation are totally compatible with the creative drives of the employed inventor. Through invention, he discovers new and useful solutions to problems. Through innovation, the corporation commercializes such technical advances. Corporate growth and profitability today depend upon planned and systematic innovation.

Such innovation requires not only the technical certainty of a useful invention, but also an evaluation and reduction of its commercial risks by such criteria as corporate fit, market timing and potential business volume. The presumed conflict between the employed inventor and the corporation is

at this interface between his empirical proof that his invention works and the corporation's pragmatic assessment of it as a business risk.

Actually, this point of stress is a constructive interfacial tension that can be most productive if kept in dynamic equilibrium. This is a task for a middleman who, more than a research director, is a technological entrepreneur; technically well-grounded and with a full grasp of corporate objectives. His role: motivating interpreter to both the employed inventor and the corporation, having the respect and confidence of each.

The institutions and environment for inventors in IBM, D. DeWitt, *SP388*, pp. 153-156 (May 1974).

Key words: environment for innovation; IBM Fellow; institutions for inventors; inventors; rewards for inventors.

IBM seeks to create and maintain in its laboratories an environment conducive to innovation. Inventors are aided by instruction in patent practice, prompt and competent evaluation of submissions, and the help of experienced patent attorneys. Innovation is encouraged by a system of recognition and rewards for patents issued and outstanding technical contributions.

The IBM Fellow appointment is an attractive long-range objective for inventive people: it is a lifetime appointment which gives the Fellow freedom to do innovative work of his own choosing, with appropriate support.

The IBM institutions for encouragement of innovations were introduced about 10 years ago, and have been modified from time to time. They are still being evaluated, but the results have been largely favorable.

The role of the inventor in an industrial laboratory, J. A. Rajchman, *SP388*, pp. 159-164 (May 1974).

Key words: antitechnical crisis; industrial laboratory; industrial research; scientist-inventor; technical innovations.

The industrial research laboratories of large corporations have been a great success; as one of the main mechanisms for harnessing the process of innovation they have benefited their sponsors, society and the scientist-inventor. To the imaginatively inclined technical man they have provided a living and a place in society. Furthermore, a seasoned laboratory provides broad options to the individual to pursue his ambitions according to his talents, as it exploits with subtlety the fact that it is at the crossroads between science, production and the market place and therefore finds good value in individual genius, cooperative work as well as managerial initiative. To a great many technical men the industrial laboratory offers the proper arena for undertaking technical innovations. The personal experiences of the author, at RCA Laboratories, as individual contributor as well as manager, illustrate the point.

The present antitechnical crisis has various symptoms. In the industrial laboratory, budgets are no longer lush, there are problems with non-growing staff, and there is a shift from science to engineering that is accompanied by short range expectations. More alarming are symptoms of disillusionment elsewhere, mostly with the young, among whom many fewer aspire to science and technology. As one possible remedy a plea is made for society to show far greater appreciation and respect toward technical innovators in addition to bestowing them with essential material awards.

Systems to stimulate employee-inventions in Europe, F. Neumeyer, *SP388*, pp. 167-174 (May 1974).

Key words: awards to inventors; employee-inventors; European incentive systems for inventors; Japanese incentive systems for inventors; legal employee-inventor incentive systems; Soviet Union incentive systems for inventors.

An analysis is made of systems, in Europe and elsewhere, to stimulate employee-inventions by legal and voluntary incentive systems, which are part of the overall pattern of the economic and political regime prevailing in a country. The following countries are examined: the Soviet Union, Sweden, Denmark, Norway, Finland, Austria, Holland, Germany, Japan, Great Britain, and Canada. The legal incentive systems in these countries include tangible and intangible rewards. Tangible rewards are: extra compensation, tax relief, standard cash payment, or release of the rights of invention. Intangible rewards include the right to be mentioned in the patent, and honorary titles conferred on the inventor. The objects of these measures are human beings; we need their imagination; and generosity and justice to them will be repaid by them manifold.

European perspective of the inventor ecology, H. Romanus, *SP388*, pp. 175-182 (May 1974).

Key words: European efforts to aid inventors; inventor; inventor ecology; Swedish Board for Technical Development.

Examines the hazards and impediments to inventors, and the methods that some states—in particular, Sweden—are taking to remove these impediments.

Inventors need technical help to develop their ideas, financial help, advice on patenting, and aid in selling their ideas to industry. Having grown from a small beginning in the 1930's, the Swedish Board for Technical Development now has the know-how and resources to perform these services for inventors who they consider are worthy of help. The Board also evaluates proposed legislation affecting inventors, and studies the climate of invention activities.

The practices of the Swedish Board for Technical Development are being followed in other European countries in an effort to support the first link in the innovation chain—invention.

The inventor—his motivations and society, S. Ruben, *SP388*, pp. 195-197 (May 1974).

SP-389, Superseded by Letter Circular 1070.

SP390. **Index of international standards,** S. J. Chumas, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 390, 222 pages (Mar. 1974) SD Catalog No. C13.10:390.

Key words: analyses; International Commission on Rules for the Approval of Electrical Equipment; International Electrotechnical Commission; International Organization for Standardization; International Organization of Legal Metrology; International Special Committee on Radio Interference; recommendations; specifications; standards; test methods.

This computer-produced Index, based on the Key-Word-In-Context (KWIC) system, contains over 2,700 standards titles of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the International Commission on Rules for the Approval of Electrical Equipment (CEE), the International Special Committee on Radio Interference (CISPR), and the International Organization of Legal Metrology (OIML).

SP391. **Report of the 58th National Conference on Weights and Measures 1973,** S. J. Wilson and R. N. Smith, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 391, 208 pages (May 1974) SD Catalog No. C13.10:391.

Key words: administration; automated checkstand systems; Conference; consumers; laws and regulations; metrication; open dating; procedures; technical requirements; technology; universal product coding; weights and measures.

This is a report of the proceedings (edited) of the Fifty-Eighth National Conference of Weights and Measures, sponsored by the National Bureau of Standards, held in Minneapolis, Minn., July 22-27, 1973, and attended by state, county, and city weights and measures officials, the Federal Government, business, industry, and consumer organizations. *These proceedings include the following papers (indented):*

Measures for progress, G. L. Johnson, *SP391*, pp. 1-3 (May 1974).

Universal product code in the grocery industry:

Effect of UPC on supermarket operations and equipment, R. H. Sloat, *SP391*, pp. 27-31 (May 1974).

Computerized checkstand weighing system, W. N. Shannon, *SP391*, pp. 32-36 (May 1974).

Digital designs in weighing systems:

Applications in retail trade, R. O. Bradley, *SP391*, pp. 36-40 (May 1974).

Large capacity scale designs, T. G. Soper, *SP391*, pp. 41-48 (May 1974).

Dynamic weighing in the railroad industry, E. W. Hodgkins, *SP391*, pp. 49-53 (May 1974).

Gasoline measurement and marketing:

Changing systems and designs, W. F. Gerdom, *SP391*, pp. 55-57 (May 1974).

Electronic components and applications, R. J. McCrory, *SP391*, pp. 58-64 (May 1974).

Weighting on the mail, A. Smith, *SP391*, pp. 64-75 (May 1974).

Net quantity—directions and determinations:

Viewpoint on net weight variations, G. M. Burditt, *SP391*, pp. 75-82 (May 1974).

Status of Handbook 67 revision, E. A. Vadelund, *SP391*, pp. 83-90 (May 1974).

Management assistance for weights and measures progress:

MIS analyses and concept development, E. G. Neigut, *SP391*, pp. 91-97 (May 1974).

Measuring inaccuracy's economic distortion, S. W. Stiefel, *SP391*, pp. 97-107 (May 1974).

New approach in weights and measures operations:

Pilot program, W. H. Korth, *SP391*, pp. 108-114 (May 1974).

Development of Dallas Department of Consumer Affairs, C. H. Vincent, *SP391*, pp. 115-121 (May 1974).

Consumer protection in Minnesota, S. Keefe, *SP391*, pp. 122-132 (May 1974).

SP392. **Vibrationally excited hydrogen halides: A bibliography on chemical kinetics of chemiexcitation and energy transfer processes (1958 through 1973),** F. Westley, Nat. Bur. Stand. (U.S.), Spec. Publ. 392, 81 pages (Apr. 1974) SD Catalog No. C13.10:392.

Key words: bibliography; chemical kinetics; chemiexcitation; gas phase; halogens; hydrogen; hydrogen halides; laser; quenching; vibrational energy transfer.

A bibliography, a reaction oriented list of references, is provided for published papers and reports containing rate data for reactions of halogen atoms with hydrogen-containing compounds, or of H (D, or T) atoms with halogen-containing compounds to form vibrationally chemiexcited hydrogen halides. The reactions for vibroexcitation of hydrogen halides through unimolecular or photochemical elimination, as well as the processes for vibrational energy transfer between hydrogen halides and various second bodies are also included. In addition, four lists of theoretical papers and a list of critical reviews and bibliographies are provided. Over 300 papers covering 50 types of reactions are listed. The period covered extends from 1958 through 1973.

SP393. **Colorimetry and spectrophotometry: A bibliography of NBS publications January 1906 through January 1973,** K. L. Kelly, Nat. Bur. Stand. (U.S.), Spec. Publ. 393, 54 pages (Apr. 1974) SD Catalog No. C13.10:393.

Key words: bibliography; color; color codes; colorimetry; color measurement; spectrophotometry; vision.

This bibiliography of publications will serve as the key to the large amount of research into color measurement and specification, and color vision carried out by the staff of the National Bureau of Standards (NBS) in colorimetry and spectrophotometry. These 623 publications appeared in NBS publications and outside scientific and technical journals between January 1906 and January 1973. This material has been in constant demand by Bureau members as well as by outside individuals and organizations. The practical value of this wealth of information lies in its ready accessibility to the scientific and technical fraternity by title, by key words or by author, in the Library of Congress and in depository libraries such as large public and university libraries. A short organizational chronology of the colorimetry and spectrophotometry program is included.

SP394. **MFPG. The role of cavitation in mechanical failures,** Proceedings of the 19th Meeting of the Mechanical Failures Prevention Group, held at the National Bureau of Standards, Oct. 31, Nov. 1 and 2, 1973, Boulder, Colo. 80302, T. R. Shives and W. A. Willard, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 394, 183 pages (Apr. 1974) SD Catalog No. C13.10:394.

Key words: bubble collapse; cavitation; cavitation damage; cavitation erosion prevention; erosion; surface roughness.

These proceedings consist of a group of 16 submitted papers and discussions from the 19th meeting of the Mechanical Failures Prevention Group which was held at the National Bureau of Standards on October 31 and November 1 and 2, 1973. The central theme of the proceedings is the role of cavitation in mechanical failures. *These proceedings include the following papers (indented):*

Physics associated with cavitation induced material damage, F. B. Peterson, *SP394*, pp. 3-12 (Apr. 1974).

Role of physical properties of liquids in cavitation erosion, A. Thiruvengadam, *SP394*, pp. 13-22 (Apr. 1974).

The role of mechanical properties in cavitation erosion resistance, G. C. Gould, *SP394*, pp. 23-30 (Apr. 1974).

Recent theories of cavitation damage including nonsymmetrical bubble collapse effects, F. G. Hammitt, *SP394*, pp. 31-35 (Apr. 1974).

Some practical examples of cavitation erosion and their prevention, A. F. Conn, *SP394*, pp. 39-47 (Apr. 1974).

Examples of oil cavitation erosion in positive displacement pumps, J. A. Halat and G. O. Ellis, *SP394*, pp. 48-53 (Apr. 1974).

Microscopic investigation of cavitation erosion damage in metals, J. V. Hackworth and W. F. Adler, *SP394*, pp. 54-61 (Apr. 1974).

Lubricant pressure rippling in dynamic Hertzian contacts induced by surface roughness, T. E. Tallian and J. I. McCool, *SP394*, pp. 62-73 (Apr. 1974).

Asperity lubrication and cavitation in face seals, J. A. Walowit, *SP394*, pp. 77-87 (Apr. 1974).

Effect of cavitation on fluid stability in polymer thickened fluids and lubricants, J. L. Duda and E. E. Klaus, *SP394*, pp. 88-99 (Apr. 1974).

Effects of viscoelasticity on cavitation in drag reducing fluids, R. Y. Ting, *SP394*, pp. 100-106 (Apr. 1974).

Progress and problems in erosion prediction, F. J. Heymann, *SP394*, pp. 107-114 (Apr. 1974).

Potential of thin, sputtered films as erosion resistant protective coatings. Part 1. Sputter-coating and film characteristics, K. Gentner, *SP394*, pp. 117-128 (Apr. 1974).

Potential of thin, sputtered films as erosion resistant protective coatings. Part 2. Erosion and the gas turbine engine, J. E. Newhart, *SP394*, pp. 129-144 (Apr. 1974).

Rain droplet erosion mechanisms in transparent plastic materials, G. F. Schmitt, Jr., *SP394*, 145-159 (Apr. 1974).

Analysis of Navy radome failure problems, G. J. Tatnall and K. Foulke, *SP394*, pp. 160-165 (Apr. 1974).

Government-industry data exchange program (GIDEP), E. T. Richards, *SP394*, pp. 166-170 (Apr. 1974).

SP395. **Simulation and gaming.** Proceedings of the 12th Annual Symposium National Gaming Council and the 4th Annual Conference International Simulation and Gaming Association, held at the National Bureau of Standards, Gaithersburg, Md., September 17-19, 1973, J. E. Moriarty, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 395, 458 pages (June 1974) SD Catalog No. C13.10:395.

Key words: computer; decision-making; games; learning; manual games; simulation.

This document contains the proceedings of a Gaming Conference along with many formal papers assembled to provide a comprehensive collection of up-to-date gaming information. The proceedings are divided into three major sections, namely, Theory and Evaluation, Design, and Applications. Each section contains the text of informal workshops held during the Conference and a selection of formal papers. There is a significant amount of reference material cited in the formal papers along with timely questions and challenges explored and amplified in the workshops. *These proceedings include the following papers (indented):*

THEORY AND EVALUATION TASK GROUP

Facilitator's Statements:

Theory and evaluation, R. A. Schusler, *SP395*, p. 21 (June 1974).

Evaluation: Classroom uses: Training planning and research uses, J. C. Thompson, Jr., and C. H. Postma, *SP395*, pp. 22-23 (June 1974).

Evaluation sub-group facilitator's statement, S. Thiagarajan, *SP395*, pp. 24-25 (June 1974).

Evaluation facilitator's statement, P. Y. Martin, *SP395*, pp. 26-27 (June 1974).

Sub-group title: Theory and evaluation facilitator's statement, S. H. Woolard, *SP395*, pp. 28-29 (June 1974).

Formal Papers:

Simulating a model of perception to shape problem recognition behavior, S. H. Woolard, *SP395*, pp. 30-39 (June 1974).

The what and why of gaming: A taxonomy of experimental learning systems, B. D. Ruben, *SP395*, pp. 40-55 (June 1974).

Conflict resolution: From power to peer relations in the helping professions, P. Y. Martin and M. W. Osmond, *SP395*, pp. 56-73 (June 1974).

A preliminary investigation of the use of Prince—a man-computer simulation of international relations—in high school courses, S. J. Kidder, R. E. Horowicz, and G. M. Kiselewich, *SP395*, pp. 74-81 (June 1974).

Obstacle course, T. Foster, Jr., *SP395*, pp. 82-90 (June 1974).

Simulation: An analysis of student cognitive retention and student teacher effective perceptions, C. H. Postma and J. C. Thompson, Jr., *SP395*, pp. 91-102 (June 1974).

Simulating an urban school and community for use in teacher education, F. P. Diulus, *SP395*, pp. 103-112 (June 1974).

Design, development, and validation of anticipation games, M. I. Semmel and S. Thiagarajan, *SP395*, pp. 113-127 (June 1974).

Using simulation to implement TABA's cognitive theory, R. A. Schusler, *SP395*, pp. 128-134 (June 1974).

The effect of instructional gaming upon absenteeism: The first step, L. E. Allen and D. B. Main, *SP395*, pp. 135-158 (June 1974).

Simulation/gaming: An autotelic inquiry technique, R. Stadsklev, *SP395*, pp. 159-164 (June 1974).

DESIGN TASK GROUP

Facilitator's Statements:

Developing computer-based simulations, facilitator's statement, R. I. Miller, *SP395*, pp. 165-166 (June 1974).

Designing computer-based simulations, facilitator's statement, M. H. Whithed, *SP395*, pp. 167-168 (June 1974).

Frame games: Design and redesign, R. H. Armstrong and M. Hobson, *SP395*, pp. 169-172 (June 1974).

Frame games: Design and redesign, E. S. Mulley, *SP395*, pp. 173-174 (June 1974).

Decision: Futures modeling, D. L. Little, *SP395*, pp. 175-177 (June 1974).

Designing interactive social simulations, facilitator's statement, G. Wilcoxson, *SP395*, p. 177 (June 1974).

Sub-group: Selecting and developing media in simulation design, C. H. Adair, *SP395*, pp. 178-179 (June 1974).

Student designed games, facilitator's statement, H. Tamminga, *SP395*, p. 180 (June 1974).

Computer-based gaming models, P. D. Patterson, *SP395*, p. 181 (June 1974).

Unstructured and game-generating games, facilitator's statement, K. F. Dette, *SP395*, pp. 183-184 (June 1974).

Formal Papers:

A process for designing, developing, and evaluating social simulation, C. H. Adair, *SP395*, pp. 185-196 (June 1974).

A model for selecting optimum media as part of the simulation design process, C. H. Adair, *SP395*, pp. 197-203 (June 1974).

Where all else fails – an approach to defining the possible uses of gaming-simulation in the decision-making process, R. H. R. Armstrong and M. Hobson, *SP395*, pp. 203-217 (June 1974).

Simulated universities, H. A. Becker, *SP395*, pp. 218-238 (June 1974).

The data behind simulation models, H. A. Becker, *SP395*, pp. 239-249 (June 1974).

Simulating alternative futures for American education, J. Debenham, *SP395*, pp. 250-274 (June 1974).

A guide for simulation design, C. H. Adair and J. T. Foster, Jr., *SP395*, p. 275 (June 1974).

APPLICATIONS TASK GROUP

Facilitator's Statements:

Applications: Research, facilitator's statement, R. L. Dukes, *SP395*, p. 303 (June 1974).

Medicine and social welfare, facilitator's statement, J. T. Foster, Jr., *SP395*, pp. 304-305 (June 1974).

Teaching-training: Urban planning, D. E. LaHart, *SP395*, p. 306 (June 1974).

Teaching-training: Elementary-secondary education, H. E. Arnold, *SP395*, p. 307 (June 1974).

Community and public policy applications of gaming simulation, J. R. Hanson, *SP395*, p. 308 (June 1974).

Community and public policy applications, G. M. McFarland, *SP395*, p. 308 (June 1974).

Issues in game use: What values are conveyed by game designers and users, G. M. McFarland, *SP395*, pp. 309-311 (June 1974).

Formal papers:

Simulations and games as growth group experiences, J. F. Karshmer, *SP395*, pp. 312-315 (June 1974).

The disorganized health clinic as a simulation, J. T. Foster, Jr., *SP395*, pp. 316-323 (June 1974).

Simulation and gaming as aids in regional and intercommunity problem solving, H. Sievering and J. Sinopoli, *SP395*, pp. 324-334 (June 1974).

Paying the piper or pay us again, Sam, S. Cipinko, *SP395*, pp. 335-340 (June 1974).

Public policy applications, G. McFarland, *SP395*, pp. 341-342 (June 1974).

Massive management gaming, R. F. Barton, *SP395*, pp. 343-351 (June 1974).

Simulating sexism: Unintentional (?) replication of reality, N. D. Glandon, *SP395*, pp. 352-357 (June 1974).

Advocacy – a community planning game for the ranking of school system goals and training needs, J. R. Hanson, *SP395*, pp. 358-364 (June 1974).

Learning tools to research instruments: A research package for starpower, R. L. Dukes, *SP395*, pp. 365-373 (June 1974).

A pedagogical schema for the development and use of computer simulation technology, D. B. Main, R. Stout, D. W. Rajecki, H. Eichenbaum, and T. Villars, *SP395*, pp. 374-381 (June 1974).

Education and training for contemporary urban planning systems: The impact of interactive simulation, R. M. Sarly, *SP395*, pp. 382-396 (June 1974).

The publication and distribution of simulation games, I. B. Naiburg, Jr., *SP395*, pp. 397 (June 1974).

TASK GROUP SUMMARIES

Design sub-group summary: Computer-based gaming simulations, P. D. Patterson, *SP395*, pp. 398-399 (June 1974).

Urban planning sub-group: Summary paper, D. E. LaHart, *SP395*, pp. 405-406 (June 1974).

Teaching and training sub-group: Business summary state of the art, M. Uretsky and R. F. Barton, *SP395*, pp. 407-408 (June 1974).

Research applications of simulation games: Summary paper, R. L. Dukes, *SP395*, pp. 409-412 (June 1974).

SP396-1. **Critical surveys of data sources: Mechanical properties of metals,** R. B. Gavert, R. L. Moore, and J. H. Westbrook, Nat. Bur. Stand. (U.S.), Spec. Publ. 396-1, 90 pages (Sept. 1974) SD Catalog No. C13.10:396-1.

Key words: commercial alloys; data sources; mechanical properties; metals.

This study was undertaken with the objective of providing a detailed critical survey of the existent sources of mechanical property data for commercially available metals and alloys. This survey was intended to assess the scope, assets and deficiencies of about forty of the most prominent sources of such information. There were included: handbooks and technical compilations, information centers, foreign information sources, technical societies, and trade associations. The initial listing of sources to be examined was prepared by the authors with the advice and the assistance of a subcommittee of the Metals Properties Council. The aim was to restrict the survey to sources which actually had compilations of mechanical property data in some form. Thus sources which offered only generalized guides to the literature, monographs, textbooks, or periodicals publishing original research or engineering articles were not to be included. Those sources from the original listing which were found upon detailed examination to fall into the latter categories are therefore treated in a separate appendix.

SP396-2. **Critical surveys of data sources: Ceramics,** D. M. Johnson and J. F. Lynch, Nat. Bur. Stand. (U.S.), Spec. Publ. 396-2, 52 pages (Dec. 1975) SD Catalog No. C13.10:396-2.

Key words: carbon (graphite); ceramics; composites; data sources; glasses; properties.

A directory was compiled for selected sources of property data of ceramics, glasses, carbon/graphite and composite materials containing a ceramic component. Included is an assessment of the scope, assets and deficiencies of the most prominent sources. These include handbooks, technical compilations, information/data centers, technical societies, and trade associations or institutes. The directory is indexed by materials and properties.

SP396-3. **Critical survey of data sources: Corrosion of metals,** R. B. Diegle and W. K. Boyd, *Nat. Bur. Stand. (U.S.), Spec. Publ. 396-3,* 38 pages (Jan. 1976) SD Catalog No. C13.10:396-3.

Key words: commercial alloys; corrosion; data sources; metals.

This survey was undertaken to provide a directory of authoritative sources of information on corrosion of metals. It assesses the scope, assets, and deficiencies of about thirty-eight of the most important sources. These include handbooks and technical compilations, information centers, technical societies, and trade associations and institutes. The initial listing of sources to be included was drafted by the authors and submitted to members of the Publications Committee of the National Association of Corrosion Engineers. This Committee thus served as an ad hoc review group for the sources which appear herein. The Directory is indexed by materials and types of corrosion.

SP396-4. **Critical surveys of data sources: Electrical and magnetic properties of metals,** M. J. Carr, R. B. Gavert, R. L. Moore, H. W. Wawrousek, and J. H. Westbrook, *Nat. Bur. Stand. (U.S.), Spec. Publ. 396-4,* 92 pages (July 1976) SD Catalog No. C13.10:396-4.

Key words: commercial alloys; data sources; electrical properties; magnetic properties; metals.

This survey is intended to provide a directory of authoritative sources of numerical data on the electrical and magnetic properties of metals, with emphasis on commercial alloys. Fifty-nine sources, including handbooks and other publications, information centers, trade associations, and technical societies are described in detail, including information on the properties and materials covered and the criteria used in the selection of data. A few additional related publications are listed with brief descriptions.

SP-397, Superseded by Special Publication 418.

SP398. **Fundamental physical constants,** B. N. Taylor, Nat. Bur. Stand. (U.S.), Spec. Publ. 398, card (Aug. 1974) SD Catalog No. C13.10:398.

Key words: fundamental constants.

This card gives values of the fundamental constants resulting from the "1973 Least-Squares Adjustment of the Fundamental Physical Constants" carried out by E. R. Cohen and B. N. Taylor under the auspices of the CODATA Task Group on Fundamental Constants and adopted for international use by CODATA. These constants have been previously given in J. Phys. Chem. Ref. Data 2, 663 (1973) and CODATA Bulletin No. 11 (Dec. 1973). Supersedes NBS SP344.

SP399. Volume 1. **NBS FORTRAN test programs. Volume 1—documentation for versions 1 and 3,** F. E. Holberton and E. G. Parker, Nat. Bur. Stand. (U.S.), Spec. Publ. 399, 171 pages (Oct. 1974) SD Catalog No. C13.10:399/V.1.

Key words: computer programming language; FORTRAN; FORTRAN validation; language validation; standard FORTRAN; test program design.

The NBS FORTRAN test programs, written in Standard FORTRAN, are designed to test whether a FORTRAN compiler accepts the forms and interpretations of the FORTRAN language as described in the American National Standard FORTRAN document X3.9-1966. The test programs, comprised of 116 test units, are structured into two versions, each containing approximately 14,500 punch card images. The test units may be used as separate executable FORTRAN programs, or may be linked end to end with other test units, with a minimum of user effort, to improve operating efficiency. Version 1 is structured into 116 executable FORTRAN programs, and Version 3, containing the same 116 test units, is structured into 14 executable FORTRAN programs for use on large FORTRAN processors.

The test program design criteria was to: Constrain all test programs to the FORTRAN Standard X3.9-1966; Reduce the effect of those areas in which the FORTRAN Standard does not prescribe a method or sulution, e.g., range, precision, size of computer, etc.; Simplify the use of the FORTRAN test programs; Test FORTRAN language elements before they are used in support of other tests; Maintain an open ended system so that tests may be changed or added.

The test programs require the use of a card reader, printer and one intermediate tape unit.

SP399. Volume 2. **NBS FORTRAN test programs. Volume 2—listings for version 1,** F. E. Holberton and E. G. Parker, Nat. Bur. Stand. (U.S.), Spec. Publ. 399, 221 pages (Oct. 1974) SD Catalog No. C13.10:399/V.2.

Key words: computer programming language; FORTRAN; FORTRAN validation; language validation; standard FORTRAN; test program design.

THE NBS FORTRAN test programs, written in Standard FORTRAN, are designed to test whether a FORTRAN compiler accepts the forms and interpretations of the FORTRAN language as described in the American National Standard FORTRAN document X3.9-1966. The test programs, comprised of 116 test units, are structured into two versions, each containing approximately 14,500 punch card images. The test units may be used as separate executable FORTRAN programs, or may be linked end to end with other test units, with a minimum of user effort, to improve operating efficiency. Version 1 is structured into 116 executable FORTRAN programs, and Version 3, containing the same 116 test units, is structured into 14 executable FORTRAN programs for use on large FORTRAN processors.

The test program design criteria was to: Constrain all test programs to the FORTRAN Standard X3.9-1966; Reduce the effect of those areas in which the FORTRAN Standard does not prescribe a method or solution, e.g., range, precision, size of computer, etc.; Simplify the use of the FORTRAN test programs; Test FORTRAN language elements before they are used in support of other tests; Maintain an open ended system so that tests may be changed or added.

The test programs require the use of a card reader, printer and one intermediate tape unit.

SP399. Volume 3. **NBS FORTRAN test programs. Volume 3—listings for version 3,** F. E. Holberton and E. G. Parker, Nat. Bur. Stand. (U.S.), Spec. Publ. 399, 226 pages (Oct. 1974) SD Catalog No. C13.10:399/V.3.

Key words: computer programming language; FORTRAN; FORTRAN validation; language validation; standard FORTRAN; test program design.

The NBS FORTRAN test programs, written in Standard FORTRAN are designed to test whether a FORTRAN compiler accepts the forms and interpretations of the FORTRAN language as described in the American National Standard FORTRAN document X.3.9-1966. The test programs, comprised of 116 test units, are structured into two versions, each containing approximately 14,500 punch card images. The test units may be used as separate executable FORTRAN programs, or may be linked end to end with other test units, with a minimum of user effort, to improve operating efficiency. Version 1 is structured into 116 executable FORTRAN programs, and Version 3, co

taining the same 116 test units, is structured into 14 executable FORTRAN programs for use on large FORTRAN processors.

The test program design criteria was to: Constrain all test programs to the FORTRAN Standard X3.9-1966; Reduce the effect of those areas in which the FORTRAN Standard does not prescribe a method or solution, e.g., range, precision, size of computer, etc.; Simplify the use of the FORTRAN test programs; Test FORTRAN language elements before they are used in support of other tests; Maintain an open ended system so that tests may be changed or added.

The test programs require the use of a card reader, printer and one intermediate tape unit.

SP400-1. **Semiconductor measurement technology. Quarterly report, July 1 to September 30, 1973,** W. M. Bullis, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-1, 68 pages (Mar. 1974) SD Catalog No. C13.10:400-1.

Key words: contact resistance; die attachment; dopant profiles; electrical properties; electronics; gold-doped silicon; hermeticity; metallization; methods of measurement; microelectronics; microwave diodes; mobility; MOS devices; oxide films; photomasks; photoresist; resistivity; resistivity standards; scanning electron microscopy; semiconductor devices; semiconductor materials; semiconductor process control; sheet resistance; silicon; S-parameters; spreading resistance; test patterns; thermal resistance; thermally stimulated capacitance; thermally stimulated current; wire bonds.

This quarterly progress report, twenty-first of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal accomplishments during this reporting period include (1) extension of the technique for measuring thermally stimulated current and capacitance to include measurements on MOS capacitors, (2) completion of the development of the thermal response method for evaluation of transistor die attachment, (3) analysis of the interlaboratory comparison of transistor scattering parameter measurements, (4) preliminary review of measurement problems in the photolithographic aspects of semiconductor device processing, of problems associated with certain hermeticity testing procedures, and of methods for evaluating metallization step coverage, and (5) initiation of new activity on characterization of oxide films in MOS structures and analysis of diffusion profiles. Results are also reported on spreading resistance, capacitance-voltage, and sheet resistance measurements; the activation energy of the gold acceptor in silicon; evaluation of the base-to-metal contact resistor test structure; metallurgical systems for ultrasonic bonding; burn-out characteristics of fine gold and aluminum bonding wire; transistor thermal resistance measurements; and microwave diode conversion loss measurements. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices.

SP400-2. **Semiconductor measurement technology: Microelectronic ultrasonic bonding,** G. G. Harman, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-2, 109 pages (Jan. 1974) SD Catalog No. C13.10:400-2.

Key words: bonding; degradation (wire bond); discrete devices; electrical interconnection; fabrication (wire bond); failure (wire bond); hybrid circuits; integrated circuits; microelectronics; reliability; semiconductor devices; testing (wire bond); ultrasonic bonding; wire bond.

This report primarily comprises excerpts of the work done under the NBS ultrasonic wire bonding program that was previously published in 17 quarterly and other reports. The material is organized into subject groupings with the intention of presenting in convenient form sufficient information for making high quality ultrasonic wire bonds as well as imparting a basic understanding of the ultrasonic systems used. The work emphasizes problems and methods of solving them. To accomplish this, the required measurement equipment is first introduced. This is followed by procedures and techniques used in setting up a bonding machine, and then various machine- or operator-induced reliability problems are discussed. The characterization of the ultrasonic system and its problems are followed by in-process bonding studies and work on the ultrasonic bonding (welding) mechanism. The report concludes with a discussion of various effects of bond geometry and wire matallurgical characteristics. Where appropriate, the latest, most accurate value of a particular measurement has been substituted for an earlier reported one. Thus all of the included material is up to date.

SP400-3. **Semiconductor measurement technology: ARPA/NBS workshop I. Measurement problems in integrated circuit processing and assembly,** H. A. Schafft, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-3, 24 pages (Feb. 1974) SD Catalog No. C13.10:400-3.

Key words: die bonding; hermeticity; integrated circuits; measurement methods; microelectronics; oxides; photolithography; process control; reliability; semiconductor devices; silicon; wire bonding.

The dual purpose of the workshop was (1) to announce and describe the new effort, "Advancement of Reliability, Processing, and Automation for Integrated Circuits with the National Bureau of Standards," sponsored by the Defense Advanced Research Projects Agency (ARPA), and (2) to obtain additional input on critical measurement problems in integrated circuit processing and assembly to assist in planning future work in the effort. More than 130 engineers representing 61 organizations from the electronics industry and government participated in the workshop. The measurement problems in silicon, oxides, photolithography, and assembly and the problems in information dissemination that were identified by the participants are summarized. Included as appendices are summaries of two talks given: one which described the results of earlier direct contacts with a cross section of industrial representatives on major measurement problems in integrated circuit processing and assembly and the other which described the initial plans for work in the new effort.

SP400-4. **Semiconductor measurement technology. Combined quarterly report, October 1, 1973 to March 31, 1974,** W. Bullis, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-4, 101 pages (Nov. 1974) SD Catalog No. C13.10:400-4.

Key words: boron redistribution; collector resistor; doping profiles; effective masses; electrical properties; electron beam induced current mode electronics; epitaxial layer thickness; flying spot scanner; gold-doped silicon; hermeticity; ion microprobe mass analysis; methods of measurement; microelectronics; microwave diodes; mobility; MOS devices; oxide films; photomasks; photoresist; platinum wire resistivity; resistivity standards; ribbon wire scanning electron microscopy; semiconductor devices; semiconductor materials; semiconductor process control; sheet resistance; silicon; spreading resistance; test patterns; thermal response; thermally stimulated capacitance; thermally stimulated current; thick film copper; voltage contrast mode; wire bonds; x-ray photoelectron spectroscopy.

This combined quarterly progress report describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal accomplishments during this reporting period include

(1) identification of major problem areas in connection with measuring and inspecting photomasks, (2) development of a mathematical model suitable for interpreting thermally stimulated current and capacitance measurements on junction diodes and metal-oxide-semiconductor (MOS) capacitors, (3) completion of a preliminary evaluation of a method, based on the transient capacitance-voltage characteristic of an MOS capacitor, for measuring thickness of epitaxial layers up to 2 μm, and (4) development of criteria for use in nondestructive wire bond pull tests. Results are also reported on spreading resistance, capacitance-voltage, and carrier mobility measurements; polynomial fits for energy band gap and hole and electron effective masses in silicon; methods for characterizing oxide films; evaluation of sheet resistance and collector resistor test structures; evaluation of a photoresist spinner test; scanning electron microscopy; bonding of aluminum ribbon wire to thick film copper; bonding of platinum wire to thin film aluminum; leak rate calculations in the transition flow regime; transistor thermal response measurements; and radiation response of microwave mixer diodes. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices.

SP400-5. **Semiconductor measurement technology: Measurement of transistor scattering parameters,** G. J. Rogers, D. E. Sawyer, and R. L. Jesch, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-5, 53 pages (Jan. 1975) SD Catalog No. C13.10:400-5.

Key words: electronics; high-frequency probes; interlaboratory comparison; scattering parameters; S parameters; transistors.

Results of an interlaboratory comparison of transistor scattering-parameter measurements are reported for transistor types 2N709, 2N918 and 2N3960. From these results it is estimated that, for such devices, between-laboratory variability of transistor S-parameter measurements in the frequency range between 200 and 2000 MHz could be held to a maximum relative sample standard deviation of 7.5 percent in the measurement of magnitude and a maximum sample standard deviation of 8 degrees in the measurement of phase of s_{11} and 3.5 degrees in the measurement of phase of other S parameters. This could be done if all participants were required to use the same calibration procedure and to limit their test signal to a level that would assure small-signal operation. In a separate study, the equivalent circuit of high-frequency probes used in characterizing the parameters of integrated circuits was evaluated by measuring S parameters at the input connectors with the probe tips in contact with known loads. These measurements revealed a resonance which would limit the usefulness of the probes for measurements in the vicinity of 1.2 GHz. Work is underway to determine design changes needed to eliminate this resonance.

SP400-6. **Semiconductor measurement technology: Microelectronic test patterns: An overview,** M. G. Buehler, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-6, 24 pages (Aug. 1974) SD Catalog No. C13.10:400-6.

Key words: integrated circuits; microelectronic test patterns.

The test patterns considered are those designed by the physical electronics engineer to evaluate fabrication processes rather than those designed by the microcircuit designer. The evaluation of fabrication processes can reveal if a process is under control and can indicate the stability and reliability of the resulting microcircuit. This evaluation is in essence an evaluation of a microcircuit's material characteristics, for process control and reliability depend ultimately on the right atoms being in the right places.

Various material analysis test structures are described, such as resistors, MOS capacitors, and gated *p-n* junctions along with the material parameters that can be derived from each. These test structures are illustrated by the NBS-2 test pattern, and its use in process control is described. Examples are given which span the range from those structures which are amenable to production testing to those which require an advanced measurement capability. In addition test structures are discussed with regard to their usability; this encompasses their size, sensitivity, correlation, contacting schemes, testability, and packaging. Test structures must be properly designed so that desired parameters are measured. In this regard various design aspects such as metal taps and diffused taps are mentioned. Finally the role of NBS in evaluating and designing test patterns is discussed.

SP400-7. **Semiconductor measurement technology: Permanent damage effects of nuclear radiation on the x-band performance of silicon Schottky-barrier microwave mixer diodes,** J. M. Kenney, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-7,* 30 pages (Apr. 1976) SD Catalog No. C13.10:400-7.

Key words: diodes; gamma rays; hardness assurance; microwave mixer diodes; mixers; neutrons; radiation hardness; receivers; Schottky-barrier diodes; semiconductors; solid-state devices; x-band measurements.

The permanent damage induced by nuclear radiation in silicon Schottky-barrier x-band microwave mixer diodes was assessed by subjecting separate groups of diodes to ^{60}Co gamma rays and fast neutrons (E>10 keV) of progressively higher levels, reaching a total gamma dose of 1.7×10^{8} rads (Si) and a cumulative neutron fluence of 5.5×10^{15} cm^{-2}. Measurements were made at a local oscillator frequency of 9375 MHz to determine changes in conversion insertion loss, local oscillator return loss and SWR, i-f output conductance, self-bias, and forward current at one dc bias voltage.

No changes due to the gamma irradiation were observed. At a neutron fluence of 1.0×10^{15} cm^{-2}, changes in conversion insertion loss and forward current were just discernible. At 5.5×10^{15} cm^{-2}, the conversion insertion loss of most diodes was degraded by up to 0.7 dB, although some diodes were unchanged and the average change was only 0.2 dB. The return loss, SWR, and self-bias voltage of most diodes were distinctly altered at this level, and the forward current of all diodes was decreased. The i-f output conductance was not significantly altered.

A group of unirradiated diodes, intermixed with the gamma and neutron groups during measurements, served as a control. Since diode stability was recognized as an important factor, the three groups were matched on the basis of pre-irradiation conversion insertion loss stability. The three-sigma repeatability of the conversion insertion loss measurement was estimated from the control group measurements to be about 0.05 dB, with a systematic drift over the course of these measurements of about the same amount.

SP400-8. **Semiconductor measurement technology. Quarterly report, April 1 to June 30, 1974,** W. M. Bullis, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-8, 70 pages (Feb. 1975) SD Catalog No. C13.10:400-8.

Key words: Boron redistribution; Darlington pairs; dopant profiles; electrical properties; electronics; epitaxial layer thickness; flying-spot scanner; gold-doped silicon; heterogeneity; measurement methods; microelectronics; micrometrology; MOS devices; oxide films; photomasks; photoresist; resistivity; scanning electron microscopy; semiconductor devices; semiconductor materials; semiconductor process control; silicon; spreading resistance; tes

patterns; thermal resistance; thermal response; thermally stimulated capacitance; thermally stimulated current; ultrasonic bonding; voltage contrast mode; wire bonds.

This quarterly progress report describes NBS activities rected toward the development of methods of measurement for miconductor materials, process control, and devices. The nphasis is on silicon device technologies. Principal accomplishents during this reporting period include (1) identification of rface preparation procedures which improve the quality of preading resistance measurements, (2) preparation of a deotaped tutorial discussion of thermally stimulated current id capacitance measurements, (3) completion of an analysis of e apparent position of an opaque edge when viewed with inoherent and coherent illumination, and (4) completion of the onstruction of a flying-spot scanner. Results are also reported n capacitance-voltage and two-probe resistivity measurements; nalyses of thermally stimulated current and capacitance meaurements on metal-oxide-semiconductor (MOS) capacitors; a view of methods for characterizing interface states associated ith thin oxide films on silicon; fabrication of a test pattern ased on the charge-coupled device; a preliminary comparison f filar and image shearing eyepieces for line-width measurent; a review of technologies in use for photomask inspection id measurements; procedures for determination of correct phoesist exposure; epitaxial layer thickness; scanning electron icroscopy; mathematical modeling of ultrasonic bonding; leak st procedures; thermal resistance measurements on transistors id Darlington pairs, and transistor thermal response measurents. Supplementary data concerning staff, publications, orkshops and symposia, standards committee activities, and chnical services are also included as appendices.

iP400-9. **Semiconductor measurement technology: ARPA/NBS Workshop II. Hermeticity testing for integrated circuits,** H. A. Schafft, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-9, 43 pages (Dec. 1974) SD Catalog No. C13.10:400-9.

Key words: bubble test; gas analysis; helium leak test; hermeticity; integrated circuits; measurement methods; microelectronics; radioisotope test; seals; semiconductor devices; weight test.

Synopses are presented of the six invited talks and two discusion periods of a meeting in which 65 engineers and scientists, epresenting 36 organizations from private industry and governent, participated. Topics ranged from failure analysis and the ature of leaks to evaluations and intercomparisons of bubble, eight, helium, and radioisotope tests. Underlying many of the roblems discussed is the lack of a technical basis for specifications on maximum allowable leak rates and contaminant levels; o data is available to relate leak rate to component life. Of conern is the proliferation of test conditions which has complicated esting and test intercomparison efforts, and has resulted, unittingly, in testing devices to significantly different actual leak ate criteria. Water vapor, sealed-in and that which penetrates ne package, is a contaminant of major concern, and the difficules of making sufficiently accurate measurements of water vapor ere detailed. The control required in the materials and assembly process to avoid hermeticity failure and false leak indications in ceramic, dual in-line packages were discussed. Finally, ne importance of performing some hermeticity tests at elevated emperatures was cited.

iP400-10. **Semiconductor Measurement Technology: Spreading Resistance Symposium.** Proceedings of a Symposium held at the National Bureau of Standards, Gaithersburg, Md., June 13-14, 1974, J. R. Ehrstein, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-10, 293 pages (Dec. 1974) SD Catalog No. C13.10:400-10.

Key words: dopant concentration; dopant profiles; metal-semiconductor contacts; resistivity; semiconductor surface preparation; silicon; spreading resistance.

This Proceedings contains the information presented at the Spreading Resistance Symposium held at the National Bureau of Standards on June 13-14, 1974.

This Symposium covered the state of the art of the theory, practice and applications of the electrical spreading resistance measurement technique as applied to characterization of dopant density in semiconductor starting materials and semiconductor device structures. In addition to the presented papers, the transcripts of the discussion sessions which were held directly after the Theory, Practice and Applications sessions are also included. These transcripts, which were reviewed by the respective respondents for clarity, are essentially as presented at the Symposium. *These proceedings include the following papers (indented):*

The physics of spreading resistance measurements, S. J. Fonash, *SP400-10,* pp. 17-26 (June 1974).

Key words: correction factor; crystallographic orientations; effective contact radius; interfaces; metal-semiconductor contacts; multilayered structure; piezoresistivity; resistivity; spreading resistance; stress; zero bias resistance.

The spreading resistance method is uniquely suitable for the determination of electrical resistivities in a number of situations. However the technique does not simply measure the resistivity beneath the contacts. Considering the two probe configuration, what is actually measured is the ratio $\Delta V/I$. Here ΔV is the difference between the Fermi levels of the probes necessary to maintain the sampling current I. This difference in the Fermi levels of the probes depends on the zero bias resistance of the probe–semiconductor contacts, the effective resistivity of the layers in a multilayer structure, and the configuration of the structure. The zero bias resistance depends on temperature and details of the metal-semiconductor contact including surface history. Effective resistivities enter into the measurement–and not the actual resistivities–because of the fact that the use of pressure probes creates a stress field under the contacts. This field falls off with a characteristic length of the order of the contact radius. Thus piezoresistivity effects–well known for Si–can be operative under the contacts. As a consequence of these various effects the interpretation of what $\Delta V/I$ is actually measuring is not straightforward. Practical application of the spreading resistance technique necessitates making certain simplifying assumptions. In light of the various phenomena involved in a spreading resistance measurement it is imperative that the implications of these assumptions to the accuracy of the measurement be understood.

Formal comparison of correction formulae for spreading resistance measurements on layered structures, P. J. Severin, *SP400-10,* pp. 27-44 (June 1974).

Key words: contact resistance; correction formulae; sheet resistance; silicon; spreading resistance.

The spreading resistance of a metal contact on a semiconductor sample is analysed for infinite geometry, with three different boundary conditions: a specified potential of the contact, a uniform contact current density and a current density dependent on contact resistance. The cases of a thin layer on a perfectly conducting substrate and on a non-conducting substrate are analysed each for the boundary conditions of uniform current density and of the current density distribution valid for the infinite geometry. With a perfectly conducting substrate the two boundary conditions yield

about 10 percent difference. With a non-conducting substrate calculations based on both current density distributions produce in the thin layer approximation the same ln r dependence required. The constant terms in both approaches are different by 5 percent and the constant current density result in addition agrees with the result obtained with a totally different transmission-line approach. The actual three-point-probe measurement situation is discussed. The danger of correcting the precise spreading resistance measurement results with an error of 1 percent, with formulae derived on the basis of a formal model which is sensitive to the choice of the boundary conditions by up to 10 percent, is stressed. The effects of undefined thickness, bevel edge and transition layer curving upwards are mentioned as further complications.

Two-point probe correction factors, D. H. Dickey, *SP400-10*, pp. 45-50 (June 1974).

Key words: boundary correction; calculations; electrostatic analogue; resistivity; semiconductor; spreading resistance.

The effects of sample boundaries on resistivity measurements made with a two-point spreading resistance probe are calculated for various boundary conditions. The results are presented in the form of dimensionless correction factors. The problem of depth-dependent resistivity in a thin layer is considered, and a method for correcting measurements on such layers is described.

On the validity of correction factors applied to spreading resistance measurements on bevelled structures, P. M. Pinchon, *SP400-10*, pp. 51-61 (June 1974).

Key words: accuracy; bevelled structures; correction application; correction factors; edge effect; profiles; resistivity profiling; small spacing; spreading resistance.

The correction factors in spreading resistance measurements are generally determined by using a plan-parallel model of a single or multi-layer structure. This paper will discuss the applicability of these factors to the profiling measurements on a bevel, and call attention to possible systematic errors which can appear in the case of an insulated layer or a low/high type of structure.

After a short discussion on the spacial resolution of the spreading resistance probe, the case of a homogeneous isolated layer is examined in more detail. A simplified expression for the value of spreading resistance was calibrated against published data using fitting coefficients.

It is then easy to show that the use of a correction derived for parallel structures is not correct for the case of a thin, isolated layer, when the measurement is made on a bevel.

Indications are also given on the parameters which could minimise the problem.

The experimental part of this paper shows a series of profiles made with P-type epitaxial layers.

After the application of the usual corrections, the various electrical boundaries or geometrical conditions are seen to affect the results in accordance with the discussion. An edge effect which is significant even at great distance from the edge, is also described.

In the absence of a three dimensional theory for correction, the use of small spacing is recommended in conjunction with a small radius of contact and a shallow bevelling angle.

SRPROF, a fast and simple program for analyzing spreading resistance profile data, B. L. Morris and P. H. Langer, *SP400-10*, pp. 63-74 (June 1974).

Key words: resistivity profiles; spreading resistance; thin film correction factors.

The spreading resistance technique is an excellent method of measuring epitaxial resistivity profiles. In many cases it is the only method by which the complete profile may be measured. However, thin film correction factors must be used to convert the spreading resistance into a corrected resistivity. Previous calculations of these correction factors have emphasized a mathematically complex solution which necessitates the use of a large computer. The correction factors used here are calculated from a relatively simple algorithm which allows the use of a minicomputer. A documented program is presented which uses these algorithms. This program, written in FOCAL for use on the PDP8 series of minicomputers, is fast, accurate, easy to use, and provides a complete data reduction system. Examples of corrected spreading resistance profiles are presented, and compared with independent results such as diode C-V and four point probe measurements.

Multilayer analysis of spreading resistance measurements, G. A. Lee, *SP400-10*, pp. 75-94 (June 1974).

Key words: computer modeling; correction factors; dopant profiles; multilayer spreading resistance model; resistivity; semiconductor dopant concentration; spreading resistance.

Spreading resistance measurements provide a highly flexible technique for the determination of dopant profiles in semiconductors. However, because each measurement samples a greater depth into the sample than the depth difference between successive measurements, the direct conversion of resistivity readings to dopant concentration values will not yield a correct profile.

The technique discussed in this report analyzes direct spreading resistance readings to deduce a "true" dopant profile. The model used is that of circular contacts to a laterally infinite medium which is partitioned vertically into layers of homogeneous resistivity, each layer corresponding to one spreading resistance measurement point. The analysis is performed by a computer program. Some detail in the development of the program is discussed.

The results of this analysis technique compare favorably to profile results of other profiling techniques such as capacitance voltage and incremental sheet resistance on profile types to which they can be applied. The program execution time is usually fast enough that the computer charge is less than the direct charge billed for making the spreading resistance measurements.

An automated spreading resistance test facility, J. C. White, Jr., *SP400-10*, pp. 95-98 (June 1974).

Key words: automated testing; epitaxial silicon; impurity concentration; resistivity; semiconductor materials; silicon; spreading resistance.

An automated spreading resistance test facility has been designed and constructed at the Allentown Works of the Western Electric Co. This system has been shown to provide a rapid, semi-nondestructive, and reproducible measurement of epitaxial layer resistivity which can be used in a production environment. The system has the advantages of operator independence, well protected probes, and four-inch capability. Surface or in-depth measurements can be performed with on-line calculations of resistivity and impurity concentration. Cycle time is less than five seconds per measurement and system reproducibility is ± 1.3 percent (IS).

Angle-bevelling silicon epitaxial layers, technique and evaluation, P. J. Severin, *SP400-10*, pp. 99-108 (June 1974).

Key words: bevel; interferometer; jig; microcontacts; silicon; spreading resistance; steel probe; topography.

The properties of a steel probe for a spreading-resistance system are discussed stressing the effect of micro- and macrocontacts. The need is explained for producing small-angle bevels and a lapping jig for making such bevels is described. With small-angle bevels the slice topography cannot be neglected and a simple instrument is described by which the surface topography of the whole slice can be recorded. By recording the slice topography before and after bevelling the local reduction of thickness by the bevelling process is determined. This method can be used for angles between 1/500 and 1/2000. It is indispensable for the proper interpretation of spreading resistance measurements on bevelled N on N^+ junctions.

Spreading resistance measurements on silicon with non-blocking aluminum-silicon contacts, J. Krausse, *SP400-10,* pp. 109-122 (June 1974).

Key words: absolute measurements; aluminum-silicon contact; four-point probe measurements; local resolution; *n*-type silicon; resistivity inhomogeneities; spreading resistance; striations.

The paper concerns the measurement of resistivity fluctuations in *n*-type silicon starting material in the resistivity range from 1 to 1000 Ω cm. The microscopic resistivity fluctuations that are associated with the well-known striations require a measurement technique of high accuracy and high local resolution. We chose the spreading resistance method. However, in contrast to the conventional method, in which the metal probe is pressed directly onto the silicon surface, we supply the silicon slice with non-blocking aluminum-silicon contacts. The radius of the contact area is exactly defined. Any contact radius can be realized according to the resolution desired in lateral direction and in depth. When the metal probe is applied to the aluminum-silicon contact, the contact is not destroyed. Thus it is possible to perform spreading resistance measurements and four-point probe measurements along one and the same measuring track and in this manner at the same time to vary the local resolution. A comparison of both measurement results will in particular yield information on the conditions of the resistivity in axial direction of the slice. Essential prerequisites for an absolute measurement are fulfilled with the aluminum-silicon contact. However, the investigations made up to now show that the resistivity calculated from the spreading resistance is smaller than the one obtained with the four-point probe measurement by approximately a factor of 0.8.

The preparation of bevelled surfaces for spreading resistance probing by diamond grinding and laser measurement of bevel angles, A. Mayer and S. Shwartzman, *SP400-10,* pp. 123-136 (June 1974).

Key words: bevelling; diamond grinding; laser bevel angle measurement; layer thickness determination; materials; resistivity measurement; silicon doping profiles; spreading resistance measurement; surface damage.

A rapid and reproducible method for preparing bevelled surfaces on silicon has been developed as a preliminary to spreading resistance probe measurement of doping profiles or junction depth determination by staining. Several chips can be bevelled simultaneously. The sample is mounted on a carrier which is clamped on the tilting table of a microtome. The tilt is adjusted until a laser beam reflected from the surface to a calibrated wall chart is deflected to the desired angle. The bevel is then ground with a high-speed diamond wheel mounted on the microtome, taking cuts of several micrometers at a time. The bevel edge is clearly defined even for very shallow angles. The angle is accurately measured with the same laser.

Because the ground surface is highly reflective, in contrast to a lapped surface, a good reading of very small angles of less than 30 minutes can be obtained. Up to a 6 meter base line is used with a lmw He-Ne laser and the reflection is visible in normal room light.

Factors entering into spreading resistance are discussed, such as mechanical damage incurred in bevelling, probe impact damage, and surface cleanliness. Judged by spreading resistance, the amount of damage incurred during grinding is small and reproducible, provided care is taken to maintain the spindle so that it runs without vibrating.

Spreading resistance correction factors for (111) and (100) surfaces, H. Murrmann and F. Sedlak, *SP400-10,* pp. 137-144 (June 1974).

Key words: contact radius; correction factors; silicon; spreading resistance; surface orientation.

The effective contact radius for spreading resistance measurements on Si has been evaluated by comparison of S.R. for epitaxial layers limited by a *pn*-junction or by a well conducting buried layer for different crystal orientation. The contact radius on (100) surfaces showed to be greater by a factor of 1.26 than for a (111) plane. Furthermore measurements were made on samples for both (100) and (111) orientation in the resistivity range of 0.01 to 80Ω cm with *n* and *p*-type doping. Data for spreading resistance and resulting from the predetermined contact radius for the resistivity dependent correction factor are given.

On the calibration and performance of a spreading resistance probe, H. J. Ruiz and F. W. Voltmer, *SP400-10,* pp. 145-154 (June 1974).

Key words: automated resistivity measurements; calibration; germanium characterization; sample preparation; silicon characterization; spreading resistance; surface effects.

In this paper, techniques are presented for material standards selection for calibration purposes, materials and calibration block preparation, and techniques for data collection and processing for the spreading resistance probe. A description of the variation with time of the calibration of a spreading resistance probe is presented. Problems encountered with characterization of high resistivity *p*-type silicon are discussed, and examples of the probe performance in the characterization of germanium are also presented.

Comparison of the spreading resistance probe with other silicon characterization techniques, W. H. Schroen, G. A. Lee, and F. W. Voltmer, *SP400-10,* pp. 155-168 (June 1974).

Key words: automation; bevelling; comparison; four-point probe; incremental MOS capacitance-voltage; incremental sheet resistance; infrared spectrometer; ion microprobe; junction capacitance-voltage; lap and stain; mercury probe; scanning Michelson interferometer; Schottky capacitance-voltage; spreading resistance.

Range and precision of doping concentration data in silicon materials gained by the spreading resistance technique are compared to values obtained by other characterization methods. They include junction and MOS capacitance-voltage techniques, mercury probe, four-point probe, incremental sheet resistance technique, ion microprobe, and optical methods. The comparison considers precision and resolution of each technique, range of silicon resistivities and layer thicknesses, experimental effort, analytical interpretation, and time and cost of data acquisition and evaluation. Examples are presented which demonstrate the range of applicability of each technique and how they can supplement each other so that they cover the total doping range of silicon devices.

Preparation of a lightly loaded, close-spaced spreading resistance probe and its application to the measurement of doping profiles in silicon, J. L. Deines, E. F. Gorey, A. E. Michel, and M. R. Poponiak, *SP400-10,* pp. 169-178 (June 1974).

Key words: bevel angle measurement; correction factor; epitaxial layer; impurity concentration; ion-implanted layer; neutron activation; probe loading; probe spacing; spreading resistance.

A commercially available spreading resistance probe, the ASR-100, was modified to operate with lighter probe loading and smaller probe spacing. The advantages of device structure profiling, increased resolution, and reduction in the "correction factor" in the converted impurity concentration profile are realizable with smaller probe spacing. The effect of the probe modifications on sample profiles and profile quality is discussed for thin epitaxial layers, bipolar transistor structures, and ion-implanted layers. Sample preparation, as influenced by the beveling technique, is also shown to have an effect on profile quality. A novel method for precise measurement of very small bevel angles is described.

A direct comparison of spreading resistance and MOS-CV measurements of radial resistivity inhomogeneities on PICTUREPHONE® wafers, J. R. Edwards and H. E. Nigh, *SP400-10,* pp. 179-184 (June 1974).

Key words: dark field coring; MOS-CV techniques; PICTUREPHONE®; radial resistivity inhomogeneities; silicon resistivity; spreading resistance techniques.

Small scale (~ 50 μm) radial impurity concentration inhomogeneities in silicon wafers have been measured using both the MOS-CV method and the spreading resistance technique. The MOS-CV measurements were made using photolithographically defined 50 μm square capacitors placed on 75 μm centers and the spreading resistance measurements were made using a model 100 ASR probe on the same wafers after removal of the MOS capacitors.

A direct comparison between these methods is presented for three specific types of ⟨111⟩ oriented silicon wafers with an impurity concentration range between 5 and 10×10^{14}/cm^3. In addition, a photograph showing the direct effect of radial resistivity variations on the dark field coring of a PICTUREPHONE® target is included.

Investigations on local oxygen distribution in silicon single crystals by means of spreading resistance technique, F. G. Vieweg-Gutberlet, *SP400-10,* pp. 185-190 (June 1974).

Key words: oxygen in silicon; silicon single crystals; spreading resistance measurements; swirls.

By means of spreading resistance measurements subsequent to heat-treatments at approx. 450 °C and 1100 °C alternatively the local distribution of oxygen in the donor state in silicon single crystals was examined. Oxygen striations have not been found which are in correspondence to a distribution coefficient of $k_o = 1.25 \pm 0.17$ for oxygen in silicon. The radial distribution of oxygen in the donor state is more or less uniform except for an edge area of about 1.5 mm where the oxygen content seems to be considerably lower. A very strong relationship between electrically activated oxygen (donor state) and swirls was found: in regions containing swirls a smaller amount of oxygen was activated to the donor state. This result fits De Kock's model describing swirls as consisting of vacancy-OXYGEN-clusters.

Use of the spreading resistance probe for the characterization of microsegregation in silicon crystals, F. W. Voltmer and H. J. Ruiz, *SP400-10,* pp. 191-199 (June 1974).

Key words: crystal growth; Czochralski; Fourier transform; microsegregation; resistivity characterization; silicon; spreading resistance.

A technique for using the spreading resistance probe to quantitatively characterize microsegregation in single crystal silicon is presented. For the first time, the use of Fourier transformations of the resistivity is developed to provide accurate quantitative information as to the periodicity and amplitude of the various components giving rise to the resistivity variations. It is demonstrated that the probe is reproducible and is capable of measuring fluctuations in resistivity to ± 1 percent, which is well below the normally observed microsegregation. Examples of the use of the technique are given by characterizing microsegregation in two Czochralski grown crystals and one modified float zone crystal. The periodicity of the principle resistivity fluctuation of the Czochralski grown crystals is evaluated by Fourier transform analysis and agrees well with the anticipated fluctuations in impurity incorporation based on growth parameters.

Effects of oxygen and gold on silicon power devices, J. Assour, *SP400-10,* pp. 201-208 (June 1974).

Key words: gold in silicon; oxygen in silicon.

Several important features that make the two-probes spreading resistance technique a unique process control tool for designing and manufacturing silicon power devices are elucidated in terms of the effects of electrically active oxygen and gold centers on the characteristics of transistors, thyristors, and rectifiers. The effectiveness of the spreading resistance technique is compared to other commonly practiced techniques for the investigation of diffusion mechanisms of oxygen in homotaxial NPN transistors and of gold in fast switching rectifiers and thyristors.

The evaluation of thin silicon layers by spreading resistance measurements, G. A. Gruber, *SP400-10,* pp. 209-216 (June 1974).

Key words: diffusion; epitaxy; ion implantation; microwave devices; profiling; spreading resistance; thin silicon layers.

The spreading resistance measurement technique is the only one capable of providing precise thickness measurements and detailed concentration profiles on any type of active device layer or structure formed in silicon on a routine basis. The methods employed in the evaluation of thin layer structures of the type used for microwave devices is discussed and the application of these methods to thin NN^+, P^+NN^+ and P^+N silicon structures formed by combinations of diffusion, epitaxy and ion implantation is illustrated.

Evaluation of the effective epilayer thickness by spreading resistance measurement, H. Murrmann and F. Sedlak, *SP400-10,* pp. 217-221 (June 1974).

Key words: epilayer thickness; silicon; spreading resistance; test pattern.

Two types of double layer structure which are dealt with in the multilayer theory have been examined: 1) a top layer is insulated against a bottom layer (i.e. *pn*-junction, $R(\infty)$); 2) a top layer is shorted by a bottom layer (i.e. n^+-buried layer, R(0)). In both arrangements the Spreading Resistance depends strongly on layer thickness d and on the radius a of contact area. Knowing the effective radius the epilayer thickness can easily be evaluated from Spreading Resistance Measurement and making use of the function $R(\infty)/R(O) = f(d/a)$. This method is nondestructive and less time consuming than other common methods. A simple test pattern is proposed for evaluating the thickness on wafers in process. A comparison between this method and an IR-reflexion method (Digilab FTG 12) showed that both are in very good agreement in thickness range of 2.....6/μm.

The experimental investigation of two-point spreading resistance correction factors for diffused layers, N. Goldsmith, R. V. D'Aiello, and R. A. Sunshine, *SP400-10,* pp. 223-234 (June 1974).

Key words: correction factors; diffused layers; spreading resistance.

Spreading resistance measurements have been made on a series of erfc and Gaussian phosphorus diffusions into *n* and *p*-type silicon. Conventional four point probe methods were used to obtain values of sheet resistance and surface concentration. Comparison between the two methods shows increasingly large disagreements as the diffusion depth is decreased. The Dickey formula for accounting for the presence of a junction is shown to work well for uniform (nondiffused) samples but to fail to correct fully and properly for diffusions less than 20 μm deep. Empiric curves for estimating errors on lapped surfaces used in this study are given for a wide variety of samples.

Application of the spreading resistance technique to silicon characterization for process and device modeling, W. H. Schroen, *SP400-10,* pp. 235-248 (June 1974).

Key words: arsenic; boron; design; device modeling; doping distribution; phosphorus; process control; process modeling; spreading resistance.

In recent years the interest in modeling of semiconductor processes and silicon device parameters has intensified considerably. Precise knowledge of the doping distribution in the semiconductor emerged as a key requirement for input and starting condition of many of these models and for their verification. It turned out that the spreading resistance technique, after careful probe calibration and multilayer data analysis, is able to supply some of the required data better than any other characterization technique available. This paper discusses these successful applications. On the other hand, this paper points out inherent limitations of the spreading resistance technique with regard to resolution and precision, and how this affects the verification of process and device models. Finally, the paper describes ways to supplement the spreading resistance technique by other material characterization or electrical techniques so that the combination of these methods is capable of generating the required experimental data for the analytical models.

Improved surface preparation for spreading resistance measurements on *p*-type silicon, J. R. Ehrstein, *SP400-10,* pp. 249-256 (June 1974).

Key words: bevel polishing; *p*-type silicon; resistivity depth profiling; resistivity radial profiling; semiconductors; spreading resistance measurements; surface effects; surface preparation.

The interpretation and the precision of spreading resistance measurements have been seen to be strongly dependent on specimen surface preparation. A bakeout at 150 °C for 15 min following specimen surface preparation with any aqueous polishing solution is considered here. It is shown both to improve the precision of the basic calibration curve for spreading resistance measurements and to significantly improve the correlation between resistivity values derived from spreading resistance measurements on a variety of specimens, and resistivity values derived from other measurement techniques. No bakeout appears to be necessary if specimen surface preparation is done with a nonaqueous polishing process.

SP400-11. **Semiconductor measurement technology: A BASIC program for calculating dopant density profiles from capacitance-voltage data,** R. L. Mattis and M. G. Buehler, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-11, 39 pages (June 1975) SD Catalog No. C13.10:400-11.

Key words: BASIC; capacitance-voltage measurements; computer programs; dopant profiles; error function; Gaussian diffusion; plotting, computer; semiconductors; silicon.

A computer program is presented which is suitable for calculating dopant density vs. depth profiles from capacitance-voltage data for the case of a Gaussian-diffused *p-n* junction diode. The program includes corrections for peripheral capacitance of round or rectangular diodes and back depletion of the space charge region into the diffused layer. Inputs to the program consist of the surface dopant density, the junction depth, the background dopant density in the diffused layer, the junction diameter, three scaling parameters, and the capacitance-voltage data pairs. Output from the program is ~~in the form~~ of a plot and an optional listing of dopant density as a function of depth. The equations underlying the program are given and are related to the program whose operation is described in detail. A second program, for generating idealized capacitance-voltage data for a Gaussian-diffused diode on material with a constant dopant density is also included.

SP400-12. **Semiconductor measurement technology: Quarterly report, July 1 to September 30, 1974,** W. M. Bullis, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-12, 59 pages (May 1975) SD Catalog No. C13.10:400-12.

Key words: acoustic emission; beam-lead bonds; boron redistribution; Darlington pairs; dopant profiles; electrical properties; electronics; epitaxial layer thickness; flying-spot scanner; gold-doped silicon; hermeticity; incremental sheet resistance; measurement methods; microelectronics; micrometrology; MOS devices; oxide films; resistivity; scanning low energy electron probe; semiconductor devices; semiconductor materials; semiconductor process control; silicon; test patterns; thermally stimulated current; thermal resistance; thermal response; ultrasonic bonding; wire bonds; x-ray photoelectron spectroscopy.

This quarterly progress report describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. The emphasis is on silicon device technologies. Principal accomplishments during this reporting period include (1) completion of Hall effect measurements to determine activation energies of the gold donor and acceptor levels in silicon; (2) successful direct measurement of fast interface state density with the circular CCD test structure; and (3) demonstration of the feasibility of the use of acoustic emission as a non-destructive means for testing individual beam-lead bonds. Results are also reported on a holder for semi-automated sheet resistance measurements, progress on development of mathematical models of dopant profiles, analysis of thermally stimulated current and capacitance measurements on junction diodes, x-ray photoelectron spectroscopy, a comparative study of surface analysis techniques, design and fabrication of a test pattern for resistivity-dopant density evaluation, epitaxial layer thickness measurement, use of the flying-spot scanner, initial work on the scanning low energy electron probe, mathematical modeling of ultrasonic bonding, an improved method for force adjustment and measurement on beam lead bonders, helium mass spectrometery for leak testing, thermal resistance measurements on Darlington pairs, and transistor thermal response measurements. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices.

SP400-13. **Semiconductor measurement technology: Improved infrared response technique for detecting defects and impurities in**

germanium and silicon *p-i-n* diodes, A. H. Sher, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-13, 26 pages (Feb. 1975) SD Catalog No. C13.10:400-13.

Key words: carrier trapping; gamma-ray detector; germanium; Ge(Li) detector; infrared response silicon.

An infrared response (IRR) technique was evaluated for its utility in qualifying germanium for radiation detector use. Because of several improvements in the sensitivity and interpretation of the technique made during the evaluation, it was possible to observe a number of discrete energy levels lying within the forbidden energy gap of germanium which had passed unobserved in previous studies. These levels correlate with the type of defects and vacancies introduced by radiation damage into germanium as measured using such techniques as photoconductivity and Hall effect measurements after irradiation. Furthermore, the improved infrared response measurement method was used to identify impurities, such as copper, gold, and iron, and dislocations resulting from heat treatments in germanium. A major advance was made when it was determined that the IRR spectra could be grouped into five distinct types on the basis of spectral features observed in the energy range from 0.6 to 0.7 eV. One of the spectrum types represented crystals from which good quality detectors could be fabricated; the other four represented crystals that yielded poorer quality detectors due to carrier trapping, or crystals that presented problems such as low lithium drift mobility in detector fabrication. Three of the four spectrum types representative of poor crystal quality could be duplicated by suitably degrading specimens of a good quality crystal. The material and detector characteristics of crystals within each spectrum type were found to be similar.

SP400-15. **Semiconductor measurement technology: ARPA/NBS workshop III. Test patterns for integrated circuits,** H. A. Schafft, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-15,* 52 pages (Jan. 1976) SD Catalog No. C13.10:400-15.

Key words: data acquisition; data display; integrated circuits; measurement technology; microelectronics; process control; reliability; semiconductors; silicon; test patterns.

Synopses are presented of talks and discussion periods at a meeting on the use and development of MOS and bipolar test patterns and associated data acquisition systems. The discussions revealed that device manufacturers and users are making increased use of test patterns as powerful new measurement tools that can electrically monitor various process parameters to aid in the control of materials, wafer processes, circuit performance, and reliability. However, the large volume of data generated from these test patterns and the requirement for rapid diagnostic feedback present severe challenges in data management and display. In this report several data acquisition systems are described, as are approaches for presenting data in more easily interpretable graphic displays. The need for improvements in the design of test patterns is emphasized. In particular, problems with measuring contact resistance and the properties of oxides, surfaces, and defects, are identified. Numerous test structures are described including charge coupled device structures which can measure some characteristics not easily measured by other means. Also described are NBS's efforts and plans to identify, analyze, and intercompare selected test structures of value to the industry and its customers, and to develop measurement methods for use with these structures.

SP400-17. **Semiconductor measurement technology: Progress report, October 1 to December 31, 1974,** W. M. Bullis, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 400-17, 79 pages (Nov. 1975) SD Catalog No. C13.10:400-17.

Key words: boron nitride; boron redistribution; capacitance-voltage methods; Darlington pairs; deep depletion; dopant profiles; electrical properties; electron beam evaporator; electron beam induced damage; electronics; epitaxial layer thickness; filar eyepiece; flying-spot scanner; hermeticity; hydrogen chloride gas; image shearing eyepiece; laser interferometry; measurement methods; microelectronics; micrometrology; MOS devices; oxide films; photomask inspection; resistivity; scanning electron microscope; scanning low energy electron probe; semiconductor devices; semiconductor materials; semiconductor process control; silicon; test patterns; thermally stimulated current; thermal resistance; thermal response; ultrasonic bonding; wire bonds; x-ray photoelectron spectroscopy.

This progress report describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. The emphasis is on silicon device technologies. Principal accomplishments during this reporting period include (1) initiation of development of measurement technology for characterizing boron nitride diffusion sources and hydrogen chloride purging gas, (2) application of dc electrical methods with a sensitivity of about 0.1 μm to the measurement of critical dimensions such as the width of diffusion windows, (3) completion of an initial comparison of line-width measurements made with an image shearing eyepiece and a filar eyepiece, and (4) development of procedures for measuring electrically the thermal resistance of the output transistor of integrated Darlington pairs. Also reported are the intermediate results of an interlaboratory evaluation of standard reference wafers for resistivity, evaluation of the deep-depletion method for measuring dopant density with an MOS capacitor, progress on development of mathematical models of dopant profiles, initial results of the reevaluation of Irvin's curve for *n*-type silicon, analysis of thermally stimulated current and capacitance measurements on MOS capacitors, study of surface carbon contamination which occurs during measurement of silicon by x-ray photoelectron spectroscopy, preliminary measurements of absorbed dose from electron-beam evaporation of aluminum films, initial evaluation of the CCD test structure operating as an MOS capacitor and an MOS transistor, analysis of a TV-microscope system for photomask inspection, initial study of calibration procedures and artifacts for photomask metrology, analysis of the range of applicability of MOS C-V methods for epitaxial layer thickness measurement, use of an optical flying-spot scanner, assessment of damage to selected integrated circuits caused by inspection with a scanning electron microscope, mathematical modeling of ultrasonic bonding, a dry gas method for gross leak testing, and measurements of transistor thermal response. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices.

SP400-18. **Semiconductor measurement technology: The destructive bond pull test,** J. Albers, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-18,* 52 pages (Feb. 1976) SD Catalog No. C13.10:400-18.

Key words: bond angle; bonding; bond pull test; bond-to-bond spacing; large wire; loop height; microelectronics; nondestructive bond pull test; position of hook; pull rate; pull strength; resolution-of-forces; semiconductor devices; ultrasonic bonding; wire bond.

This report summarizes the work done at NBS on the destructive bond pull test as applied to small-diameter (approximately 1 mil or 25 μm) ultrasonically bonded aluminum wire. This work was performed during the period from 1969 to 1974. The report begins with a brief summary of the calculation of the resolution-of-forces operative in the bond system during the application of

the pulling force. Next, comparisons of the theoretical and experimental dependencies of the pull strength on the variables involved in the resolution-of-forces calculation are given. Some of the variables which are not directly involved in this calculation are then considered and their effects on the measured pull strength are presented. The report ends with a sensitivity calculation as to how well the variables must be controlled to maintain the variability of the pull strength to within given limits. Bond pull specifications for large-diameter wire as well as recommended force levels to be used in the application of the nondestructive bond pull test, both of which have resulted from the pull test work, are considered in the appendices.

SP400-19. **Semiconductor measurement technology: Progress report, January 1 to June 30, 1975,** W. M. Bullis, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-19,* 95 pages (Apr. 1976) SD Catalog No. 13.10:400-19.

Key words: acoustic emission; beam-lead bonds; bias-temperature stress test; boron redistribution; capacitance-voltage methods; charge-coupled device structures; Darlington pairs; deep depletion; dopant profiles; electrical properties; electron beam induced current; electron beam induced damage; electronics; epitaxial layer thickness; four-probe method; hermeticity; leak tests; measurement methods; microelectronics; moisture infusion; optical flying-spot scanner; oxide films; passivation overcoats; photomask metrology; pull test; resistivity; Rutherford backscattering; scanning electron microscope; scanning low energy electron probe; semiconductor devices; semiconductor materials; semiconductor process control; shear test; sheet resistors; silicon; silicon on sapphire; spreading resistance; test patterns; thermal resistance; thermal response; transistors; ultrasonic bonding; wire bonds; x-ray photoelectron spectroscopy.

This progress report describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Both in-house and contract efforts are included. The emphasis is on silicon device technologies. Principal accomplishments during this reporting period included (1) completion and analysis of an interlaboratory evaluation of standard reference wafers for resistivity measurement by the four-probe method, (2) analysis of the effect of finite contact size on sheet resistance as measured with a van der Pauw structure, (3) calculation of errors introduced in measuring line width with typical microscope systems, (4) development of procedures for predicting the magnitude of electron beam induced current in silicon device structures, (5) application of the optical flying-spot scanner to observation of hot spots and nonlinearities in rf power transistors and of logic patterns in an MOS shift register, and (6) determination of a more accurate electrical method, based on peak junction temperature measurement, for establishing safe operating area curves for medium power transistors. Also reported are the results of work on spreading resistance measurements, ionization of dopant impurities in silicon, Rutherford backscattering measurements, x-ray photoelectron spectroscopy, ion microprobe mass analysis, tests for determining the surface quality of sapphire substrates, reevaluation of Irvin's curves, mathematical models of dopant profiles, deep depletion measurements of resistivity profiles, measurement of epitaxial layer thickness by the deep depletion method, bias-temperature stress test measurements on MOS capacitors, a high voltage capacitance-voltage method for measuring characteristics of thick insulator films, ion implantation parameters, methods for determining integrity of passivation overcoats, optical imaging and calibration standards for photomask metrology, line-width measurements, charge-coupled device test structures, test pattern design and analysis for silicon on sapphire MOS device technologies, nondestructive acoustic emission test for beam-lead bonds, pull and shear tests for wire bonds, a rapid cycle dry gas gross leak test, leak detection by helium mass spectrometry, correlation of moisture infusion in semiconductor packages with leak size and device reliability, an automated scanning low-energy electron probe, electron beam induced damage in silicon device structures, and thermal resistance measurements on Darlington transistors. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices. A sixth appendix is included to summarize the results of a study which was carried out to assess the impact of automation of integrated circuit processing and assembly on future measurement requirements in the industry.

SP400-20. **Semiconductor measurement technology: Optical and dimensional-measurement problems with photomasking in microelectronics,** J. M. Jerke, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-20, 42 pages (Oct. 1975) SD Catalog No. C13.10:400-20.

Key words: integrated circuits; microelectronics; micrometrology; photolithography; photomask; semiconductor technology.

Photomasks are the basic artifacts for transferring design geometry to the semiconductor wafer in integrated circuit (IC) production. Currently, photolithographic techniques using optical equipment are the primary means for both fabricating masks and using masks to print patterns on wafers. The present study was to identify the major optical and dimensional-measurement problems related to the fabrication and use of masks.

The results show that the primary optical problems are those related directly to the use of optical instruments for dimensional measurements of IC pattern geometry. Furthermore, most suppliers and users of optical equipment for mask fabrication do not conduct sufficient optical testing to determine imaging performance. The basic limitations derived from light diffraction and coherence continue to limit the quality of masks and IC devices with sub-micrometre geometry, and acceptable units are produced generally on a best-effort basis. The primary dimensional-measurement problems are (1) accurate measurements below about 10 μm, (2) edge definition or location of a physical edge for a line, and (3) mask registration. Recommendations to improve the accuracy of dimensional measurements are given.

A bibliography of publications related to the optical and micrometrological aspects of photomasking is included.

SP400-21. **Semiconductor measurement technology: Planar test structures for characterizing impurities in silicon,** M. G. Buehler, J. M. David, R. L. Mattis, W. E. Phillips, and W. R. Thurber, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-21,* 32 pages (Jan. 1976) SD Catalog No. C13.10:400-21.

Key words: MOS capacitors; *p-n* junctions; resistivity of silicon; semiconductor devices; semiconductor process control; sheet resistors; test patterns; thermally stimulated currents.

Various test structures such as sheet resistors, *p-n* junctions, and MOS capacitors and their associated physical models have been developed to characterize dopants and defects in silicon. These structures address various needs within the semiconductor industry for (a) well-designed and miniaturized test structures such as an orthogonal van der Pauw sheet resistor, (b) simple and economical measurements such as the oxide window width of a diffused layer, (c) updated values for the resistivity versus dopant density relation, and (d) improved detection methods for identifying defect centers which control the lifetime and leakage currents of devices.

SP400-22. **Semiconductor measurement technology: Microelectronic test pattern NBS-3 for evaluating the resistivity-dopant density relationship of silicon,** M. G. Buehler, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-22,* 57 pages (June 1976) SD Catalog No. C13.10:400-22.

Key words: dopant density; microelectronics; MOS capacitors; *n-p-n* transistor fabrication; *p-n* junctions; resistivity; semiconductor electronics; sheet resistors; silicon; test pattern; test structures.

Test pattern NBS-3 is a microelectronic test vehicle designed by the National Bureau of Standards to evaluate the electronic materials used in discrete semiconductor devices and integrated circuits. Designed for fabrication on silicon wafers, the test pattern is an aid in better understanding integrated circuit fabrication technologies. The main pattern consists of four masks designated BASE, EMITTER, CONTACT, and METAL and contains 33 test structures such as sheet resistors, MOS capacitors, *p-n* junctions, bipolar and MOS transistors, and etch control and resolution structures.

The pattern was designed primarily to aid in the evaluation of the relationship between resistivity and dopant density in both *n*- and *p*-type silicon. This relation is needed in the design of silicon solid-state devices and in the analysis of various physical measurements. Other test structures are included for use as diagnostic tools to verify that proper fabrication procedures were followed. The remaining structures allow the exploration of new designs and measurement methods.

The structures are arranged in a square pattern 200 mil (5.08 mm) on a side. A detailed layout of each test structure is presented including both a top view and a cross sectional view. A description of each structure is given and where applicable the formulas for evaluating such quantities as resistivity, dopant density, and sheet resistance are given. The fabrication of the test pattern is illustrated by an *n-p-n* transistor process and values obtained from various test structures are presented.

SP400-23. **Semiconductor measurement technology: ARPA/NBS Workshop IV. Surface analysis for silicon devices,** A. G. Lieberman, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-23,* 238 pages (Mar. 1976) SD Catalog No. C13.10:400-23.

Key words: Auger spectroscopy; depth profiles; electron beam induced imaging; ESCA; insulator films; interface characteristics; internal photoemission; ion scattering spectroscopy; nuclear resonance profiling; photodepopulation; photovoltaic imaging; Rutherford backscattering; SCANIIR; secondary ion mass spectroscopy; semiconductor devices; silicon; surface analysis; x-ray photoelectron spectroscopy.

This report contains the proceedings of the ARPA/NBS Workshop IV, *Surface Analysis for Silicon Devices,* held at the National Bureau of Standards on April 23-24, 1975.

The Workshop, as part of an NBS program to develop measurement technology for the field of semiconductor devices, was held to discuss the present capabilities and future prospects of modern analytical beam techniques as applied to silicon, and associated insulator films and device structures. Of particular interest were the determination of impurity profiles, surface contamination, and interface characteristics. Techniques utilizing impinging electron, ion, neutral or photon beams were considered. The Workshop was directed at the analysts, the semiconductor manufacturers who use the analysts' results, and the instrument people who design and manufacture the analytical equipment. Transcripts of the discussions following each paper are also included within these proceedings. *These proceedings include the following papers (indented):*

Introductory concepts for silicon surface analysis, A. G. Lieberman, *SP400-23,* pp. 3-6 (Mar. 1976).

Identification of integrated circuit process areas amenable to diagnosis and control by analytical beam techniques, B. E. Deal, *SP400-23,* pp. 7-20 (Mar. 1976).

Low energy ion scattering spectrometry studies of Si, SiO_2 and related materials, W. L. Harrington, *SP400-23,* pp. 21-30 (Mar. 1976).

Surface analysis by secondary ion mass spectroscopy techniques, R. D. Dobrott, *SP400-23,* pp. 31-43 (Mar. 1976).

Some effects limiting SIMS depth profile analysis and methods for improvement, R. K. Lewis, *SP400-23,* pp. 45-59 (Mar. 1976).

Qualitative assessment of ion erosion damage by means of electron channeling patterns, D. E. Newbury, *SP400-23,* pp. 61-63 (Mar. 1976).

The effect of specimen cooling on the migration of sodium in thin film SiO_2, B. F. Phillips, A. E. Austin, and H. L. Hughes, *SP400-23,* pp. 65-72 (Mar. 1976).

Silicon-on-sapphire impurity analysis, D. W. Phillips, *SP400-23,* pp. 73-79 (Mar. 1976).

Surface composition by analysis of impact radiation, C. W. White, *SP400-23,* pp. 81-84 (Mar. 1976).

Nuclear resonance and backscattering surface analysis of silicon and related insulators, K. L. Dupning, *SP400-23,* pp. 95-104 (Mar. 1976).

Applications of scanning Auger spectroscopy (SAM) to the silicon integrated circuit (SIC) technology, J. M. Morabito, *SP400-23,* pp. 105-118 (Mar. 1976).

Use of Auger electron spectroscopy to determine the structure of silicon oxide films, J. S. Johannessen, W. E. Spicer, and Y. E. Strausser, *SP400-23,* pp. 119-123 (Mar. 1976).

An Auger electron spectroscopy study of silicon spectra from silicon monoxide, silicon dioxide and silicon nitride, Y. E. Strausser and J. S. Johannessen, *SP400-23,* pp. 125-138 (Mar. 1976).

Surface compositional changes with electron bombardment observed by AES, S. Thomas, *SP400-23,* pp. 139-141 (Mar. 1976).

Combined scanning electron microscopy—Auger spectroscopy for micro-spot surface and in-depth analysis of silicon and transistor metallizations, A. Christou, W. Weisenberger, and H. M. Day, *SP400-23,* pp. 143-150 (Mar. 1976).

Applications of x-ray photoelectron spectroscopy (ESCA) to MIS devices, F. J. Grunthaner, *SP400-23,* pp. 151-173 (Mar. 1976).

Choosing between ESCA and Auger for surface analysis, G. E. McGuire, *SP400-23,* pp. 175-182 (Mar. 1976).

Silicon device applications using a combined ESCA/AES analysis system, L. E. Davis and G. E. Riach, *SP400-23,* pp. 183-187 (Mar. 1976).

Photodepopulation technique for the study of electronic traps in insulators, T. H. DiStefano and J. M. Franz, *SP400-23,* pp. 189-195 (Mar. 1976).

Photoemission and photovoltaic imaging of semiconductor surfaces, T. H. DiStefano, *SP400-23,* pp. 197-209 (Mar. 1976).

Electron beam induced imaging of silicon surfaces, W. R. Bottoms, *SP400-23,* pp. 211-218 (Mar. 1976).

A comparison of the techniques for silicon surface analysis, C. A. Evans, Jr., *SP400-23,* pp. 219-232 (Mar. 1976).

SP400-25. **Semiconductor measurement technology. Progress Report, July 1 to December 31, 1975,** W. M. Bullis, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-25,* 87 pages (Oct. 1976) SD Catalog No. C13.10:400-25.

Key words: acoustic emission; Auger electron spectroscopy; beam-lead bonds; bias-temperature stress test; boron redistribution; capacitance-voltage methods; dopant profiles; electrical properties; electronics; four-probe method; hermeticity; interface states; ion implantation; ion microprobe mass analysis; leak tests; measurement methods; microelectronics; moisture infusion; optical flying-spot scanner; passivation overcoats; photoresist; pull test; resistivity; scanning acoustic microscope; scanning electron microscope; scanning low energy electron probe; semiconductor devices; semiconductor materials; semiconductor process control; silicon; silicon dioxide; silicon on sapphire; spreading resistance; test patterns; thermally stimulated current; thermal resistance; ultrasonic wire bonding; voltage contrast mode; x-ray photoelectron spectroscopy.

This progress report describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Both in-house and contract efforts are included. The emphasis is on silicon device technologies. Principal accomplishments during this reporting period included (1) preliminary results of a systematic study of the effects of surface preparation on spreading resistance measurements; (2) development of an optical test for surface quality of sapphire; (3) development of a basis for an exposure sensitivity specification for photoresists; and (4) development of a modular cell concept for test structure design and layout. Also reported are the results of work on four-probe resistivity measurements, comparison of techniques for surface analysis, ion microprobe mass analysis, analysis of process chemicals with flame emission spectrometry, redistribution profiles, thermally stimulated current response of interface states, bias-temperature stress test measurements on MOS capacitors, a high voltage capacitance-voltage method for measuring characteristics of thick insulator films, hydrogen chloride oxidation, ion implantation parameters, methods for determining integrity of passivation overcoats, measurement of free sodium in an oxidation furnace by resonance fluorescence, a square array collector resistor test structure, an electrical alignment test structure, two dimensional wafer maps, test pattern design and analysis for silicon-on-sapphire MOS device technologies, a nondestructive acoustic emission test for beam-lead bonds, wire bond pull test, bondability of doped aluminum metallizations, leakage into double hermetic enclosures, a static expansion dry gas gross leak test, correlation of moisture infusion in semiconductor packages with leak size and device reliability, an automated scanning low-energy electron probe, an optical flying-spot scanner, scanning electron microscopy, scanning acoustic microscopy, and thermal resistance measurements on power transistors and simple integrated circuits. Supplementary data concerning staff, publications, workshops and symposia, standards committee activities, and technical services are also included as appendices.

SP400-26. **Semiconductor measurement technology: Defects in PN junctions and MOS capacitors observed using thermally stimulated current and capacitance measurements—videotape script,** M. G. Buehler, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-26,* 20 pages (Apr. 1976) SD Catalog No. C13.10:400-26.

Key words: cryostat; defects; gold-doped silicon; measurement methods; microelectronics; MOS capacitor; *p-n* junctions; semiconductors; silicon; thermally stimulated capacitance; thermally stimulated current.

Two measurement methods are described which detect and characterize defects which can control such device characteristics as lifetime and junction leakage. The methods can be used as diagnostic tools in the fabrication of bipolar and MOS devices. The number of different kinds of defects and their densities may be obtained with little effort and simple apparatus. Positive identification of these defects may be obtained with more effort and more sophisticated apparatus. Of more importance, the measurements characterize defects in an environment which is identical to that of the finished product. Thus, the answers derived are directly applicable to process control and device design.

These methods involve thermally stimulated capacitance and current measurements which utilize the ability of defects in the vicinity of a *p-n* junction or in a MOS capacitor to trap holes or electrons and emit them after receiving sufficient thermal energy. Values for defect densities, energy levels, and emission rates can be derived from these measurements. The limit of detectability can be as low as 10^{10} defects/cm^3. These values provide sufficient information to positively identify the defects.

Three vehicles are used to illustrate the methods: a gold doped n^+-p diode, a p^+-n diode with a process-induced defect center, and a gold doped n-type MOS capacitor. Two cryostats are described which have a maximum heating rate of 10 K/s.

SP400-27. **Semiconductor measurement technology: Laser scanning of active semiconductor devices—Videotape script,** D. E. Sawyer and D. W. Berning, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-27,* 26 pages (Feb. 1976) SD Catalog No. C13.10:400-27.

Key words: failure analysis; hot spots; integrated circuits; laser scanner; measurement method; nondestructive test; nonlinear operation; optical scanner; reliability; transistors.

This is the script of a videotape presentation which describes new and powerful applications for laser scanning in semiconductor device design and reliability work. The design of the scanner is described in detail and many of its applications are displayed and discussed. The optical scanner can, in a completely nondestructive way, reveal the inner workings of semiconductor devices. For example, it is shown that the scanner can (1) map dc and high-frequency gains in transistors, (2) reveal areas of the device operating in a nonlinear manner, (3) electronically map temperature in the transistor, and (4) detect the location of hot spots that can develop for certain operating conditions. The vehicle used to show these capabilities of the scanner is a bipolar interdigitated UHF transistor. A dual input NAND gate is used to demonstrate the use of the scanner to determine internal logic states and otherwise observe internal operation of the circuit. To show the ability of the scanner to examine MOS devices without detectable degradation, a MOS shift register is used. The location and progress of internal logic in the register is clearly shown by the scanner. Not only can internal logic be mapped and marginally-operating logic cells detected, but individual logic states can be changed by the scanner without affecting other elements.

SP400-28. **Semiconductor measurement technology: NBS/FDA workshop. Reliability technology for cardiac pacemakers,** H. A. Schafft, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-28,* 49 pages (June 1976) SD Catalog No. C13.10:400-28.

Key words: cardiac pacemaker; data banks; failure analysis; failure modes; hermeticity; hybrid devices; leak testing; measurement technology; microelectronics; MOS devices;

process control; reliability; semiconductor devices; surgical implants.

Brief summaries are presented of 20 invited talks on the following topics: procurement and assurance of reliable, long lived semiconductor electronic parts; leak testing of device packages and pacemaker systems; activities of standardization organizations; and availability and use of resources for information and expertise. The purpose of the workshop was to address technical questions relevant to the enhancement and assurance of cardiac pacemaker reliability, and to bring together representatives from the pacemaker, military, aerospace, and other communities to discuss areas of mutual concern. The technical sessions highlighted the problems of pacemaker manufacturers associated with obtaining high reliability electronic components – problems shared with the most demanding users in the military and space communities. It was also noted that no government agency has the authority or responsibility for the development of methods to permit assured procurement of high quality electronic components for critical applications by organizations in the civilian sector. These organizations must rely on spin-off from military and space programs even when parts of this civilian sector have reliability requirements which are more severe than all but the most stringent military and space requirements. Included in appendices are measurement technology areas of concern identified by the pacemaker community; information about utilizing reliability data banks and facilities for searching literature and data; and organizations offering services in the microelectronics field.

SP400-34. **Semiconductor measurement technology: Safe operation of capacitance meters using high applied-bias voltage,** A. M. Goodman, *Nat. Bur. Stand. (U.S.), Spec. Publ. 400-34,* 57 pages (Dec. 1976) SD Catalog No. C13.10:400-34.

Key words: bias-isolation unit; capacitance measurements at high applied-bias voltage; capacitance-meter; extended-range capacitance measurement; high-voltage C(V) measurements; modified MIS C(V) measurements.

The use of capacitance meters (C-meters) to determine small-signal (differential) capacitance at 1 MHz as a function of applied-bias voltage is widespread. The maximum value of the bias voltage which may be applied to a sample under test with any commercially available C-meter is 600 V or less. A larger bias-voltage capability is required for certain applications.

This report describes a technique for using a commercial C-meter with a Bias-Isolation Unit (BIU) for capacitance measurements at bias-voltage magnitudes up to 10 kV without damage to the measurement equipment. The basic principles of operation and the details of the electrical design of a BIU are discussed.

The use of the BIU imposes certain limitations on the range of sample capacitance which may be measured without introducing excessive error. The theory of these limitations is presented and compared with experimental results obtained from the use of the BIU with each of three commercially available C-meters. The measurement capability demonstrated by these results appears to be adequate for all current and future applications. For less than ± 1 percent error in the indicated (measured) capacitance, the measurable range of the sample capacitance is found to be from 0 to at least 400 pF. In some applications, it is important to be able to accurately measure small changes in the sample capacitance; for less than ± 1 percent error in the indicated (measured) value of a small change in the sample capacitance, the measurable range of the sample capacitance is found to be from 0 to at least 130 pF.

Construction details of the BIU are appended.

SP401. **Computer performance evaluation.** Proceedings of the Eighth Meeting of Computer Performance Evaluation Users Group [CPEUG], held at NBS, Gaithersburg, Md., December 4-7, 1973, H. J. Highland, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 401, 155 pages (Sept. 1974) SD Catalog No. C13.10:401.

Key words: computer evaluation; computer performance; computer scheduling; hardware monitors; simulation of computer systems; software monitors; systems design and evaluation; time-sharing systems evaluation.

The Eighth Meeting of the Computer Performance Evaluation Users Group [CPEUG], sponsored by the United States Army Computer Systems Command and the National Bureau of Standards, was held December 4-7, 1973 at NBS, Gaithersburg. The program chairman for this meeting was Merton J. Batchelder of the U.S. Army Computer Systems Command at Fort Belvoir, Va. 22060 [CSCS-ATA Stop H-14].

About 150 attendees at this meeting heard the 17 papers presented on computer performance, evaluation and measurement. Among the papers presented were those dealing with hardware and software monitors, workload definition and benchmarking, a report of FIPS Task Force 13, computer scheduling and evaluation in time-sharing as well as MVT environment, human factors in performance analysis, dollar effectiveness in evaluation, simulation techniques in hardware allocation, a FEDSIM status report as well as other related topics.

These proceedings represent a major source in the limited literature on computer performance, evaluation and measurement. *These proceedings include the following papers (indented):*

Getting started in computer performance evaluation, P. J. Kiviat and M. F. Morris, *SP401,* pp. 5-13 (Sept. 1974).

A methodology for performance measurement, D. M. Venese, *SP401,* pp. 15-22 (Sept. 1974).

Use of SMF data for performance analysis and resource accounting on IBM large-scale computers, R. E. Betz, *SP401,* pp. 23-32 (Sept. 1974).

Using SMF and TFLOW for performance enhancement, J. M. Graves, *SP401,* pp. 33-36 (Sept. 1974).

USACSC software computer system performance monitor: SHERLOC, P. Balcom and G. Cranson, *SP401,* pp. 37-43 (Sept. 1974).

Benchmark evaluation of operating system software: Experiments on IBM's VS/2 system, B. A. Ketchledge, *SP401,* pp. 45-48 (Sept. 1974).

Report on FIPS Task Group 13 workload definition and benchmarking, D. W. Lambert, *SP401,* pp. 49-53 (Sept. 1974).

Performance measurement at USACSC, R. Castle, *SP401,* pp. 55-62 (Sept. 1974).

A computer design for measurement – the monitor register concept, D. R. Deese, *SP401,* pp. 63-72 (Sept. 1974).

The use of simulation in the solution of hardware allocation problems, W. A. Hesser, *SP401,* pp. 73-79 (Sept. 1974).

Human factors in computer performance analyses, A. C. Shetler, *SP401,* pp. 81-84 (Sept. 1974).

Dollar effectiveness evaluation of computing systems, L. J. Cohen, *SP401,* pp. 85-98 (Sept. 1974).

Computer scheduling in an MVT environment, D. A. Verbois, *SP401,* pp. 99-97 (Sept. 1974).

Performance evaluation of time sharing systems, T. W. Potter, *SP401*, pp. 107-114 (Sept. 1974).

A case study in monitoring the CDC 6700—a multi-programming, multi-processing, multi-mode system, D. M. Conti, *SP401*, pp. 115-118 (Sept. 1974).

FEDSIM status report, M. F. Morris and P. J. Kiviat, *SP401*, pp. 119-122 (Sept. 1974).

Data analysis techniques applied to performance measurement data, G. P. Learmonth, *SP401*, pp. 123-126 (Sept. 1974).

A simulation model of an AUTODIN automatic switching center communications data processor, R. B. McManus, *SP401*, pp. 127-136 (Sept. 1974).

SP403. **Energy conservation through effective energy utilization.** 1973 Engineering Foundation Conference, New England College, Henniker, NH, Aug. 19-24, 1973, J. C. Denton, S. Webber, and J. Moriarty, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 403,* 251 pages (June 1976) SD Catalog No. C13.10:403.

Key words: automobile; break-even analysis; conservation; cooling; economics; energy; environment; fuel; heating; imports; industry; management; manufacturing; paper; petroleum; resources; standards; steel; thermal; thermodynamics.

These proceedings of the 1973 Engineering Foundation Conference focus on effective utilization of thermal energy as a means of energy conservation. It is hoped publication will help stimulate the national dialogue toward a balanced national program for more energy conservation.

The varied professional backgrounds of the participants provided an interdisciplinary approach for action steps to be taken in areas where research is needed and will provide a significant impact. For example, the development of better stack controls was recommended as a specific research task, and the improvement of energy accounting systems and energy use norms was recommended as a useful research area. Broad agreement was reached that there is much left to be accomplished in thermal process technology as used in industrial processes, in industrial equipment, and in heating, ventilating, and air conditioning (HVAC) equipment for buildings.

A clear conclusion of the conference is that while new technology is important the introduction of much technology that is already available is equally, if not more, important. Institutional barriers relating to economics, management, finance, and national policy keep available technology standing in the wings. The conference papers and discussions show that engineering design, when it can be rigorously applied, does result in striking reductions in energy use in the thermal process technologies. *These proceedings include the following papers (indented):*

Effective utilization of energy and other natural resources, C. A. Berg, *SP403*, pp. 3-12 (June 1976).

Key words: costs; economics; energy; fuel; imports.

An overview of the Nation's energy problems is presented to provide a basis of definition for the term "energy crisis." The term does not represent a crisis of depletion of energy resources but rather refers to energy cost. The dependency of the United States on fuel imports illustrates the problems that questionable reliability and increasing costs of fuel imports pose for American industry. Improving energy use efficiency would reduce energy consumption and, considering rising energy costs, may prove to be economically attractive to industry. A policy of national life-term costing of equipment, which includes energy cost of that equipment, should be promoted rather than the present criterion of justification which is based primarily on first costs. Further, a rational economic method for achieving effective and balanced use of all natural resources, based on total life-term costing, is advocated.

Energy conservation goals and methods, R. E. Shepherd, *SP403*, pp. 13-18 (June 1976).

Key words: conservation; energy; organization.

The goals of the President's energy message of early 1973 and the feasibility of the 1974 goal of a 5 percent energy use reduction nationally are discussed. An overview of the Federal government's organizational structure is presented and discussed with reference to attaining these goals. Voluntary energy conservation measures and a major educational program directed at energy users are urged to help solve the Nation's energy problems.

National benefits of energy conservation, L. R. Glicksman and D. C. White, *SP403*, pp. 21-41 (June 1976).

Key words: correlation; economic; energy; imports; international; petroleum.

Starting from the correlation between a nation's gross national product and its energy consumption per capita, the consequences of economic growth on the world's estimated energy resources is discussed. In the absence of new energy technologies or a reduction of energy consumption in relationship to GNP, sustained high economic growth will be difficult and costly to achieve as our own resource base diminishes. The developing nations of the world will be competing for resources as their own GNP's increase, further exacerbating the resource depletion problem. As the nations of the world compete for scarce resources, there are potential international complications beyond those presently apparent in the effect of petroleum imports on America's transportation sector.

Options for energy conservation, B. Hannon, *SP403*, pp. 43-56 (June 1976).

Key words: economic; energy; input-output model.

An input-output model useful in measuring energy use, efficiency of production processes, and product uses is presented. The model provides estimates of total energy and employment shifts in a variety of processes and products. Several of these demand shifts and their potential impacts are discussed. United States industry, in general, becomes more energy-intensive as it grows. The impacts of demand shifts and changing character of industry as it evolves on consumer cost, employment, and pollution should be thoroughly understood before policy recommendations should be initiated.

Measures of thermal energy utilization, B. B. Hamel and H. L. Brown, *SP403*, pp. 57-64 (June 1976).

Key words: energy; heating systems; model; thermodynamics.

It is necessary to quantify, or structure, the ideas of thermal energy utilization in order to develop an efficiency of energy utilization. Such a quantitative analysis is useful in assessing any modification or change in design of an energy system. A method of analysis useful in assessing modifications in an energy system is presented. The concept of thermodynamic availability is used to determine maximum energy utilization efficiency. The method is illustrated by evaluating the efficiencies of several water heating systems.

Economic and environmental implications of effective utilization of energy, J. C. Denton, *SP403*, pp. 65-74 (June 1976).

Key words: automobile; economic; energy; model; transform analysis.

Technology uses energy, materials, money, people, etc. to produce products and services for society. The resultant products and their impacts on resources, society and the environment exist in a dynamic interrelationship. Technology transform analysis is an analytical model which is proposed to identify and elucidate the interrelationships between these elements and to assess the consequences of their modification. The technology transform analysis is prerequisite to the application of input-output analysis if the interrelationships between energy, environmental, economic, and human factors is to be displayed in a compatible fashion. An abbreviated example analysis of the automobile industry is presented to demonstrate the complexities which must be included and the subtleties which appear. Possible pitfalls of an incomplete analysis are discussed.

Industrial energy analysis and forecasting, D. R. Limaye, J. R. Sharko, and J. H. Kayser, *SP403*, pp. 77-93 (June 1976).

Key words: break-even analysis; economics; energy; industrial.

Although the industrial sector is one of the largest consumers of energy (over 33% of total energy consumption), relatively little is known in detail about the end use characteristics in this sector because of the diversity of processes and practices. Two approaches are discussed: a detailed engineering process analysis, involving an in-depth look at each major product in each industry; and a survey approach employing interviews and questionnaires. Studies are presented on the Chemical and Allied Products industry (SIC 28). A break-even analysis is employed to determine the prices at which two fuels are economically equivalent. An overall methodology is presented for integrating all of the different aspects of industrial energy analysis. The initial steps are the identification of end use characteristics, energy requirements per unit of output, process economics, and qualitative factors affecting energy use. Based on these and on estimates of total industrial output, the total energy requirements can be determined.

Management's role in industrial thermal energy utilization, A. S. Cook, *SP403*, pp. 95-101 (June 1976).

Key words: conservation; costs; economics; energy; thermal.

The industrial sector has a vital role and stake in decisions with respect to utilization of the country's thermal energy resources. Energy management responsibility requires a significant reorientation of the management job toward energy conservation. Industrial management's present dedication is to competitive free enterprise and energy substitution for human toil. The reorientation is toward acceptance of higher energy costs and toward security of energy supply. Discussions are presented on what industrial manufacturing can do and some factors external to industrial process thermal energy utilization. In the former category a new process technology, ultraviolet curing, is presented to exemplify conservation results from application of a new technology. In the latter category, it is emphasized that a given company cannot operate in isolation in its energy conservation efforts without running the risk that the total energy required by the society may increase.

Development of industrial energy management policies, M. C. Noland, *SP403*, pp. 103-111 (June 1976).

Key words: conservation; economic; energy; management; manufacturing.

A systematic approach to energy management at the operational level must be custom-fitted to specific industrial facilities. Preliminary results of attempts to (1) determine the steps being taken by industry in response to changing energy supply conditions and the potential for conservation inherent in that response and (2) develop guidelines for the establishment of plant energy management policies in the manufacturing and process industries are presented. The major incentive for future conservation of energy by industry is cost. The only alternative is regulation and enforcement. The economic incentive involves both direct energy cost and the indirect costs of energy security. The approach to energy problems taken by different firms follows no discernibly systematic pattern, varying from little concern to progressive programs. An outline of steps in the development of industrial energy management policies is presented.

Case histories of effective energy utilization in industry, W. Rudoy, *SP403*, pp. 113-117 (June 1976).

Key words: attitudes; conservation; energy; industrial; systems.

Energy conservation through effective energy utilization falls into three classes: better "housekeeping" or energy management of present systems; application of present off-the-shelf technology to existing systems; and revision of existing systems to provide the same objective with less energy. Three general components enter into any implementation of energy conservation—technology, economics, and people. There is a great deal of off-the-shelf technology that could be employed and case studies are presented showing significant gains in energy conservation in the area of comfort conditioning of the industrial environment. In most cases, the rule-of-thumb economic payback period of two years for revising a system is not met. The decision to move toward more efficient utilization, even when the other two components are favorable, is often influenced by the attitudes of key personnel.

A projection of energy demand by the iron and steel industry, D. Larson, *SP403*, pp. 121-152 (June 1976).

Key words: energy; forecast; industry; iron; steel.

The iron and steel industry is not only one of the larger consumers of energy (7.5% of the total U.S. energy use in 1968), but is also a very complex industry. The interrelationships between projected demand for products and the amounts of fuels needed for manufacturing the products are discussed as well as the trends that could change the amounts of fuels needed per unit of product. Conclusions drawn are that there should be a 65 percent increase in production and a 28 percent increase in energy consumption in the industry between 1971 and 1985. The growth rate of energy consumption decreases with time and should almost level off by 1985. The change in energy requirements per ton of finished product is primarily the result of technological changes. Therefore, trends that phase out obsolete inefficient equipment can accelerate this energy utilization efficiency. Most of the improved efficiency is expected in the iron-making and steel-making processes and very little change is forecast in the reheating and finishing portion of the industry.

Potential energy savings in the forming of paper, T. Speidel and D. Kallmes, *SP403,* pp. 153-161 (June 1976).

Key words: energy; industrial; paper.

The United States produced 59 million tons of paper and paper products in 1972 requiring 320×10^{12} BTU exclusive of the energy required to produce the necessary wood pulp. The conventional paper forming process is described in brief. A new method of forming paper is described having the potential of saving 40 percent of the energy conventionally required to form paper. The new method can make high quality paper utilizing up to 2 percent suspended wood pulp. A helical mixer with a high shear component in the jet permits a 35 percent decrease in the heat required during the process. This process is particularly attractive where fuel oil or fuel gas is used to supply the heat rather than waste bark and black liquor.

Potential for energy conservation in heating, ventilating, and air-conditioning equipment for buildings, G. Kelly, T. Kusuda, and J. Hill, *SP403,* pp. 163-191 (June 1976).

Key words: conservation; cooling; cost; energy; heating.

Approximately one-third of the Nation's energy use is presently used in residential and commercial buildings. Over seventy percent of the energy is being used for heating, cooling, and providing hot water. The potential for energy conservation through proper design and use of heating, ventilating, and air conditioning equipment within or in the proximity of buildings is discussed. The topics presented include a discussion of the positive and negative features of both unitary and central HVAC equipment, a description of typical all-air and air-water HVAC systems, the heat pump and how it can be combined with other equipment to conserve energy, and the recovery of energy from the building exhaust air. A brief description is given of total energy systems, modular integrated utility systems, and the utilization of waste heat from incineration plants. Considerable savings could be obtained from judicious choice of standard equipment based on energy conservation considerations. The use of life cycle costing rather than lowest possible first cost would vastly upgrade the present standards of practice.

ASHRAE and energy conservation, P. E. McNall, Jr., *SP403,* pp. 193-195 (June 1976).

Key words: energy; environment; food.

ASHRAE is concerned with all aspects of environmental control for people, as well as for plants and animals as the latter relate to food production and processing. The ASHRAE Guide is discussed and its excellent treatment on thermal comfort in buildings is emphasized. The need for better energy management and the importance of first cost to the building industry in speculative type investments is discussed. The utility of reheat HVAC systems is emphasized since they are easy to maintain and have low initial costs. ASHRAE has considerable know-how which is not optimally used at present because of inadequate incentive. Labor is no substitute for energy since a man is worth only 10 per day in energy expended.

Factors controlling the manufacture and marketing of energy conserving products, J. B. Comly and C. M. Huggins, *SP403,* pp. 199-213 (June 1976).

Key words: costs; energy; heating; manufacturing; marketing.

The complex of factors relating to decisions to manufacture and market new or improved products is discussed, with examples taken from consumer equipment of importance in conservation of energy at the point of utilization. The heat pump and the incandescent light bulb are used as specific examples. Premature marketing of the heat pump as a heating system impaired its degree of acceptance. The tradeoff between energy efficiency and replacement cost of the incandescent light bulb illustrates the optimization of these two factors in a product. Technological development alone does not assure immediate implementation of energy efficient systems. The prospect of commercial success of a product should be evaluated well before that product is brought to market.

Economic, energy, environment trade-offs, P. Swatek, *SP403,* pp. 215-223 (June 1976).

Key words: costs; economics; energy; environment.

The individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in the community but his ethics prompt him also to cooperate. Believing that pecuniary motivation is high on the list of human priorities, freer market mechanisms than presently exist are urged. The market should be unshackled, both removing subsidies to the energy industry (oil depletion allowance) and having the producers internalize the now externalized social and environmental cost of their operations. Such measures are projected to be effective in all energy consuming sectors, await the development of no new technologies, require no legislation of rigid criteria and technical standards, require no bureaucracy, rely on the normal operation of the free market, do not depend on changes in basic motivation of consumers, and will work and produce an efficient allocation of resources.

Regulatory, legal, and tax constraints on energy conservation—Polemic or fact?, C. Warren, *SP403,* pp. 225-235 (June 1976).

Key words: energy; legal; regulatory; standards.

Recognizing the vital role of power in society, an education and voluntary basis for balancing the different mechanisms in the market (such as the adjustment of electric rate structures) is urged. In the last analysis, if this approach is unsuccessful, regulation will be required drawing upon the power of the State. Regulatory enactments should be directed toward behavioral norms in the every day activities of people rather than adjudicating conflicts. The State would set standards for the building industry, controlling lighting and insulation, be prepared to establish allocations of energy, and prescribe levels of operating efficiency. Since the standards proposed are essentially performance criteria rather than product quality criteria, one could enforce conformity at the point of end use.

Financial feasibility of energy conservation, S. Sixfin, *SP403,* pp. 237-241 (June 1976).

Key words: costs; energy; financial; resources; risk.

Energy availability is approached from a purely economic point of view. The technology to be used is determined by the rate of return on the investment. A sample cost feasibility analysis for a 100,000 square foot industrial plant is presented as an example. Besides price, the ultimate criterion for choosing an energy source is its availability. Where critical energy shortages are foreseen, incentives must be provided to encourage the flow of capital in the

directions necessary to alleviate the shortages. Private investors should be compensated for the risk that they undertake in the location and development of energy resources.

National context for energy conservation, J. C. Denton, *SP403*, pp. 245-246 (June 1976).

Energy management in industry, R. G. Gatts, *SP403*, pp. 247-250 (June 1976).

Application of thermal process technology, K. G. Kreider, *SP403*, pp. 251-252 (June 1976).

Institutional considerations respecting energy conservation, S. Z. Klausner, *SP403*, pp. 253-254 (June 1976).

SP404. **Approaches to privacy and security in computer systems.** Proceedings of a Conference held at the National Bureau of Standards, Gaithersburg, Md., March 4-5, 1974, Clark R. Renninger, Editor, Nat. Bur. Stand. (U.S.), Spec. Publ. 404, 84 pages (Sept. 1974) SD Catalog No. C13.10:404.

Key words: Computer systems; confidentiality; privacy; privacy and security; security.

This publication summarizes and contains the proceedings of a conference held at the National Bureau of Standards on March 4-5, 1974 to continue the dialog in search of ways to protect confidential information in computer systems.

Proposals are presented for meeting governmental needs in safeguarding individual privacy and data confidentiality that were identified at a conference held in November 1973. Among the proposals are the enactment of privacy legislation, improved computer system architecture and access controls, information and security management guidelines and the development of a systematic, balanced approach to system security.

The proposals were presented by legislators, citizens, computer industry associations and companies, professional societies, and public interest groups. *These proceedings include the following papers (indented):*

The privacy issue, A. R. Miller, *SP404*, pp. 2-3 (Sept. 1974).

Current legislative proposals in Congress, E. I. Koch, *SP404*, pp. 3-4 (Sept. 1974).

Current legislative proposals in Congress, B. M. Goldwater, Jr., *SP404*, pp. 5-6 (Sept. 1974).

A citizen's view of the privacy issue, J. L. Hardaway, *SP404*, pp. 6-8 (Sept. 1974).

The issues of privacy and computer security within the State of Ohio, S. J. Aronoff, *SP404*, pp. 8-10 (Sept. 1974).

The issues of privacy and computer security within the State of California, M. Cullen, *SP404*, pp. 10-14 (Sept. 1974).

The issues of privacy and computer security within the State of Massachusetts, A. R. Miller, *SP404*, pp. 14-15 (Sept. 1974).

The views of the computer and business equipment manufacturers association (CBEMA), P. McCloskey, *SP404*, pp. 16-19 (Sept. 1974).

A call for non-proprietary security systems, A. C. W. Biddle, *SP404*, pp. 19-20 (Sept. 1974).

The views of the association of data processing service organizations, J. B. Christiansen, *SP404*, pp. 21-22 (Sept. 1974).

The professional aspects of privacy and confidentiality, R. W. Rector, *SP404*, pp. 22-24 (Sept. 1974).

Data processing management association statement on privacy and security in computer systems, D. W. Sanford, *SP404*, pp. 25-26 (Sept. 1974).

A systematic approach to data security, R. L. Thomas and R. H. Courtney, *SP404*, pp. 26-32 (Sept. 1974).

Security in computer networks, P. S. Browne, *SP404*, pp. 32-37 (Sept. 1974).

Computer system architecture and access controls, O. R. Smoot, *SP404*, p. 37 (Sept. 1974).

Security architecture using encryption, R. R. Keys and E. H. Clamons, *SP404*, pp. 37-41 (Sept. 1974).

Access controls in Burroughs large systems, H. W. Bingham, *SP404*, pp. 42-45 (Sept. 1974).

Systems architecture for security and protection, J. P. Anderson, *SP404*, pp. 45-50 (Sept. 1974).

Pragmatic approaches to software security, R. L. Caplan, *SP404*, pp. 50-53 (Sept. 1974).

Information and security management, J. F. Cunningham, *SP404*, pp. 53-54 (Sept. 1974).

Risk analysis in planning for physical security, R. V. Jacobson, *SP404*, pp. 54-55 (Sept. 1974).

Security considerations in information systems design, S. B. Lipner, *SP404*, pp. 55-59 (Sept. 1974).

Auditing current systems, D. B. Parker, *SP404*, pp. 59-61 (Sept. 1974).

The medical patient's right to privacy, L. A. Bowden, *SP404*, p. 62 (Sept. 1974).

Confidentiality of the medical record, M. Beard, *SP404*, p. 63 (Sept. 1974).

Model legislation, B. Backus, *SP404*, pp. 63-64 (Sept. 1974).

On information files and people, M. P. Kriger, *SP404*, pp. 64-65 (Sept. 1974).

The need for privacy legislation, R. H. Long, *SP404*, p. 65 (Sept. 1974).

The administrative burdens of privacy legislation, E. I. Golding, *SP404*, p. 66 (Sept. 1974)

SP405. **Benchmarking and workload definition: A selected bibliography with abstracts,** J. L. Walkowicz, Nat. Bur. Stand. (U.S.), Spec. Publ. 405, 46 pages (Nov. 1974) SD Catalog No. C13.10:405.

Key words: benchmarking; bibliography; computer performance measurement; computer procurement; workload definition.

These 85 citations to the literature of benchmarking and workload definition were selected from a longer list of documents encompassing a somewhat broader scope, that was submitted to Federal Information Processing Standards (FIPS) Task Group 13 in response to a request made to attendees of the Task Group's Planning Session held on July 12, 1973, at the National Bureau of Standards. One of the topics discussed at the Planning Session was the collection of a selected bibliography on workload definition and benchmarking. The bibliographic effort was to be directed not so much toward exhaustiveness as toward the development of a bibliography that the attendees had found useful and would, therefore, recommend to other workers in the

field. Of the approximately 250 citations submitted to the Task Group, these 85 were selected on the basis of two criteria: (1) the item dealt primarily with benchmarking or workload definition; and (2) hard copy was available at the Institute for Computer Sciences and Technology. The citations are arranged alphabetically by last names of the first authors. Each citation has an abstract, a classification category assignment, and a list of keywords. The category assignments are made from a classification scheme that was developed for the collection and that is used here as a Category Index to the Bibliography. A Keyword Index is also provided.

P406. **Computer performance evaluation: Report of the 1973 NBS/ACM Workshop**, T. E. Bell, B. W. Boehm, and S. Jeffery, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 406, 180 pages (Aug. 1975) SD Catalog No. C13.10:406.

Key words: computer architecture; computer performance evaluation; installation management; measurement; modeling; monitoring; operating systems; performance objectives.

An ACM/NBS Workshop on Computer Performance Evaluation (CPE) was held in San Diego, Calif., in March 1973. The papers, workshop discussions, conclusions, and recommendations presented in this volume address specific problems in making computer performance evaluation a commonplace and productive practice.

While several of the conclusions indicate that improvements are needed in performance analysis tools, another suggests that improved application of CPE could be achieved by better documentation of analysis field to develop its full potential. Participants noted that the common emphasis on data collection or modeling, to the exclusion of considering objectives, often seriously degrades the value of performance analysis. *These proceedings include the following papers (indented):*

Computer system performance factors at Mellon Bank, G. P. DiNardo, *SP406*, pp. 27-31 (Aug. 1975).

Key words: reduction of measurement data; software measurement tools; total computing capacity; user satisfaction measurement.

Mellon Bank has acquired or developed a series of software measurement tools which gather statistics related to job production and system utilization. No one software tool meets all the bank's needs and, on occasion, resort is made to a hardware probe. Of particular benefit have been data reduction schemes, file managers, and query languages that facilitate rapid reduction, summarization, search, and calculation of the raw measurement data. A continuing aim has been to use the same body of basic measurement data for job production statistics, system tuning data, and user costing schemes. In spite of the use of benchmarks, etc., there is concern about a basic inability to access accurately total third generation computing capacity in a rapidly changing hardware and software environment. The increasing need and the capability to make more accurate, timely, usable, and meaningful data immediately available to the final user requires use of teleprocessing, file management, and query systems that in a narrow and traditional sense are "wasteful" of system resources on a massive scale.

Computer performance analysis: Industry needs, E. Seals, *SP406*, pp. 33-38 (Aug. 1975).

Key words: Computer Performance Evaluation (CPE); CPE education; CPE imagination; CPE instrumentation; CPE policy; EDP productivity.

The computer has grown in its ability to provide information processing support to the automobile industry. The budget for computers and related items has also grown, both in magnitude and as a percentage of the expense of sales. Computer Performance Evaluation (CPE) has begun to offer help in increasing the productivity of EDP equipment. The auto industry has recognized the need for CPE and engages in CPE programs with vigor. The general CPE consciousness taking hold within the EDP community promises benefits to the auto industry, which currently is involved with generating its own CPE talent and techniques.

This paper discusses the CPE needs of the automobile industry with specific references to General Motors where the author was previously involved in CPE activities.

Performance factors for university computer facilities, J. C. Browne, *SP406*, pp. 39-42 (Aug. 1975).

Key words: end-user satisfaction; performance evaluation; performance factors; resource utilization; user competence.

The unique problems of performance evaluation in a university computer facility arise because of the diversity of usage patterns and resource demand patterns with which a single facility must cope. In such an environment, one key element of performance evaluation is the characterization of the workload; another is that a high premium must be placed upon adaptability and flexibility of the management algorithm. Subsystem performance can normally be subdivided into the service given the different classes of users. It is a balanced and adequate performance in these subsystems which is basically the most important criterion in universities.

Certain performance factors are discussed, such as end-user satisfaction, resource utilization, and usage of system subcomponents. The skewed competence of users, peculiar to a university environment, is also discussed as a factor affecting performance.

Computer sub-system performance, G. Carlson, *SP406*, pp. 45-52 (Aug. 1975).

Key words: distribution; low utilization; overhead; suboptimization; subsystem measurement; variability.

The goal of performance measurement is to improve the performance of the system and reduce the cost. The present measurement tools start at the computer subsystem level. A thorough understanding of these tools seems to be necessary before we can move beyond the subsystem level into the overall system, then the computer operations, then the computer management, and hopefully beyond. Subsystem measurements have a direct impact on equipment configurations in terms of reduction of presently installed equipment, postponement of planned equipment, selection of new equipment, and comparison between different vendors. How to detect and interpret low and high device utilization and uneven distributions of activities is covered.

Overhead is explored in several contexts and an attempt to generalize the concept of overhead is made. Performance comparisons are made between theoretical and practical maximums. Suboptimization is discussed, pointing out that some suboptimization can have no bad side effects and should be achieved.

Variability in present measurement techniques is bothersome and is discussed briefly. A need for better reporting techniques is indicated.

Computer system performance factors—Their changing requirements, R. L. Morrison, *SP406*, pp. 53-60 (Aug. 1975).

Key words: computer system; factors; measurement; parameters; performance; performance terminology; predictability; requirements; variables; workload.

Advances in programming and computer system architecture are causing additional performance factors to be

identified faster than the relationships among them are being understood. This must necessitate changes in the technology, terminology, and methodology, used to measure and describe computer system performance in the future. Problems and limitations resulting from using several measures of performance popular today, and suggestions for meeting tomorrow's needs, are noted in this paper. Insights gained from evaluating IBM's recently delivered storage systems during their development and early release stages provide the basis for discussing these changing requirements.

End-user subsystem performance, P. J. Kiviat, *SP406*, pp. 61-64 (Aug. 1975).

Key words: computer performance evaluation; efficiency measurement data; measures of computer performance; system effectiveness.

Subsystem end-users should be concerned primarily with measures of system effectiveness that are cost or value based. Only through these measures can they relate the operations of their subsystem to the goals of the larger system. Individual subsystem effectiveness measures should be related through a total systems effectiveness model to permit tradeoff and marginal allocation decisions to be made.

Subsystem end-users are usually not concerned with measures of system efficiency, which are the traditional computer performance measurements, but they are responsible for seeing that their effectiveness is achieved at minimum cost, which is determined and achieved by analysis of computer performance measurement data. Subsystem end-users therefore should see that their operating units receive system efficiency measurement data and that they understand how resource efficiency is related to system effectiveness.

End-user system performance, N. R. Nielsen, *SP406*, pp. 65-71 (Aug. 1975).

Key words: computer performance evaluation; computer resource allocation; computer service parameters; computer system performance; cost/effectiveness; cost/performance; performance evaluation; user control of computing; users' performance evaluation; users' performance measures.

The end-user's view of a computer system's performance is generally quite different from that of the computer professional or of the service provider. He is unconcerned about such traditional system performance measures as CPU utilization, channel balance, memory fragmentation, and I/O queues. He is concerned only with the indirect effects of these measures as manifested in the cost he incurs or in the performance he receives. Factors reflected in these measures encompass items in the areas of accounting cost, control, system service, reliability, user interface, output, programming, and user (rather than system) performance.

In addition to the usual perceptual differences that exist between server and user, there are also significant disparities in the items taken to define performance, in the measures used to reflect that performance, and in the criteria employed to evaluate the measured performance. The paper explores some of these differences as well as discussing certain aspects of system performance which are of particular concern to the end-users of computer systems.

Complementary pursuits—Computer design, W. T. Wilner, *SP406*, pp. 75-78 (Aug. 1975).

Key words: computer architecture; functional evaluation; hardware monitor; measurement tools; performance measurement.

The relationship between computer design and performance analysis is argumentatively claimed to be an information-producing symbiosis. Performance analysis can add precision to the conceptual models which designers use to generate new systems. Most of the major aspects of good models, however, are unquantifiable. Computer design can help or hinder performance analysis, mainly by adding or omitting those few components which allow hardware monitors to recognize significant system events.

Validation aspects of performance evaluation, R. J. Rubey *SP406*, pp. 79-82 (Aug. 1975).

Key words: actual system performance; computer performance evaluation; performance prediction; simulation; software validation; tools.

This paper describes the relationship between software validation and computer performance evaluation. A brief review of validation objectives and methods is presented. With this background, three principal aspects of the relationship between validation and evaluation are explored.

The first aspect to be explored is the activity undertaken during validation to compare the actual system performance with performance predicted earlier. The second aspect, with which the paper is concerned, is the difficulty of validation. This should be an important consideration in the evaluation of a particular software or hardware system. The third aspect of the relationship is the similarity of the tools used in validation and performance evaluation.

Security vs. performance, D. R. Chastain, *SP406*, pp. 83-86 (Aug. 1975).

Key words: computer performance; computer security; hardware monitors; performance evaluation of secure computer systems; security, data transmission; security, file access; security, identification (password); security, input and output processing; security software; software monitors.

The necessity for security often overrides the concern for optimum performance of a computer system. However, it is important that the relationships between security and performance be recognized. In this paper three major areas concerning these relationships are discussed.

The first concern is with some of the types of hardware and software that are required in order to maintain security internally in an ADP system, and the effect of this hardware and software on the performance of the system.

The second area discusses some of the complex problems of evaluating the impact of security software on the performance of computer systems.

The final area discusses a number of other technical and human problems often associated with evaluating performance in a secure environment.

Performance evaluation techniques and system reliability—A practical approach, J. Hughes, *SP406*, pp. 87-96 (Aug. 1975).

Key words: hardware monitoring; monitoring register; software monitoring; system reliability.

A literature search discloses very few papers devoted to the improvement of system reliability through the use of performance evaluation techniques. A brief description is provided of an existing hardware monitor of advanced design which is capable of discerning both software and hardware events. In terms of such a tool, methods are discussed by which an attack may be launched on a number of the root causes of system unreliability. In order that new forms of packaging technology may not jeopardize the continuing use of such techniques, a proposal is made for the inclusion of a monitoring register in future computer systems.

On the power and efficiency of a computer, L. Hellerman, *SP406*, pp. 131-134 (Aug. 1975).

Key words: computer efficiency; evaluation; measurement; performance; power; work.

The concept of power is defined and proposed as a new performance measurement tool for computer systems. Several examples are given that illustrate the calculation of power for small devices. The efficiency of a system is then discussed in terms of power. Finally, the new methods are compared with other methods of system evaluation.

The Weltansicht of software physics, K. W. Kolence, *SP406*, pp. 135-137 (Aug. 1975).

Key words: computer performance measurement; software physics; software units; software work.

This paper is a brief exposition of the idea that a "software physics" exists, and furthermore that it is based on the same concepts as used in the natural sciences. The idea of a software unit is introduced to name the entities embodying the basic observable properties of software physics. These properties are identified as work and time. (Another property, existence, is not referenced in this paper.) The relation of these properties, in a general sense, to the variables of performance monitors and modeling is commented on.

Standards in performance evaluation and measurement, R. W. Bemer, *SP406*, pp. 141-144 (Aug. 1975).

Key words: accuracy; audit; certification; code-independent; documentation; optimization; precision; run statistics; security; terminology; validation; warranty.

Giving "evaluation" equal billing with "measurement" opens the door to discussion of performance that is good or bad, as oppposed to fast or slow. Through this opening come considerations of security and confidentiality, validation of software and hardware means for performing arithmetic operations and evaluating mathematical functions (to varying degrees of precision and accuracy), code independency, auditing and warranty, optional optimization in compilation of running programs in high-level languages, and retention of statistics of every aspect of operation—for later analysis and reduction of duplicate work.

The role of the technical societies in the field of computer measurement, R. W. Hamming, *SP406*, pp. 151-153 (Aug. 1975).

Key words: computer measurement; technical societies.

It is comparatively easy to make measurements of computer performance, but this does not mean that there is, or can be, any single set of "right" measurements of performance—much as we may wish otherwise! This being the situation, the technical societies should not get themselves involved in trying to set standards of measurement (in the sense of what to measure), though they should encourage high quality measurement and subsequent data processing, publication, and oral presentation of results.

Computer performance evaluation—R&D, J. H. Burrows, *SP406*, pp. 155-157 (Aug. 1975).

Key words: accounting; computer performance evaluation; efficiency; measurement; research and development.

Computer performance evaluation has moved to the forefront of a long list of tools to help the field practitioner. However, as long as R&D is applied only to large installations pushing the margin of feasibility (a noble and rewarding effort) that R&D will not contribute to the majority of data processing installations. Something useful is needed for the more normal installation.

In addition, it is becoming increasingly clear that CPE leads one to discuss and evaluate procedures and goals set for and acting upon the whole "user" community and not just the hardware monitor. More needs to be done in the external environment.

University education in computer measurement and evaluation, J. D. Noe, *SP406*, pp. 159-163 (Aug. 1975).

Key words: computer measurement and evaluation; computer science curriculum; hardware monitors; modeling.

The paper presents the view that computer measurement and evaluation should be taught in universities to stimulate research activity and to establish in the minds of students the importance of the measurement and evaluation viewpoint. It is recommended that measurement and evaluation initially be taught as a separate course, but the ultimate aim should be for the viewpoint to pervade all course work on hardware and software systems, at which time the need for the specific course should vanish. A list of suggested concepts is included.

SP407. **59th National conference on weights and measures 1974,** S. J. Edgerly, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 407, 284 pages (June 1975) SD Catalog No. C13.10:407.

Key words: digital indicators; drained weight; laws and regulations; metrication; metric conversion; net weight; package control; petroleum products; scales; survey; temperature compensation; uniformity; weights and measures.

This is a report of the proceedings (edited) of the Fifty-Ninth National Conference on Weights and Measures, sponsored by the National Bureau of Standards, held in Washington, D.C., July 7-12, 1974, and attended by state, county, and city weights and measures officials, the Federal Government, business, industry, and consumer organizations. *These proceedings include the following papers (indented):*

Advancing measurement assurance in the marketplace, J. H. Lewis, *SP407*, pp. 1-6 (June 1975).

Address, Betsy Ancker-Johnson, *SP407*, pp. 6-11 (June 1975).

Expanding the Nation's measurement system, A. O. McCoubrey, *SP407*, pp. 11-23 (June 1975).

International diplomacy in weights and measures, B. Athané, *SP407*, pp. 26-34 (June 1975).

Observations on our mutual objectives, H. F. Wollin, *SP407*, pp. 35-45 (June 1975).

Weighing the future—A new challenge, J. D. Zelazny, *SP407*, pp. 46-54 (June 1975).

Metric conversion:

Role of the American National Metric Council, M. E. O'Hagan, *SP407*, pp. 54-60 (June 1975).

Consumers call for a rational approach, L. A. Young, *SP407*, pp. 61-66 (June 1975).

Conversion in Australia, J. A. Servin, *SP407*, pp. 67-79 (June 1975).

Metric plans, programs, problems:

The metric conversion of scales as viewed by the scale industry, W. N. Shannon, *SP407*, pp. 87-92 (June 1975).

Petroleum industry, K. E. Bailey, *SP407*, pp. 93-96 (June 1975).

Metric conversion for gasoline dispensing systems, A. C. Evans, *SP407*, pp. 97-107 (June 1975).

The implications of metrication for the packaging industry, W. E. Young, *SP407*, pp. 108-113 (June 1975).

NCWM committee on metric planning, E. H. Stadolnik, *SP407*, pp. 114-117 (June 1975).

Net weight—Policy and procedure:

Progress towards uniform compliance testing, C. S. Brickenkamp, *SP407*, pp. 131-136 (June 1975).

USDA net weight philosophy and procedures, I. Fried, *SP407*, pp. 136-142 (June 1975).

The case for state and local enforcement, H. Cohen, *SP407*, pp. 142-153 (June 1975).

An industry in-plant quality control program, E. E. Wolski, *SP407*, pp. 153-158 (June 1975).

Temperature correction of petroleum products at retail:

Why temperature correction?, G. E. Mattimoe, *SP407*, pp. 166-180 (June 1975).

Temperature correction of petroleum products at retail, H. E. Harris, *SP407*, pp. 181-196 (June 1975).

SP408. **Standard reference materials and meaningful measurements**, R. W. Seward, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 408, 820 pages (Mar. 1975) SD Catalog No. C13.10:408.

Key words: certification; certified reference materials; materials; meaningful measurements; measurement; reference materials; SRM's; standard materials; standard reference materials; standards.

This book presents the proceedings of the 6th Materials Research Symposium on "Standard Reference Materials and Meaningful Measurement" held at the National Bureau of Standards, Gaithersburg, Maryland, on October 29 through November 2, 1973. The symposium was sponsored by the NBS Institute for Materials Research. The purpose of the symposium was to explore ways that Standard Reference Materials (SRM's) could be used more effectively to bring about meaningful measurements both on a national and international scale, to explore the meaning of meaningful measurements, and to review the major paths now used to reach these measurements.

Starting with the relationship of SRM's to a national measurement system, the symposium reviewed SRM activities at the international level, various national programs, and industrial needs. The use of statistics, selection criteria, and steps for certifying SRM's were reviewed. Fifteen panel sessions reviewed the current status of SRM's and outlined future needs. *These proceedings include the following papers (indented):*

Standard reference materials and meaningful measurements—An overview, R. D. Huntoon, *SP408*, pp. 4-56 (Mar. 1975).

Possibilities for international cooperative efforts in standard reference materials, J. P. Cali, *SP408*, pp. 57-67 (Mar. 1975).

Activity by the International Organization for Standardization with respect to standard reference materials, F. L. LaQue, *SP408*, pp. 68-73 (Mar. 1975).

The analytical quality control programme of the International Atomic Energy Agency, O. Suschny and D. M. Richman, *SP408*, pp. 74-102 (Mar. 1975).

The activities of the European economic community in the field of reference materials and methods, K. F. Lauer and H. Laurent, *SP408*, pp. 103-117 (Mar. 1975).

Calibration and test materials for physicochemical measurements, H. Kienitz, *SP408*, pp. 118-126 (Mar. 1975).

Selection criteria of a material as standard reference material and steps for certification, G. Milazzo, *SP408*, pp. 127-145 (Mar. 1975).

Statistics and standard reference materials, J. Mandel, *SP408*, pp. 146-160 (Mar. 1975).

National SRM program in France, G. Denegre and A. Marschal, *SP408*, pp. 161-166 (Mar. 1975).

National RM program in Germany (FRG), R. J. A. Neider, *SP408*, pp. 167-188 (Mar. 1975).

The current status of SRM activities in Japan, T. Tsuchiya, *SP408*, pp. 189-200 (Mar. 1975).

National SRM programs in Poland, T. Plebanski, *SP408*, pp. 201-223 (Mar. 1975).

Reference materials in the United Kingdom, J. D. Cox, *SP408*, pp. 224-236 (Mar. 1975).

The national standard reference materials program in the U.S.A., H. T. Yolken, *SP408*, pp. 237-245 (Mar. 1975).

The SRM story at NBS, R. E. Michaelis, *SP408*, pp. 246-257 (Mar. 1975).

The role of the American National Standards Institute in national and international consensus standards programs, R. P. Trowbridge, *SP408*, pp. 258-266 (Mar. 1975).

ASTM in the U.S. measurement system, W. T. Cavanaugh, *SP408*, pp. 267-274 (Mar. 1975).

Chemical composition control problems and solutions related to metals and alloys, R. S. Cremisio, *SP408*, pp. 275-297 (Mar. 1975).

Measurement problems in physical and mechanical properties of industrial metals and the use of SRM's, J. Convey, *SP408*, pp. 298-319 (Mar. 1975).

High-purity compounds: An overview, A. J. Barnard, Jr., *SP408*, pp. 320-335 (Mar. 1975).

Industrial SRM needs and measurement problems in inorganic materials—chemical properties, V. A. Stenger, *SP408*, pp. 336-354 (Mar. 1975).

Industrial standard reference material (SRM) needs: Organic materials, J. Mitchell, Jr., *SP408*, pp. 355-365 (Mar. 1975).

"Meaningful Measurement" in clinical chemistry, J. H. Boutwell, *SP408*, pp. 366-386 (Mar. 1975).

Standard reference materials and environmental monitoring, E. W. Bretthauer, G. B. Morgan, and R. E. Jaquish, *SP408*, pp. 387-394 (Mar. 1975).

SRM needs and measurement problems in science—chemical properties, T. W. Mears, *SP408*, pp. 395-410 (Mar. 1975).

SP409. **Marine pollution monitoring (petroleum).** Proceedings of a Symposium and Workshop Held at the National Bureau of Standards, Gaithersburg, Md., May 13-17, 1974, R. C. Junghans, Conference Coordinator, Nat. Bur. Stand. (U.S.), Spec. Publ. 409, 293 pages (Dec. 1974) SD Catalog No. C13.10:409.

Key words: analytical methods; data reporting procedures; Intergovernmental Oceanographic Commission (IOC); marine pollution (petroleum) monitoring; Maritime Administration (MarAd); National Bureau of Standards (NBS); National Oceanic and Atmospheric Administration (NOAA); oil slicks and tar balls; petroleum hydrocarbon measurement; sampling methods; World Meterological Organization (WMO).

These proceedings contain the invited plenary lectures representing pertinent scientific, environmental, and regulatory aspects of petroleum hydrocarbon measurements, the summaries of the contributed papers, dealing with specific scientific developments and recommendations, and the recommendations of the topical discussion groups. Also included is a report of an international workshop which provides specific recommendations for the initiation of a coordinated Pilot Project for marine pollution (petroleum) monitoring. *These proceedings include the following papers (indented):*

United Nations environment program Earthwatch and marine pollution, R. M. White, *SP409*, pp. 3-7 (Dec. 1974).

Scientific problems of the systems for global monitoring and investigation of oil pollution in the world ocean, A. I. Simonov, *SP409*, pp. 9-14 (Dec. 1974).

Environmental quality, B. E. Willard, *SP409*, pp. 15-18 (Dec. 1974).

Comments, P. Thatcher, *SP409*, pp. 19-20 (Dec. 1974).

Pilot project on marine pollution monitoring under the framework of IGOSS, A. Tolkachev, *SP409*, pp. 21-26 (Dec. 1974).

Survey analyses for petroleum derived hydrocarbons in the ocean, S. Hori, *SP409*, pp. 27-28 (Dec. 1974).

Analysis standards and intercomparison of data, S. R. Galler, *SP409*, pp. 29-31 (Dec. 1974).

Maritime consideration of oil transportation, H. F. Casey, *SP409*, pp. 33-39 (Dec. 1974).

Marine pollution data archiving and exchange, R. M. Morse, *SP409*, pp. 41-49 (Dec. 1974).

Biological environmental effects, M. E. Stansby, *SP409*, pp. 45-48 (Dec. 1974).

Maritime considerations, J. J. Nachtsheim, *SP409*, pp. 49-56 (Dec. 1974).

Regulatory functions, T. A. Wastler, *SP409*, pp. 57-59 (Dec. 1974).

Regulatory functions as related to vessel construction and operation, S. A. Wallace, *SP409*, pp. 61-65 (Dec. 1974).

Quantitative monitoring and variability of pelagic tar in the North Atlantic, J. N. Butler and B. F. Morris, *SP409*, pp. 75-58 (Dec. 1974).

Tar ball loadings on Golden Beach, Florida, W. A. Saner, *SP409*, pp. 79-81 (Dec. 1974).

Tar ball sampling in the western North Atlantic, W. E. McGowan, W. A. Saner, and G. L. Hufford, *SP409*, pp. 83-84 (Dec. 1974).

Evaluation of thin film oil samplers, W. J. Chang and J. R. Jadamec, *SP409*, pp. 85-88 (Dec. 1974).

Oil spillage monitoring, sampling and recovery systems, J. G. Zahka, *SP409*, pp. 89-90 (Dec. 1974).

Sampling of oil spills and fingerprinting by infrared spectroscopy, C. W. Brown, M. Ahmadjian, and P. Lynch, *SP409*, pp. 91-92 (Dec. 1974).

A new infrared instrument for monitoring oil films on water, D. E. Wright and J. A. Wright, *SP409*, pp. 93-94 (Dec. 1974).

Mapping and identification of oil on water by the use of an airborne laser system, G. K. Schwemmer and H. H. Kim, *SP409*, pp. 95-96 (Dec. 1974).

Movement of spilled oil in San Francisco Bay as predicted by estuarine nontidal drift, T. J. Conomos, *SP409*, pp. 97-100 (Dec. 1974).

Oil pollution along the Indian coastline, S. N. Dwivedi and A. H. Parulekar, *SP409*, pp. 101-105 (Dec. 1974).

Sampling errors in the quantitation of petroleum in Boston Harbor water, A. M. Ahmed, M. D. Beasley, A. C. Efromson, and R. A. Hites, *SP409*, pp. 109-111 (Dec. 1974).

Hydrocarbon concentrations in seawater along the Halifax-Bermuda section: Lessons learned regarding sampling and some results, D. C. Gordon, Jr., and P. D. Keizer, *SP409*, pp. 113-115 (Dec. 1974).

Determination of aromatic hydrocarbons in sea water using an electrolytic stripping cell, S. P. Wasik and R. N. Boyd, *SP409*, pp. 117-118 (Dec. 1974).

Determination of aromatic and total hydrocarbon content in submicrogram and microgram quantities in aqueous systems by means of high performance liquid chromatography, A. Zsolnay, *SP409*, pp. 119-120 (Dec. 1974).

Determination of $C_1 - C_{10}$ hydrocarbons in water, C. D. McAucliffe, *SP409*, pp. 121-125 (Dec. 1974).

Suspensions of crude oils in sea water: Rapid methods of characterizing light hydrocarbon solutes, R. M. Bean, *SP409*, pp. 127-130 (Dec. 1974).

Measurement and characterization of nonvolatile hydrocarbons in ocean water, R. A. Brown, J. J. Elliott, and T. D. Searl, *SP409*, pp. 131-133 (Dec. 1974).

Identification, estimation and monitoring of petroleum in marine waters by luminescence methods, A. W. Hornig, *SP409*, pp. 135-144 (Dec. 1974).

Recent developments in the identification of asphalts and other petroleum products, F. K. Kawahara, *SP409*, pp. 145-148 (Dec. 1974).

Identification of hydrocarbons in an extract from estuarine water accommodated No. 2 fuel oil, R. H. Bieri, A. L. Walker, B. W. Lewis, G. Losser, and R. J. Huggett, *SP409*, pp. 149-153 (Dec. 1974).

The role of standard reference materials in environmental monitoring, H. T. Yolken, *SP409*, pp. 157-160 (Dec. 1974).

Standard and intercomparison criteria: Tar balls and particulate matter, R. W. Traxler and R. H. Pierce, Jr., *SP409*, pp. 161-162 (Dec. 1974).

Analyses of hydrocarbons in marine organisms: Results of IDOE intercalibration exercises, J. W. Farrington, J. M. Teal, J. G. Quinn, P. L. Parker, J. K. Winters, T. L. Wade, and K. Burns, *SP409*, pp. 163-166 (Dec. 1974).

IDOE-5 intercalibration sample: Results of analysis after sixteen months storage, G. C. Medeiros and J. W. Farrington, *SP409*, pp. 167-169 (Dec. 1974).

Use of low molecular-weight-hydrocarbon concentrations as indicators of marine pollution, W. M. Sackett and J. M. Brooks, *SP409*, pp. 171-173 (Dec. 1974).

Fluorescence monitoring study at ocean weather station "P", W. J. Cretney and C. S. Wong, *SP409*, pp. 175-177 (Dec. 1974).

Sampling marine organisms and sediments for high precision gas chromatographic analysis of aromatic hydrocarbons, H. E. Bruce and S. P. Cram, *SP409*, pp. 181-182 (Dec. 1974).

Field sampling methods and techniques for marine organisms and sediments, D. Straughan, *SP409*, pp. 183-187 (Dec. 1974).

Methods for establishing levels of petroleum contamination in organisms and sediment as related to marine pollution monitoring, R. C. Clark, Jr., *SP409*, pp. 189-194 (Dec. 1974).

Quantitative determination of hydrocarbons in marine organisms, J. S. Warner, *SP409*, pp. 195-196 (Dec. 1974).

Methods for trace organic analysis in sediments and marine organisms, H. S. Hertz, S. N. Chesler, W. E. May, B. H. Gump, D. P. Enagonio, and S. P. Cram, *SP409*, pp. 197-199 (Dec. 1974).

Long term weathering characteristics of Iranian crude oil: The wreck of the "Northern Gulf", D. W. Mayo, D. J. Donovan, L. Jiang, R. L. Dow, and J. W. Hurst, Jr., *SP409*, pp. 201-208 (Dec. 1974).

Analytical techniques for isolating and quantifying petroleum paraffin hydrocarbons in marine organisms, R. C. Clark, Jr., and J. S. Finley, *SP409*, pp. 209-212 (Dec. 1974).

Determination of hydrocarbons in marine organisms and sediments by thin layer chromatography, L. Hunter, H. E. Guard, and L. H. DiSalvo, *SP409*, pp. 213-216 (Dec. 1974).

Determination of extractable organic material and analysis of hydrocarbon types in lake and coastal sediments, J. W. Blaylock, R. M. Bean, and R. E. Wildung, *SP409*, pp. 217-219 (Dec. 1974).

Hydrocarbons in blue mussels from the Kiel Bight, M. Ehrhardt and J. Heinemann, *SP409*, pp. 221-225 (Dec. 1974).

Identification of mineral oils by field ionization mass spectrometry, M. Anbar, M. E. Scolnick, and A. C. Scott, *SP409*, pp. 229-232 (Dec. 1974).

Pelagic tar in the Gulf of Mexico and Caribbean Sea, L. M. Jeffrey, W. E. Pequegnat, E. A. Kennedy, A. Vos, and B. M. James, *SP409*, pp. 233-235 (Dec. 1974).

Marine environmental monitoring: Trace elements in persistent tar ball oil residues, M. H. Feldman and D. E. Cawlfield, *SP409*, pp. 237-241 (Dec. 1974).

Distribution of tar balls and Neuston sampling in the Gulf Stream system, K. Sherman, J. B. Colton, R. L. Dryfoos, K. D. Knapp, and B. S. Kinnear, *SP409*, pp. 243-244 (Dec. 1974).

Estimation of the modern oil pollution of the North Atlantic Waters, A. I. Simonov, S. G. Oradovski, and A. A. Justchak, *SP409*, p. 245 (Dec. 1974).

Value of oil pollution monitoring in marine organisms, G. La Roche, *SP409*, pp. 249-250 (Dec. 1974).

Effects of oils on Baltic Littoral Community, as studied in an outdoor model test system, M. Notini and Å. Hagström, *SP409*, pp. 251-254 (Dec. 1974).

Hydrocarbon content and chlorophyll correlation in the waters between Nova Scotia and the Gulf Stream, A. Zsolnay, *SP409*, pp. 255-256 (Dec. 1974).

Effect of an oil spill on benthic animals in the lower York River, Virginia, M. E. Bender, J. L. Hyland, and T. K. Duncan, *SP409*, pp. 257-259 (Dec. 1974).

Marine pollution by carcinogenic hydrocarbons, J. B. Sullivan, *SP409*, pp. 261-263 (Dec. 1974).

SP-410, Superseded by Special Publication 410 1977 Edition.

SP411. **Fire safety research.** Proceedings of a Symposium held at the National Bureau of Standards, Gaithersburg, Md., August 22, 1973, M. J. Butler and J. A. Slater, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 411, 251 pages (Nov. 1974).

Key words: children; flammable fabrics; sleepwear; standards development; statistics.

The general methodology used in the development of a mandatory flammability Standard is presented. An illustrative summary is given of the hazard analysis of the accident data and the subsequent test development and laboratory investigations conducted in the development of the children's sleepwear flammability standards (DOC FF-3-71 and DOC PFF 5-73). Some of the problems encountered in the development of a mandatory standard and the resolution of those problems are discussed.

A comparison between potential hazard reduction from fabric flammability standards, ignition source improvement and public education, B. Buchbinder and A. Vickers, *SP411*, pp. 1-4 (Nov. 1974).

Key words: cigarettes; education; fabric; fire; flammability; hazard; ignition source; kitchen ranges; matches; mattresses; sleepwear; standards; upholstered furniture.

Mandatory standards have been and are being promulgated for flammable fabric item types (e.g., children's sleepwear, mattresses, upholstered furniture) to reduce the fire hazard inherent in the use of common ignition sources (e.g. matches, cigarettes, kitchen ranges). Trade-offs should be made between potential hazard reduction from fabric item standards and from design changes or improved quality control in ignition source fabrication. Public education is a third approach to the reduction of certain hazards.

Development of the standards for the flammability of children's sleepwear, E. Braun, J. H. Winger, and J. A. Slater, *SP411*, pp. 5-16 (Nov. 1974).

Key words: children; flammable fabrics; sleepwear; standards development; statistics.

The general methodology used in the development of a mandatory flammability Standard is presented. An illustrative summary is given of the hazard analysis of the accident data and the subsequent test development and laboratory investigations conducted in the development of the children's sleepwear flammability standards (DOC FF-3-71 and DOC PFF-5-73). Some of the problems encountered in the development of a mandatory standard and the resolution of those problems are discussed.

Sampling plans in mandatory standards, P. Gottfried, *SP411*, pp. 16-19 (Nov. 1974).

Key words: flammable fabrics; product safety; sampling; standards.

The Children's Sleepwear Standard for sizes 0-6X provides an example of the necessary interplay between sampling theory, industry capabilities and consumer safety assurance. The sampling plan imposes requirements for the fabric, for garment design and for garment production. These requirements address the differences between hazards due to design and those due to production error. The requirements also interact to provide improved assurance of safety by limiting the potential for severe injury.

Human activity patterns and injury severity in fire incidents involving apparel, L. B. Buchbinder, *SP411*, pp. 20-29 (Nov. 1974).

Measurement tools, C. D. Warner, *SP406*, pp. 99-102 (Aug. 1975).

Key words: computer; evaluation; hardware monitors; measurement; performance; software monitors; throughput.

First generation computers were designed to operate in a serial fashion—performing one operation at a time (e.g., input, output, process). Performance evaluation was simply a matter of determining, with a watch or calendar, the time from the start of a job to the end. After several generations of computers, we now have systems with an enormous degree of complexity and parallelism.

In an effort to keep pace in the performance evaluation area, several computer manufacturers, as well as companies not directly involved in the manufacture of computers, have built a number of performance measurement tools. These tools cover the whole spectrum, from a simple device using electromechanical counters, to a system larger than most computers it would measure.

Future measurement systems will involve both hardware and software. Special software sometimes will communicate with the hardware monitor over a special I/O interface. These new measurement systems will then not only provide information about system performance, but will provide much more accurate job accounting information than is currently available, as well as doing a better job of scheduling.

State of the art: Experiment design and data analysis, H. D. Schwetman, *SP406*, pp. 103-108 (Aug. 1975).

Key words: computer system performance evaluation; experimental assessment of system behavior; performance data analysis; performance data presentation; performance monitoring.

Experimental observations form an important part of computer system performance evaluation. It is through experimentation that models are validated, simulations parameterized and systems tuned. This paper surveys several approaches to designing experiments to aid in the assessment of systems behavior. Data gathering tools and techniques are discussed, as are the important topics of data presentation and data analysis. The paper concludes with a critical examination of the state of the art of experimentation. The key problems are found to include: (1) a lack of generally applicable guidelines, (2) a missing link between low-level data and high-level questions, and (3) a lack of means for dealing with variations in behavior attributable to variations in the workload.

Computer performance variability, T. E. Bell, *SP406*, pp. 109-112 (Aug. 1975).

Key words: computer performance analysis; measurement; performance monitoring; performance variability.

The performance of a computer varies significantly, even when it is subjected to the same load. Analysts who are performing between-machine comparisons, predicting performance, or merely trying to understand performance can be led to incorrect decisions if random variability is interpreted as representing real differences. Tightly controlled tests employing a flexible synthetic job indicated that elapsed time, processor time, and response time vary enough to deceive analysts. Several trends seem to indicate that variability will increase with time, so the effect will increase in importance. Both computer manufacturers and performance analysts should take specific actions to preclude problems due to computer performance variability.

Domains for performance measurement, S. Jeffery, *SP406*, pp. 113-117 (Aug. 1975).

Key words: accounting systems; hardware monitors; performance evaluation; performance measurement; software monitors.

In lieu of an integrated approach to performance, it may be helpful to propose a structure for consideration of the entities of Performance Measurement: systems, applications, and measurement techniques. It is proposed that these entities can be compartmentalized into "domains," for the categorization of performance measurement. It is likely that definite domains will be uncovered indicating the use of performance measurement, or more important and less widely recognized, where it is not cost-effective to perform system measurement.

The tools for measuring performance—hardware monitors, software monitors, and accounting systems—are discussed in terms of system level or application level management programs.

Several tasks are suggested that need to be addressed: (1) the gathering of currently available information on the use of accounting systems, and the development and publication of guidelines for the employment of accounting data; (2) the development and postulation of a set of Computer Performance Evaluation domains; (3) a Performance Measurement Handbook comprising guidelines for utilization of computer performance evaluation over all domains.

Queueing theoretic models, P. J. Denning and R. R. Muntz, *SP406*, pp. 119-121 (Aug. 1975).

Key words: analytical models; evaluation; measurement; networks; performance; queues.

Tradeoffs between methods of solving analytical queueing models are discussed. It is suggested that representing the multiple (simply defined) resources of a computer system and the sequencing of tasks among these resources gives models which are simple enough to yield to analysis and yet are applicable to systems of interest. Theoretical results from the study of such networks are summarized and directions of future research are briefly discussed.

An analytic framework for computer system sizing and tuning, S. R. Kimbleton, *SP406*, pp. 123-126 (Aug. 1975).

Key words: analytical; computer systems modeling; end users; performance.

Performance analysis, as practiced by end users, appears to be dominated by the trial and error approach. Computer systems modeling techniques have received relatively little usage by such users except for the sporadic application of commercially available computer system simulators. Vendors, by contrast (cf. the various ACM and IEEE publications) have been extensive users of both analytical and simulation based techniques for performance analysis. This paper discusses some of the reasons underlying the lack of extensive usage of such techniques by end users, identifies an area of performance analysis appropriate to the usage of modeling techniques and discusses an approach to its investigation through their usage.

Relating time and probability in computer graphs, R. R. Johnson, *SP406*, pp. 127-130 (Aug. 1975).

Key words: evaluation; graphs; measurement; networks; performance; Petri Nets; probability.

Program behavior is discussed in terms of Petri Nets. Using probabilistic information, an experimental method is given to determine the time spent in each state. To illustrate the method, two examples are given for program graphs.

Key words: accident patterns; apparel; apparel fires; burn injury; FFACTS; fire; flammable fabrics; flammable liquids; garment fires; garment parameters; injury severity; victim's activity; victim's reactions.

Activities immediately preceding an apparel fire are identified, classified and related to the age/sex groups involved. The level of severity of burn injuries resulting from apparel fire accidents is discussed and is related to the type of activity causing the accident. The relationships defined in the study indicate the importance of the human behavioral aspects of a fire accident and aid in defining types of remedial action likely to be effective in reducing human loss due to fabric fires.

Chemical aspects of flame inhibition, J. W. Hastie, *SP411*, pp. 30-36 (Nov. 1974).

Key words: fire retardants; flames; inhibition.

The role played by inorganic chemical additives in fire retardancy and flame inhibition is considered. Particular attention is given to the molecular level aspects of commercially important systems containing compounds of antimony and halogens.

Mechanism of flame retardant action in textiles, R. H. Barker, *SP411*, pp. 37-49 (Nov. 1974).

Key words: calorimetry; cellulose; flames; flammable gases; nylon; oxidation reactions; oxygen index; phosphorus; polyester; polymer substrates; pyrolysis-gas chromatography; textiles; thermal analysis.

Flame retardants may exert their effect on textile materials by either modifying the pyrolysis reactions of the polymer substrates so that smaller quantities of flammable gases are produced or by interfering with the oxidation reactions in the flame. The modes of action for several common types of retardants on cellulose, nylon, and polyester have been determined by use of thermal analysis, pyrolysis-gas chromatography, oxygen index, and calorimetric techniques.

Additional studies of the transfer of flame retardant effects with cellulosic fabrics, B. Miller, *SP411*, pp. 50-58 (Nov. 1974).

Key words: cellulosics; cotton; DAP; fabric flammability; flame retardants; flammability; rayon; thermogravimetric analysis.

Burning rate measurements on double layers of the same fabric when one layer has been treated with a flame retardant have indicated that certain effects of the retardant can be transferred to the untreated layer. To learn more about the mode and chemistry of this phenomenon, a study of nonflaming combustion of cellulosics has been carried out on mixed systems using thermogravimetric analysis. By arranging to have untreated cotton physically separated from the flame retardant material during heating it was possible to determine that the transfer depends on a chemical process and is most likely the effect of a volatile product generated during heating. Data are presented also showing that rayon containing an alkoxy-phosphazene flame retardant does not transfer its flammability properties to untreated rayon.

An evaluation of flame spread test methods for floor covering materials, J. Quintiere and C. Huggett, *SP411*, pp. 59-89 (Nov. 1974).

Key words: corridor fires; fire test methods; flame spread; flammability tests; floor covering flammability; floor coverings.

Flammability properties of materials have traditionally been measured by small scale laboratory tests. The relationships between test results and performance in real fires have been largely inferred by intuition or subjective judgement. Flame spread test methods for floor covering materials are examined. Through full-scale fire experiments and laboratory studies the nature of the potential flame spread hazard of flooring materials is presented. The factors promoting flame spread in each test method are identified. Test method results are compared with relevant full-scale fire experiments involving floor covering materials in a corridor. An effort is made to relate test results, where possible, to the potential flame spread hazard of floor covering materials in building corridors and exitways.

Mathematical modeling of radiant panel test methods, J. A. Rockett, *SP411*, pp. 90-96 (Nov. 1974).

Key words: fire modeling; fire test methods; flame spread test method.

Standard flame spread tests characterize complex physical phenomena by a relatively simple experiment. Analytic modeling of the standard test identifies the sample geometry and material properties controlling the test outcome. Systematic variation of the model parameters verifies the analytic model for many broad classes of test samples provided parameter values appropriate to each test are determined by independent measurements. In most cases the standard test is not a satisfactory way to quantify the important sample parameters. The standard test is a suitable way to verify the applicability of a particular model or set of analytic models for a particular sample. If sample parameters are independently determined, the applicable models may then be used for hazard determination.

Flame spread over a porous surface under an external radiation field, T. Kashiwagi, *SP411*, pp. 97-104 (Nov. 1974).

Key words: carpet flammability; flame spread; ignition.

Flame spread over carpet surfaces was studied under various constant external radiant fluxes from 0.4 to 1.1 W/cm². Characteristics of ignition and flame spread including speed of spread and net heat release rate were measured. The results indicate that these values increase rapidly with increasing external radiant flux. It was also observed that there exists a minimum radiant flux necessary to sustain steady flame spread for each carpet. The underlayment of a carpet has a significant effect on ignition and flame spread speed for nylon carpets due to melting of fibers before flameover. However, this effect is negligible for low pile density acrylic carpets.

Physiological and toxicological effects of the products of thermal decomposition from polymeric materials, M. M. Birky, *SP411*, pp. 105-124 (Nov. 1974).

Key words: combustion; polymer; pyrolysis; smoke; specific optical density; toxic gases; toxicity.

A program that combines the capabilities of the College of Medicine and the College of Engineering of The University of Utah has been instituted to evaluate the physiological and toxicological effects of the products of thermal degradation and combustion of cellulose, a polyvinyl chloride, a flexible polyurethane, and wood (Douglas fir). The products produced from these materials are being identified and quantified with a gas chromatograph-mass spectrometer-computer system. In addition, a National Bureau of Standards smoke chamber has been modified with a weight loss transducer to correlate, on a continuous basis, the quantities of smoke produced with sample weight loss. Extensive studies on the effects of these degradation products on rats is in

progress. The results of exposure of the rats to carbon monoxide are reported. All of the laboratory results are being correlated with full-scale fire studies at the National Bureau of Standards.

Contribution of interior finish materials to fire growth in a room, J. B. Fang and D. Gross, *SP411*, 125-138 (Nov. 1974).

Key words: buildings; fire intensity; flame spread; flames; furnishings; heat release; interior linings; material ignitability; room fires; smoke; upholstery; waste receptacle; wood crib.

Characterization of the fire environment from the burning of the combustible contents of wastebaskets, upholstered furniture and interior finish materials is important for developing rational tests and establishing design criteria for reduction of fire hazard in buildings. Some experimental results on the burning characteristics of an upholstered chair, contents of waste receptacles and wood crib arrays in a well-ventilated room are presented. A procedure has been developed for evaluating the contribution to fire growth of wall and ceiling panels in a full-scale room corner with a standardized wood crib duplicating the conditions produced by an incidental fire. Results of full-scale and laboratory tests with selected interior finish materials on ease of ignition, surface flammability, flame penetration and smoke and heat generation measurements are presented and compared.

Fire build-up in reduced size enclosures, W. J. Parker and B. T. Lee, *SP411*, pp. 139-153 (Nov. 1974).

Key words: fire tests; flashover; heat release rate; scale models; thermal radiation.

A $30 \times 30 \times 32$ inch enclosure was constructed to study the fire build-up process in a room. Conductive and radiative heat flux, temperature, air velocity, fuel supply rate, and oxygen concentration were measured. In order to relate the phenomena observed in the small enclosure to that in a full size room, the possibility of small-scale modeling with combustible walls was examined. This was done on a preliminary basis by comparing the results of some corner fire tests conducted both in the model and in a full size room. A preliminary examination was also made of the effect of the fuel flow rate and the location of the burner on the temperature and oxygen profiles in the enclosure. Since the ceiling temperature closely follows the upper air temperature the latter is a suitable measure of the degree of fire build-up in the room. Any analysis of the fire build-up process must account for this temperature.

An analytic model for calculating the fire resistance of simply supported prestressed and reinforced concrete beams, L. A. Issen, *SP411*, pp. 154-164 (Nov. 1964).

Key words: analytic methods; concrete; creep; elevated temperature; finite differences; finite elements; fire endurance; fire tests; isotherms; prestressed concrete; reinforced concrete; steel.

At present the fire resistance of concrete beams is determined either by running a fire test or by interpolation from existing fire test data. The second method can only be used if the data are for beams that are closely similar to the object beam. Other ad hoc empirical methods are equally limited. To overcome these difficulties an analytic model was developed for the rational analysis of prestressed and reinforced concrete beams. This model will be checked against available test data. A computer program based on the analytic model is being tested and will be used for developing graphical tools (graphs, nomograms, tables) for estimating the fire endurance of simply supported prestressed and reinforced concrete beams.

Smoke and carbon monoxide generation from burning selected plastics and red oak, T. Y. King, *SP411*, pp. 165-177 (Nov. 1974).

Key words: carbon monoxide; electrostatic precipitation; particulate mass; scanning electron microscope; smoke.

This paper presents preliminary results of simultaneous smoke and carbon monoxide measurements from burning selected plastics and red oak in the smoke density chamber. An attempt was made to correlate smoke optical density with mass concentration of smoke. Particulate shape and approximate size range of the smokes were obtained using a scanning electron microscope.

A field study of non fire-resistive multiple dwelling fires, F. L. Brannigan, *SP411*, pp. 178-194 (Nov. 1974).

Key words: apartments; building codes; fire; fire walls; garden apartments; gypsum board; insurance; livability; multiple dwellings.

A field study was made of structural and building design factors contributing to the spread of fire in more than 40 non fire-resistive, multiple occupancy dwellings, typically "Garden Apartments." Most deficiencies could be corrected by preserving the integrity of a gypsum board sheath serving as a fire barrier. Examples are given of penetrations and openings in fire barriers which permitted substantial fire spread.

The current status of fire detection, G. Sinnott, *SP411*, pp. 195-200 (Nov. 1974).

Key words: alarm communications; false alarms; fire alarms; fire detectors; risk benefit; smoke detectors; standards.

The status of residential fire detection systems is presented in terms of the major problems encountered in their use. This includes a discussion of risk benefit considerations, false alarms, and the effectiveness of alarms. The impact of these considerations on acceptance standards for residential fire detection systems is pointed out.

Sequencing the purchase and retirement of fire engines, P. B. Saunders and R. Ku, *SP411*, pp. 201-214 (Nov. 1974).

Key words: dynamic programming; equipment replacement; fire engines.

A mathematical model and solution method are presented for the problem of determining an "optimum" manner of sequencing the purchase and retirement of fire engines. The method calculates that stream of "buy and retire" decisions which, subject to certain natural constraints (such as limits on annual acquisitions), minimizes the operating cost of the fleet of engines over a prescribed planning period. Implemented as an efficient computer program, the model has been applied to illustrative data from the Washington, D.C. Fire Department. The approach carries over to problems dealing with the replacement of other types of items (e.g., ambulances, small fleets of aircraft, typewriters) whose reliability-maintenance becomes increasingly expensive with age.

FIFI—Fire information field investigation, F. J. Kauffman and M. E. Grimes, *SP411*, pp. 215-229 (Nov. 1974).

Key words: field investigation; fire information; fire investigations; fire training; programmed instruction.

The Research Phase of FIFI defined and evaluated those state-of-the-art investigation techniques used at the scene of fires to report on the cause and circumstances of those fires. The two most significant conclusions reached during the research phase were (a) that very little literature is available to an officer interested in studying methods of general fire

cause determination, since most existing literature is arson oriented, and (b) that standardized training programs in systematic investigative practices do not exist. The Development Phase of the project isolated the most valid of the investigative techniques evaluated in the research phase, and synthesized them into a new, simplified, logical, process-of-elimination investigation sequence known as HEP (Hexagonal Elimination Process) based on the NFPA Standard 901, *Coding System for Fire Reporting*. Two prototype training packages were developed; designed to aid firefighters in carrying out the systematic HEP investigation sequence in their initial, on-scene, routine fire investigations. The prototype training packages were field tested in six fire departments of varying sizes and types.

National Science Foundation RANN Program, R. H. Long, Jr., *SP411*, pp. 230-238 (Nov. 1974).

Key words: fire programs; fire research; National Science Foundation; RANN; research grants.

The fire research effort at NSF is part of the Research Applied to National Needs (RANN) Program of NSF, which provides funds for problem-oriented research on selected problems of national importance. The current effort is funded at $2 million and about 20 projects are under way. An outline of the thrust of the total program will be given. Also, several projects which are closely related to interests of the National Bureau of Standards will be indicated. Related activities within NSF will be mentioned.

SP412. **Aerosol measurements.** The Proceedings of a Seminar on Aerosol Measurements, May 7, 1974, W. A. Cassatt and R. S. Maddock, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 412, 193 pages (Oct. 1974) SD Catalog No. C13.10:412.

Key words: aerosol instrument performance; aerosol measuring instruments; beta-ray absorption; Doppler shift; electromobility; laser light scattering; optical imaging; piezoelectric effect.

Papers followed by discussions were given in a closed seminar and workshop sponsored by the National Bureau of Standards and the Food and Drug Administration to define the state of development of aerosol measuring instruments. The instruments discussed were based upon a variety of operating principles including laser light scattering, optical imaging, Doppler shift, electromobility, piezoelectric effect, and beta-ray absorption. Two review papers were given which described other phenomena upon which aerosol measurements are based. The general summary includes a table which lists the specifications of the instruments discussed to illustrate the range of capabilities available in this field. Discussion among seminar attendees revealed that many questions remain to be answered before the more difficult aerosol measurements problems can be solved. For example, in the analysis of very dense aerosols questions arise concerning coincidence losses or agglomeration effects that may result from collisions between particles as they are drawn into the measuring volume. Volatilization or condensation effects may alter the size distribution if the measurements are made late in time. Finally, variations in particle shape or index of refraction can alter the instrument response and cause difficulties in interpretation. *These proceedings include the following papers (indented):*

A review of the methods for the particle size analysis of aerosol spray can droplets, R. Davies and J. D. Stockham, *SP412*, pp. 1-12 (Oct. 1974).

Key words: aerosol instrumentation; aerosol measurements; aerosol review; aerosols; aerosol scattering; aerosol sizing; droplet imaging; droplet sizing; electrical mobility; impaction; momentum methods; particle imaging; particle measurements; particle scattering; particle size determinations; particulates; sprays.

This paper reviews the methods that have been used for sizing droplets, sprays, and mists, but places particular emphasis on the methods that are applicable to the sizing of aerosol spray can droplets.

The methods reviewed include photographic imaging, collection, deposition and size reconstruction, momentum transfer, pulse counting, hot wire anemometry, electrical mobility, optical scattering, and interference.

From the various techniques discussed in each class, laser holographic imaging is considered the best approach, but the method has an extremely high capital cost. Light scattering methods are the second choice, but these, too, have a relatively high capital cost. If capital cost is an important factor, then methods such as photographic imaging and impaction can be usefully employed.

Light scattering by single aerosol particles, M. Kerker, *SP412*, pp. 13-20 (Oct. 1974).

Key words: aerosol fibers; light scattering; particle size measurements; particulates; refractive index.

Although angular light scattering is a sensitive measure of particle size, sensitivity is rapidly lost when a mixture of particulates covers a range of particle sizes. However, instrumentation for studying scattering by single particles can overcome this limitation. This will be illustrated with reference to scattering by single fibers and spheres.

Light scattering methods for the characterization of particulate matter in real time, C. C. Gravatt, *SP412*, pp. 21-32 (Oct. 1974).

Key words: aerosol sizing; aerosol spectrometer; chemical characterization of particles; fire produced particles; laser light scattering by aerosols; particle size measurements; particulates; refractive index; smoke detector.

This paper presents a brief overview of new light scattering methods for the rapid characterization of particulate matter in air. An instrument has been developed which determines the size distribution of particulate matter in air in essentially real time by a forward lobe light scattering method. The basic concept involves the simultaneous measurement of the intensity of light scattered by a single particle at two small scattering angles. The ratio of the two intensities is a direct measure of the size and is fairly independent of the index of refraction of the particle. Numerical solutions of the Mie equations for spheres have indicated that the sizing error by this method is not greater than ± 15 percent for the range of particle sizes from 0.2 to 4 μm for essentially all possible indices of refraction. In addition, it appears feasible to extend the lower limit of size determination to 0.05 μm by the measurement of a single forward lobe intensity. Also, a technique has been developed which permits some degree of chemical characterization of particles, and which has been employed in a smoke detector capable of distinguishing between fire-produced and nonfire-produced aerosols.

Flow apparatus for the characterization of aerosols, M. B. Ranade, *SP412*, pp. 33-40 (Oct. 1974).

Key words: aerosol size measurements; aerosol spectrometer; aerosol sprays; condensation on aerosol droplets; evaporation of aerosol droplets; laser light scattering by aerosols; therapeutic aerosols.

A flow apparatus has been developed to enable the size measurement of liquid aerosols to be measured under defined conditions with the help of a light scattering technique. This apparatus was used to study the evaporative behavior of submicron aqueous aerosols during transportation in air. The apparatus is currently being used to characterize large (~ 50 μm) aerosol particles under sedimentation. Portable versions of the flow apparatus are presently

under development to characterize acid mist droplets, and to investigate the characteristics of therapeutic aerosols.

360° scattering diagrams from individual aerosols in a flowing stream, T. R. Marshall, C. S. Parmenter, and M. Seaver, *SP412*, pp. 41-56 (Oct. 1974).

Key words: aerosol light scattering; aerosol size measurements; aerosol spectrometer; aerosol sprays; laser light scattering by aerosols; refractive index; scattering diagrams; 360° scattering by particles.

Nearly complete 360° scattering diagrams have been obtained from each of a large number of individual aerosols which stream in an air sheath through a laser beam. A computer analysis of diagrams from a "monodisperse" aerosol (polystyrene spheres with mean diameter near 1.2 μm) shows that *both* diameter and refractive index can be determined from each scattering diagram to compile a statistical characterization of the aerosol. Diameter precision is about 0.4 percent and the refractive index can be determined to within 0.7 percent.

The method is clearly a practical approach to routine characterization of aerosol sprays containing spherical particles whose diameters range from about 0.3 μm to at least 20 μm. The refractive index determination will reveal differences between particle composition and bulk composition of the parent material as well as composition changes during aging of aerosol sprays.

Active scattering aerosol spectrometry, R. G. Knollenberg, *SP412*, pp. 57-64 (Oct. 1974).

Key words: aerosol light scattering; aerosol sizing; aerosol spectrometer; cloud droplet measurements; interferometer; laser imaging of particles; laser light scattering by aerosols; particle size measurements.

An active scattering aerosol spectrometer is one that uses the active open cavity of a laser as the source of particle illumination. The interferometric aspects of the oscillating radiation illuminating the particles produces both forward and backward scattered radiation at all collecting angles. This, coupled with the fact that the collecting optics solid angle can be considerably greater than one steradian, and an extremely intense source, results in a system with an extremely high sensitivity, fully capable of sizing particles several hundred Angstroms diameter using solid state silicon detectors.

Rapid measurement of droplet size distributions by optical heterodyne spectroscopy, I. Chabay, *SP412*, pp. 65-72 (Oct. 1974).

Key words: aerosol cloud chamber; aerosol light scattering; aerosol size measurements; aerosol spectrometer; cloud droplet measurements; Doppler measurements of particle size; laser heterodyne; laser scattering by aerosol particles; particle sizing.

A new technique which allows rapid, direct determination of particle size distributions by measurement of the Doppler shift of laser light scattered by falling particles will be discussed. The technique has been successfully applied to the measurement of parameters associated with cloud droplet growth (from 1 to 10 micrometer radius) in a diffusion cloud chamber. Applications to other types of particles in the size range 0.5-50 micrometers radius will be pointed out.

Measurements of aerosol size distributions with a laser Doppler velocimeter (LDV), W. J. Yanta, *SP412*, pp. 73-88 (Oct. 1974).

Key words: aerosol sizing; aerosol spectrometer; aerosol sprays; Doppler measurements of particle size; droplet sizing; interferometer; laser light scattering by aerosols; particle size measurements; particle velocity measurements.

A miniature wind tunnel has been built which together with the Laser Doppler Velocimeter (LDV) has been used to determine aerosol size distributions. In principle the LDV was used to measure the particle lag of individual aerosol particles as they were accelerated through a small supersonic nozzle. The measured velocity lag was then used in conjunction with numerical predictions to determine the particle size. An optical owl was used to determine the mean of the size distributions. The LDV measurements were in good agreement with the owl measurements.

An optical transform technique for measuring the size distribution of particles in fluids, A. McSweeney, *SP412*, pp. 89-96 (Oct. 1974).

Key words: aerosol light scattering; aerosol sizing; aerosol spectrometer; laser light scattering by aerosols; optical transform; particle size measurements.

Real-time inversion of the data obtained from the total diffraction pattern due to particles in a relatively large volume yields a measure of the size distribution of the particles. A significant advantage of this technique is that the sample volume may be large, removing the requirement for piping the sample through small tubes. This technique may be applied to particles in gases, in liquids, or on microscope slides.

Sizing aerosols in real time by pulsing UV laser machine, G. A. Hotham, *SP412*, pp. 97-126 (Oct. 1974).

Key words: aerosol impact studies; aerosol sizing; aerosol spectrometer; aerosol sprays; laser holography; laser imaging of particles.

A new laser machine will be described which utilizes a pulsing UV laser to produce "instantaneous" images of aerosol droplets on a TV screen in real time. With this instrument it is possible to measure from 0.3 to 1000 micrometers.

Rapid respirable mass measurement, L. Doemeny, G. Carson, and B. Almich, *SP412*, pp. 127-136 (Oct. 1974).

Key words: aerosol size measurements; beta absorption; cascade impactor; coal dust monitor; dust inhalation hazards; environmental sampler; respirable dust sampler.

The respirable mass concept of dust sampling will be used to introduce the GCA Corporation, beta absorption particulate aerosol sampler. NIOSH has extensively evaluated the GCA instrument as a coal dust monitor and is beginning to apply it to the sampling of other aerosols. The evaluation included mass loading, accuracy and environmental simulations. Other sampling methods which look promising will be discussed.

Particulate mass measurement by piezoelectric crystal, R. L. Chuan, *SP412*, pp. 137-148 (Oct. 1974).

Key words: aerosol sizing; cascade impactor; particle detection by impaction; particle size measurements; piezoelectric crystal; quartz crystal microscope.

An adhesive-coated quartz crystal working as the impaction surface capturing particulates from decelerating jets measures mass by frequency change, to a sensitivity of 10^9 Hz gm^{-1}. The scheme is applied to a number of working instruments which measure continuously and directly particulate mass concentration, and particulate mass distribution (by using the devices in a cascade).

Development, calibration and application of size distribution instruments at the University of Minnesota, V. A. Marple, *SP412*, pp. 149-173 (Oct. 1974).

Key words: aerosol electrical analyzer; aerosol generators; aerosol instrument calibration; aerosol size measurements; aerosol spectrometer; aerosol sprays; nuclei counters; particle generators; particle size measurements; particle size measurements by electromobility; particle standards.

Work with size distribution instruments has been in the areas of development, calibration, and application. Instruments have been developed in the area of particle size determination, such as the electrical aerosol analyzer, and in the area of monodisperse particle generation, such as the vibrating orifice generator and the differential mobility analyzer. These aerosol generators, along with new techniques, have been used to calibrate a variety of aerosol measuring instruments such as optical particle counters, nuclei counters, and the electrical aerosol analyzer. These instruments have then been used to study a range of particle types, from fairly ideal particles such as atmospheric aerosols to very nonideal particles such as coal dust.

SP413, 1976 Edition. **Special technical facilities at the National Bureau of Standards,** H. L. Mason and I. M. Lloyd, Eds., (Supersedes NBS Special Publication 413, 1975 Edition), *Nat. Bur. Stand. (U.S.), Spec. Publ. 413, 1976 Edition,* 50 pages (Mar. 1976) SD Catalog No. C13.10:413/1976 Ed..

Key words: accelerators; acoustic facilities; calorimeters; electrical measurements facilities; high pressure facilities; high temperature facilities; spectroscopy facilities.

Among the major technical facilities of the NBS laboratories in Gaithersburg, Md., and Boulder, Colo., are some which are unique and many which feature equipment that is relatively uncommon. These important resources deserve to be more widely known and used by the scientific and engineering community, including the Bureau's own staff, other Government agencies, industrial research associates, academic researchers, and postdoctoral fellows. Those facilities which are available for shared use, either occasional or extended, are briefly described in the pages of this publication.

SP414. **Laser induced damage in optical materials: 1974.** Proceedings of a Symposium Sponsored by Office of Naval Research, The American Society for Testing and Materials, and by the National Bureau of Standards, May 22-23, 1974, NBS, Boulder, Colo., 80302, A. J. Glass and A. H. Guenther, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 414, 256 pages (Dec. 1974) SD Catalog No. C13.10:414.

Key words: IR windows and mirrors; laser damage; laser materials; self-focusing; thin films.

The Sixth ASTM-ONR-NBS Symposium on Laser Induced Damage in Optical Materials was held at the National Bureau of Standards in Boulder, Colo., on May 22-23, of this year. These Symposia are held as part of the activities in Subcommittee II on Lasers and Laser Materials, of the ASTM. Subcommittee II is charged with the responsibilities of formulating standards and test procedures for laser materials, components, and devices. The Chairman of Subcommittee II is Haynes Lee, of Owens-Illinois, Inc. Co-chairmen for the Damage Symposia are Dr. Arthur Guenther, Chief Scientist of the Air Force Weapons Laboratory, and Dr. Alexander J. Glass, Head, Theoretical Studies, Y Division, Lawrence Livermore Laboratory.

Over 150 attendees at the Symposium heard 31 papers on topics relating to laser induced damage in crystalline and non-linear optical materials, at dielectric surfaces, and in thin film coatings as well as discussions of damage problems in the infrared region due both to cw and pulsed irradiation. In addition, several reports on the theoretical analysis of laser-materials interaction relative to the damage process were given, along with tabulations of fundamental materials properties of importance in evaluation of optical material response to high power laser radiation. Attention was given to high power laser system design considerations which relate to improved system performance and reliability when various damage mechanisms are operable in such systems.

Because of the growing importance and acceptance of machined components in high power laser systems, a workshop on the machining of optics was held, under the coordination of Captain T. T. Saito of the Air Force Weapons Laboratory. Nine papers on various facets of the topic were presented dealing with machining procedures, surface characterization of machined elements, coating of machined components, and the polishing and damage resistance of polished, coated, and bare metal reflectors. Abstracts on these papers are included in the Symposium Proceedings proper.

The proceedings of these Symposia represent the major sources of information in the field of laser induced damage in optical materials. The Symposia themselves, along with the periodic meetings of Subcommittee II, provide a unique forum for the exchange of information regarding laser materials specifications among the manufacturers and users of laser devices, components, and systems. The Symposia also serve as a mechanism of information gathering to enable the Subcommittee to write informed and realistic specifications. *These proceedings include the following papers (indented):*

Laser beam divergence and damage in glass amplifiers, K. A. Brueckner, B. Guscott, S. Jorna, K. Moncur, and L. Siebert, *SP414,* pp. 2-6 (Dec. 1974).

Key words: apodizers; glass lasers; self-focusing.

The power limit in glass amplifiers is determined by the onset of nonacceptable beam distortion of self-focusing leading to glass damage, which results from the power-dependent index in the glass. Self-phase modulation due to the variation of index with power also can at very high power result in pulse distortion and gain loss. These effects can be analyzed quantitatively by integration of Maxwell's equations together with the equation for gain variation of the lasing medium. Under conditions of rapid intensity change, diffraction effects can be ignored and the eikonal equation used to determine beam propagation.

To study these problems for small amplitude disturbances we have analyzed the equations using dispersion theory. For larger amplitudes we have developed several computer codes which allow exact simulation of the laser system and of selected components which are essential for control of the beam intensity.

The intensity of the laser beam must be carefully controlled to avoid both large scale and small scale effects. The large scale effects which increase beam divergence result from the initial beam radial intensity variation combined with nonuniform gain in the laser amplifiers. The small scale effects usually result from diffraction and interference and can be minimized by reducing interference effects as far as possible. This can best be done by the use of graduated or "soft" apertures placed at critical points in the beam. The beam intensity profile can also be controlled by the use of attenuators with graduated transmission.

These techniques offer highly flexible and effective control of the laser beam and allow operation well above 5 GW/cm^2.

Nonlinear propagation studies, E. S. Bliss, *SP414,* pp. 7-16 (Dec. 1974).

Key words: apodization; beam breakup; instability theory; nonlinear propagation; propagation codes; self-focusing.

The desire to avoid damaging the components of high-power solid-state laser-systems being built for laser fusion experiments has led to increased interest in all aspects of in-

tense pulse propagation. This paper describes a variety of observations of nonlinear propagation phenomena and the instrumentation used for measuring them, presents comparisons with theoretical predictions, and outlines some approaches to minimization of the resulting problems in large systems. The intent of the paper is to present an up-to-date summary of the progress being made in characterizing and controlling nonlinear propagation effects.

Suppression of parasitic oscillation in laser rod amplifiers, J. M. McMahon, R. P. Burns, and T. H. DeRieux, *SP414*, pp. 17-22 (Dec. 1974).

Key words: disc lasers; laser amplifiers; laser design; parasitic suppression.

The most common glass laser rod amplifier geometry is one in which the laser rod is centered in glass water jacket and pumped by Xenon flashlamps surrounding the water jacket. By suppressing parasitic modes in the amplifier much higher gains can be realized than previously achieved with a consequent increase in the short pulse damage threshold. 30-50 percent improvements have been attained in the NRL system and factor of two improvements are possible.

Optical requirements for laser mirrors, H. E. Bennett and P. C. Archibald, *SP414*, pp. 23-30 (Dec. 1974).

Key words: infrared absorption; laser damage; laser mirror; laser optical train; laser window; microroughness; optical figure; scattered light.

The surface and coating requirements for mirrors used in laser systems are very severe. They may be summarized as follows: (1) excellent figure under thermal load, (2) high catastrophic damage threshold and an absence of localized sites where damage is likely to occur, and (3) low scattering levels. Backscattering is particularly important since it can easily damage the laser itself. The figure requirements for components increase rapidly when multicomponent "real world" optical trains are used. For example, to satisfy Maréchal's criterion for a 10 component system used at a wavelength of 3.8 μm, each component must have an initial figure of approximately 1/8th wave in the visible region and thermal distortion over the surface of less than 1000 Å. Very high reflectance coatings with excellent uniformity are thus required. Light scattering at short wavelengths provides a powerful, nondestructive tool for measuring microroughness (which reduces the infrared reflectance of metal coatings), and for identifying potential sites where damage is likely to occur. The damage threshold of a metal mirror is not necessarily determined by its absorption, and our understanding of the laser mirror problem is still incomplete.

Diffraction theory of absorbing windows, M. Flannery and J. Marburger, *SP414*, pp. 31-38 (Dec. 1974).

Key words: birefringence; laser windows; thermal distortion.

The diffraction-optical theory of coherent polarized beams incident on realistic absorbing windows is developed here with emphasis on tracing the origin of qualitative features of the diffraction field. The influence of incident polarization, stress induced birefringence, and other parameters, on the transmitted beam is described, and both analytical and numerical solutions for the transmitted diffraction field are presented. Our development of the theory allows the influence of the window material to be characterized by two parameters in the transient regime rather than the three previously believed to be necessary. Implications for IR window design are summarized.

Damage resistance of dielectric reflectors for picosecond pulses, B. E. Newnam, *SP414*, pp. 39-47 (Dec. 1974).

Key words: damage thresholds; dielectric reflector; laser-induced scatter; picosecond pulses; spark thresholds; thin films; weak-signal scatter.

A state-of-the-art survey has been conducted to determine the range of damage thresholds of electron-gun-produced dielectric reflectors irradiated by 30-ps laser pulses at 1.06 μm. Seven commercial coating companies, experienced in producing refractory-oxide coatings, supplied total reflectors of a specified TiO_2/SiO_2 design deposited on low-scatter glass substrates provided by LASL. Optional reflectors of ZrO_2/SiO_2 were also evaluated. Single-shot thresholds were determined by laser-induced scatter and photoelectric detection of spark radiation. Thresholds of TiO_2/SiO_2 reflectors ranged from 1 to 4 J/cm^2; those for ZrO_2/SiO_2 reflectors ranged from 0.5 to 2 J/cm^2. Reflectors which exhibited a large amount of diffuse, weak-signal scatter generally had low thresholds.

Damage studies at 1.06 μm with 100-200 ps pulses, G. W. Leppelmeier and M. Finkelstein, *SP414*, pp. 48-52 (Dec. 1974).

Key words: laser damage; mirror damage; thin films.

Studies have been conducted of the damage threshold at 1.06 μm of multilayer dielectric films used as polarizing beamsplitters, mirrors, and anti-reflection coatings, $K(H_xD_{2-x})PO_4$, several high Verdet constant glasses, and micromachined silver. The laser pulse used had less than 4 percent spatial and temporal ripple. Pulse energy of up to 1 joule permitted using a collimated beam. Damage thresholds in the range 1-5 J/cm^2 were obtained.

Damage thresholds in ZnSe, A/R coated NaCl and micromachined mirrors by 10.6 μm multijoule, nanosecond pulses, E. E. Stark, Jr., and W. H. Reichelt, *SP414*, pp. 53-58 (Dec. 1974).

Key words: A/R coatings; damage thresholds; machined mirrors; ZnSe.

Multijoule, nanosecond pulses at 10.6 μm were used to determine the damage thresholds of uncoated and antireflection (A/R) coated ZnSe, A/R coated NaCl and micromachined mirrors. The ZnSe results indicate that the A/R coatings have a higher damage threshold than the bulk material. Antireflection coatings on NaCl were found to have a damage threshold slightly lower than uncoated NaCl. Damage thresholds for micromachined copper and gold are greater than 4 joules/cm^2.

Pulsed CO_2 laser damage in windows, reflectors, and coatings, V. Wang, J. E. Rudisill, C. R. Giuliano, M. Braunstein, and A. Braunstein, *SP414*, pp. 59-65 (Dec. 1974).

Key words: As_2S_3; laser coatings; laser reflectors; laser windows; pulsed CO_2 laser damage, ThF_4; ZnSe.

Recent 10.6 μm damage measurements using a TEM_{oo} laser of 0.6 μsec pulse length are reported for a variety of windows, reflectors, and coatings. Reduction of the density of inclusions in ZnSe was found to have a large effect upon scatter but a smaller effect upon damage resistance. Absorptions and damage thresholds of thin films of ZnSe, As_2S_3 and ThF_4 were measured upon relatively defect-free KCl substrates, and then tested in antireflection and multilayer reflector configurations. Also reported is a five-fold increase in damage resistance of simple polished copper reflectors by surface etching.

Pulsed CO_2 laser damage studies of RAP grown KCl, S. D. Allen, M. Braunstein, C. Giuliano, and V. Wang, *SP414*, pp. 66-75 (Dec. 1974).

Key words: etch-polishing; KCl; laser damage; laser windows; RAP; 10.6 μm.

Laser damage thresholds in high purity RAP (Reactive Atmosphere Processing) KCl were measured as a function of surface and bulk processing techniques. Single crystal and press forged material was prepared in a "conventionally" polished and HCl etch-polished manner and the bulk and surface damage thresholds measured and correlated with absorption (cw CO_2 laser calorimeter), Auger, LEED and SEM data. The damage measurements were made with a TEM_{oo} CO_2 TEA laser with a 0.6 μsec pulse length.

A comparison of 10.6 μm pulsed laser damage in sputtered vs electron beam deposited Ge-coated KCl, A. Golubovic, W. Ewing, J. Bruce, J. Comer, and D. Milan, *SP414*, pp. 76-84 (Dec. 1974).

Key words: characterization of laser damage; e-beam deposition of germanium; germanium coating; laser damage mechanism; laser induced damage; multiple beam damage apparatus; potassium chloride; sputtering of germanium.

Germanium films deposited on KCl substrates by electron beam and sputter techniques have been irradiated at 10.6 μm. A comparative damage study of germanium films prepared by these techniques under pulsed irradiation is reported. A novel mulitple beam pulsed laser damage apparatus was used for this study. Well characterized RAP Bridgeman and Czochralski grown KCl substrates with (100) and (111) orientation were used.

10.6 μm pulsed laser damage in ZnSe, H. Posen, J. Bruce, and D. Milam, *SP414*, pp. 85-92 (Dec. 1974).

Key words: CO_2 pulsed laser damage; damage threshold; laser windows; twin structure; zinc selenide.

The effect of 10.6 μm pulsed laser radiation on large grain ZnSe is examined with respect to the local crystallography of the material. In particular, the presence of twin boundaries, a common defect in II-VI materials, is shown to have very little effect on the damage threshold. Damage effects were monitored by Nomarski interference contrast microscopy, electron microscopy and x-ray topography.

Evaluation of single crystal $LaCl_3$ AS CO_2 laser window material, F. Varsanyi and L. G. DeShazer, *SP414*, p. 93 (Dec. 1974).

Key words: absorption coefficient; infrared materials; $LaCl_3$. thin film material.

We report calorimetric measurements of the $LaCl_3$ absorption coefficient at 10.6 μm. Single crystal $LaCl_3$ of substantial size (one inch diameter, two or more inches long) were grown repeatedly in our laboratories in the past years, mostly for spectroscopic purposes. $LaCl_3$ is transparent in the visible extending up to 25 μm and, if pure, is only slightly hygroscopic. Its phonon spectrum has been well investigated and terminates around 260 cm^{-1}. A rather elaborate program of mechanical and optical property evaluation was initiated. In the preliminary experiments reported here, we studied a $LaCl_3$ single crystal ($2 \times 11 \times 12$ mm) with a CO_2 laser. We feel $LaCl_3$ compares favorably with KCl as a laser window material, but without some of its problems.

Laser window damage from CW 10.6-μm radiation, J. S. Loomis and C. A. Huguley, *SP414*, pp. 94-102 (Dec. 1974).

Key words: CO_2 laser radiation; CW laser damage; infrared windows; KCl; NaCl; optical distortion; ZnSe.

Damage studies have been conducted using a CW, one-kilowatt CO_2 laser. Some analytic calculation of local temperature rise as a function of laser power, spot size, and irradiation time will be discussed. Results of optical distortion and stress-field observations on uncoated and coated samples of KCl, NaCl, and ZnSe are reported.

10.6 micrometer CW laser damage studies of metal substrate mirrors, T. T. Saito, G. B. Charlton, and J. S. Loomis, *SP414*, pp. 103-112 (Dec. 1974).

Key words: CW laser damage; diamond turned optics; dielectric enhanced metal mirrors; laser beam characterization; metal mirrors.

The CW damage properties of metal substrate mirrors were studied by focusing a 1 KW CW CO_2 laser onto the mirrors. Mirrors studies included polished and diamond machined bare metals, noble metal evaporated coatings, electroplated and then machined metals, and dielectric coated. Experimentally determined damage thresholds and damage statistics are discussed. Extensive efforts to characterize beam area of focused kilowatt beam is included. Evidence of a self-cleaning of mirrors by slowly raising laser power is described. Dust on mirrors reduces the damage threshold below 100 W/cm^2.

High absorption damage in infrared filters, W. S. Otaguro, *SP414*, pp. 113-118 (Dec. 1974).

Key words: high absorption damage; infrared filters; laser-induced damage.

The damage morphology, degradation of filter transmission, and thresholds for damage of infrared filters subjected to a hostile environment where the radiation incident on the filters includes high power densities in a wavelength region of high absorption have been examined. Infrared filters cooled to 10 kelvin exhibited damage thresholds at 5 megawatts per square centimeter when illuminated with a Q-switched ruby laser. A thermodynamic model based on intrinsic absorption of the material composing the multilayer coatings is compared to the measured damage thresholds.

Q-switched laser induced surface damage at 1.06 microns, N. L. Boling, J. A. Ringlien, and G. Dubé, *SP414*, pp. 119-130 (Dec. 1974).

Key words: electron avalanche; laser; laser induced damage.

Our studies of the effect of "superpolishing" on the surface damage threshold indicate that such polishing does not increase the practical threshold on ED-2 glass. Impurities introduced in the polishing process often outweigh any advantages that might be gained in longer polishing to reduce geometrical defects.

On commercially available, "conventionally" polished laser glass, the surface threshold is about 150 J/cm^2 (5 GW/cm^2). This is at least an order of magnitude below the intrinsic bulk threshold. Some problems encountered in using small beams to measure the surface-to-bulk ratio are discussedd.

The effect of treating ED-2 laser glass with boiling nitric acid is also briefly described. This treatment can permanently raise the threshold by as much as a factor of three, while leaving the surface in good optical condition. The efficacy of the treatment is highly dependent on the polishing history of the sample.

Damage in nonlinear optical materials at 1.06 μm: Surface treatment of $LiNbO_3$ in Ar-O_2 plasmas and high pressure O_2 environment, J. C. Potosky and C. R. Giuliano, *SP414*, pp. 131-134 (Dec. 1974).

Key words: $LiNbO_3$; 1.06 μm; oxygen deficiency; surface damage; surface treatment.

Surface damage in $LiNbO_3$ has been studied at 1.06 μm as a function of different surface treatments. While the use of ion beam polishing on $LiNbO_3$ has resulted in general degradation of surface finish and decrease in damage resistance, a different type of plasma treatment shows a distinct improvement. This method of surface treatment is one in which the sample is bombarded in a low energy rf-excited plasma of argon and oxygen. Under this type of plasma treatment, the damage resistance is substantially improved ($\sim 50\%$) over that of the conventionally polished surface of the same sample. To avoid complications of possible cumulative effects in the damage experiments, each point on the surface is laser irradiated only once at any given power. The results are presented in terms of the fraction of surface which resists damage for a given incident energy.

That this improvement in threshold involves a surface-oxygen effect is supported by another series of preliminary measurements in which damage tests were performed on $LiNbO_3$ at 10 to 15 atm O_2 pressure. Under these conditions, the surface was usually seen to completely resist damage at levels of irradiation at least twice that at which damage occurred at ambient conditions or in a high pressure nitrogen environment.

Surface characteristics related to laser damage of lithium niobate and potassium chloride surfaces, J. O. Porteus, E. A. Teppo, and J. H. Dancy, *SP414*, pp. 135-140 (Dec. 1974).

Key words: Auger electron spectroscopy; ion beam profiling; laser-induced damage; lithium niobate; potassium chloride; surface acoustic waves; surface characterization; transmission electron microscopy.

Laser damage of transparent materials is promoted by irregularities in topography and surface composition. Changes in these characteristics following laser irradiation can provide insight on damage mechanisms. Transmission electron micrographs of replicated $LiNbO_3$ surfaces which have been chemically etched show submicroscopic pitting similar to that previously observed following laser irradiation. Experiments designed to explore a possible role of surface-acoustic waves in the laser-induced pitting are in progress. Auger analysis of coated $LiNbO_3$ surfaces following visible laser damage have helped to identify redistributed surface material. Profiling of the coating shows evidence of C contamination layers near the substrate surface. Preliminary Auger spectra of KCl surfaces show promise for similar studies on this material.

Characterization of infrared laser window materials at the National Bureau of Standards, A. Feldman, I. Malitson, D. Horowitz, R. M. Waxler, and M. Dodge, *SP414*, pp. 141-148 (Dec. 1974).

Key words: As_2S_3; chalcogenide glass; coefficient of thermal expansion; elastic constants; infrared laser window materials; KCl; photoelasticity; polycrystalline ZnSe; refractive index; stress-optical constants; thermal coefficient of refractive index.

A program has been established for measuring refractive index, n, stress-optical constants, q_{ij}, change of index with temperature, dn/dT, thermal expansion coefficient, α, and elastic compliances, s_{ij}, of infrared laser window materials. These parameters are necessary for determining the optical distortion that occurs in windows due to heating by the absorption of high power laser radiation. n and dn/dT are measured over a spectral range 0.2 to 50 μm by the method of minimum deviation on precision spectrometers. Twyman-Green and Fizeau interferometers, which operate at 0.6328 μm, 1.15 μm, and 10.6 μm, are used for measuring q_{ij}, α, dn/dT and s_{ij}. Materials currently under study are polycrystalline ZnSe, As_2S_3 glass, chalcogenide glass (Ge 33%, As 12%, Se 55%), and KCl. Results are given for n and dn/dT in KCl, and q_{ij} and s_{12} in ZnSe, As_2S_3 glass, and chalcogenide glass.

Testing the surface quality of laser materials, M. J. Soileau and H. E. Bennett, *SP414*, pp. 149-156 (Dec. 1974).

Key words: laser damage; light scattering; optical surface quality; scratch detection.

Research presented at the 1973 Laser Damage Symposium clearly showed that surface microcracks and pits influence laser damage thresholds for optical materials. In addition, backscatter from laser amplifiers can result in damage to oscillator optics in high power oscillator-amplifier systems. The scratch and dig specifications presently used to specify optical surface quality are inadequate since (1) they address only the problem of surface irregularities larger than 2 μm (Bloembergen has shown theoretically that pits or scratches as small as 100 Å can significantly reduce damage thresholds), and (2) compliance is determined in a subjective manner. The relationship between surface quality and light scattering from transparent optical components is discussed, and an instrument for measuring bulk scattering and surface quality described. Quantitative measurements on a set of standard scratches and digs are presented, as well as measurements of surface imperfections and bulk scattering in optical materials used in infrared laser systems.

Statistical characterization of mirror and window surfaces, J. M. Bennett, *SP414*, pp. 157-162 (Dec. 1974).

Key words: autocovariance laser damage statistical characterization of surface; FECO interferometry; scattered light; surface roughness.

In order to evaluate the contribution of surface structure to laser damage and to calculate the magnitude and angular distribution of scattered light from laser mirrors, windows, and other optical surfaces, the autocovariance function, rms roughness and height distribution functions are required. These and other statistical parameters for optical surfaces can now be determined with a FECO Scanning Interferometer, which consists of a FECO interferometer, slow scan television camera, signal averager, minicomputer, and teletype. Wavelengths are measured at 512 equally spaced points along the length of an interference fringe (which contours irregularities on the optical surface under investigation). The fringe length corresponds to a total length of 1 mm on the interferometer surface. The statistics for the surface are obtained from the wavelength data. The system has the advantages that it does not depend on visual estimates of fringe width to yield a value of the rms roughness, and additional statistical information such as the autocovariance function and height distribution function can be obtained which cannot be determined visually.

Roughness measurement by light scattering, J. C. Stover, *SP414*, pp. 163-168 (Dec. 1974).

Key words: light scattering; sinusoidal grating diffraction; spatial spectral density function; surface roughness.

Theoretical and experimental descriptions of how light scatters from sinusoidal gratings lead to the relationship between light scattered from an arbitrary surface and the spatial power spectral density function of that surface. With an appropriate measurement system, this relationship lends

itself to studying the correlation between damage threshold and surface topography for surfaces in the 10 to 500 Å (rms) range. Experimental results are given for various types of sinusoidal gratings (variation in magnitude, frequency and material) and several arbitrary surfaces. Measurements of samples submitted by outside laboratories have been taken.

Laser-damage-mechanism identification by the measurement of survival times, D. Milam, R. A. Bradbury, R. H. Picard, and M. Bass, *SP414*, pp. 169-178 (Dec. 1974).

Key words: absorbing inclusions; absorption; bulk dielectrics; dielectric films; dielectric surfaces; electric field enhancement; electron-avalanche breakdown; laser-damage statistics.

The mechanism responsible for laser-induced damage can be determined from the statistical fluctuation in the times required to produce damage at many sites which were sequentially irradiated by equally-intense, square-waveform pulses. Damage mechanisms are readily separated into three general categories: (1) Homogeneous absorption, (2) damage due to material defects or inclusions, and (3) intrinsic damage due to electron-avalanche breakdown or other fast intrinsic mechanisms.

The dynamics of transmitted, reflected, and scattered laser pulses above and below damage threshold: The search for precatastrophic damage, C. R. Giuliano, *SP414*, pp. 179-189 (Dec. 1974).

Key words: back-scattering; precatastrophic damage; pulse dynamics; reflection; ruby laser; surface damage; temporal pulse monitoring; transmission; 0.694 μm.

This paper deals with a detailed study of the temporal shapes on a nanosecond time scale of laser pulses that are transmitted, back reflected, Brewster reflected, and backscattered at small angles for different powers below and above surface damage threshold. The sharp cutoff in transmitted light above damage threshold is accompanied by a corresponding cutoff in reflected light while the small angle backscattered light shows a sharp increase at the same time. The shapes of the transmitted and reflected pulses are essentially the same over a wide range of powers from below damage threshold to ~ 10x above threshold. The small angle backscattered intensity is the most sensitive measure of the very onset of surface damage in that while the transmitted pulse shows essentially no change in shape for powers slightly above damage threshold, the backscattered component shows a marked increase in intensity. These results, along with the intensity dependence of Brewster reflected pulses, are discussed in terms of possible precatastrophic damage effects.

Rutherford backscattering diagnostics of laser-irradiated GaAs, R. R. Hart, C. R. Giuliano, and H. L. Dunlap, *SP414*, pp. 190-192 (Dec. 1974).

Key words: ion channeling; laser-damaged GaAs; Rutherford backscattering; scattering centers.

The Rutherford backscattering of 280 keV He^{++} has been used to study the amount and depth distribution of lattice disorder introduced in GaAs by intense laser irradiation. The lattice remains largely intact after irradiation at a laser power level of three times the damage threshold (optical) except within a 175 Å surface layer. In this surface layer the number of scattering centers increases to about 2.5 times the number of Ga and As atoms present in the surface oxide on undamaged GaAs.

Surface defects on crystals of TiO_2 and YVO_4 studied by laser-induced damage effects, K. M. Leung and L. G. DeShazer, *SP414*, pp. 193-199 (Dec. 1974).

Key words: damage morphology; polishing compounds; spot-size dependence; surface defects; rutile crystal damage; yttrium orthovanadate crystal damage.

The nature of surface defects on single crystals of rutile (TiO_2) and yttrium orthovanadate (YVO_4) was investigated by laser-induced damage effects using a TEM_{00} Q-switched ruby laser. It was demonstrated that damage to these crystal surfaces can be distinguished as defect damage and intrinsic damage, where the damage thresholds decreased with increasing focal spot-size of the laser beam. The dependence on the directions of crystallographic axes and electric field was studied. The morphology of the surface damage sites was examined by the scanning electron microscope revealing that polishing imperfections were the cause of damage on TiO_2 surface and inclusions were the cause of damage in the case of YVO_4.

Pulsed CO_2 laser window damage processes, R. A. Shatas, J. D. Stettler, L. M. Narducci, S. S. Mitra, and H. C. Meyer, *SP414*, pp. 200-206 (Dec. 1974).

Key words: damage threshold of GaAs; extended Shockley avalanche; pulsed laser damage; semiconductor infrared windows; solid state plasma; two-stream instability threshold.

We examine the applicability of the extended avalanche breakdown process to describe the semiconductor window surface damage by pulsed high pressure CO_2 lasers. In the extension to optical frequencies of Shockley's avalanche theory construed originally for a dc electric field, a hard momentum-reversing collision of the free carrier is required to occur at the instant of optical field reversal. In contrast to alkali halides, the mobility is very high in semiconductors, and the probability of a momentum-reversing collision is too small to account for experimental observations of damage thresholds. Alternate models of damage processes are discussed. They are based on quantum mechanical photon assisted tunneling probability calculations between the bound and the quasi-free states and resonant collective excitations of carriers in the quasi-free state. Theoretical predictions for maximum pulsed CO_2 laser fluxes are made for some typical semiconducting window materials.

Frequency dependence of the nonlinear optical susceptibility of five glasses, R. Hellwarth, J. Cherlow, and T-T. Yang, *SP414*, pp. 207-213 (Dec. 1974).

Key words: ac Kerr effect; glasses; nonlinear optical effects; nonlinear optical susceptibility; self-focusing; three-wave mixing.

The frequency dependence of the nonlinear susceptibility throughout the optical region of fused quartz, ED-4, LSO, SF-7, and LaSF-7 glasses is derived in a novel and useful form from Raman-scattering and intensity-induced polarization change measurements.

The refractive index dependence of pulsed laser induced damage, J. R. Bettis, A. H. Guenther, and A. J. Glass, *SP414* pp. 214-218 (Dec. 1974).

Key words: bulk; electro-absorption; electron avalanche laser damage; local field corrections; refractive index; surfaces; thin films.

The dependence of the laser induced damage threshold on refractive index has been investigated. A simple theoretical

expression, based upon several factors such as the local electric field and avalanche mechanisms, has been derived. Comparison is made with several series of previously published results to verify the proposed dependence. Strikingly good agreement is obtained between theory and experiment for materials with refractive indices ranging from 1.38 to 2.36. The available experimental data used for comparison were obtained (1) on the surface of uncoated dielectrics, (2) in the bulk of alkali halides, (3) with $\lambda/4$ dielectric coatings and (4) with vapor phase mixture thin films. Extrapolations of these results to conditions for air at STP give remarkable agreement with reported values of pulsed laser induced air breakdown.

Extrinsic absorption in laser window materials, C. J. Duthler and M. Sparks, *SP414,* pp. 219-226 (Dec. 1974).

Key words: absorbing inclusions; alkali halides; impurity absorption; laser damage.

Two types of extrinsic absorption are discussed. First, our calculations on absorbing inclusions, presented at the 1973 symposium, have been extended to explain the cone-shaped surface pits observed by Boling. For a spherical inclusion of radius a located a distance d below the surface, the cone half-angle is $\theta_m = \cos^{-1}(a/d)$. The second type of absorption is that due to polyatomic molecular-ion impurities in alkali halides. A literature survey indicates that concentrations of less than 0.1 ppm of NO_2^-, HCO_3^-, SO_4^{2-}, or CrO_4^{2-} will result in a bulk absorption coefficient $\beta(10.6\ \mu m) > 10^{-4\ cm-1}$.

SP415. **Biomaterials.** Proceedings of a Symposium held in conjunction with the Ninth Annual Meeting of the Association for the Advancement of Medical Instrumentation, New Orleans, April 19-20, 1974, E. Horowitz and J. L. Torgesen, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 415, 109 pages (May 1975) SD Catalog No. C13.10:415.

Key words: biocompatibility; biomaterials; blood protein; ceramic implants; implantable electrodes; metallic implants; nerve prosthesis; synthetic implants; thromboresistance.

This volume is based on papers presented at the Symposium on Biomaterials, held in conjunction with the Ninth Annual Meeting of the Association for the Advancement of Medical Instrumentation, New Orleans, LA, April 19-20, 1974. It provides a review of special topics in biomaterials research selected to focus attention on some noteworthy achievements. The topics covered include plasma-polymerized polymers and their application in biomedicine; biocompatibility of ceramic materials and their application both as inert coatings for synthetic implants and as porous materials for bone repair; the selection of metallic implant materials through engineering and medical considerations; in vitro testing of thromboresistance; adsorption of blood proteins on synthetic substrates; a prosthesis for nerve regeneration; and properties of fibrous biomaterials. *These proceedings include the following papers (indented):*

Plasma formed polymers for biomedical application. Part I. Synthesis and fundamental studies, K. G. Mayhan, A. W. Hahn, M. R. Havens, and B. W. Peace, *SP415,* pp. 1-12 (May 1975).

Key words: plasma-formed polymers; polymer films; polymerization; polymer permeability.

The deposition of polymeric coatings through Rf plasma techniques is a unique process from several points of view. By introducing monomeric gases into an inert gas Rf plasma, the monomers are converted to ultrathin continuous polymer films. These films can be made to vary in thickness from less than 1 μm to 10 μm or more. These materials are insoluble to common organic solvents and are not attacked by strong mineral acids. In addition, the monomeric materials in the reactor are distilled gases and are therefore quite pure in comparison to monomers used for ordinary linear polymerizations. As a result, the polymer coatings which are formed do not contain residual catalysts or activists and are in a highly purified state. We have utilized the plasma polymerization process to produce polymer films intended for biomedical application. Plasma coatings have been formed from a wide variety of monomers. These coatings have been applied to various nonmetallic, metallic and organic substrates. In each instance it was found that continuous adherent films could be deposited after suitable substrate preparation and reactor operation parameters were established. It has been our experience that a general cleaning procedure for all substrates cannot be dictated and that the preparative steps involved are dictated by the environment to which the final product will be subjected.

Plasma-formed polymers for biomedical applications. Part II. Biocompatibility and applications, A. W. Hahn, K. G. Mayhan, J. R. Easley, and C. W. Sanders, *SP415,* pp. 13-17 (May 1975).

Key words: biocompatibility; inflammatory response; plasma polymers; tissue reaction.

Different polymer films generated by rf plasma techniques and deposited on glasses of varying chemical composition, on implant alloys, and on formed prosthetic polymers have been implanted in New Zealand white rabbits and various canine species and have shown minimum tissue reactions after periods of time up to six months. It has further been found that the substrates upon which the plasma polymers are formed are more detrimental to cell cultures than the polymers themselves. These findings, along with other implant work, indicate that plasma-formed polymers will play a definite role as biocompatible materials in the future.

Interfacial behavior of ceramic implants, L. L. Hench, H. A. Paschall, W. C. Allen, and G. Piotrowski, *SP415,* pp. 19-36 (May 1975).

Key words: bioglass-ceramic; ceramic implants; flame spray coating; hip prosthesis; segmental bone replacement.

Recent studies of bioglass, bioglass-ceramic, and alumina implants have produced an understanding of the chemical nature of interfacial tissue reactions to bioceramics. Significant differences between hard and soft tissue reactions are due to the influence of surface chemical reactivity on the ultrastructural histology as revealed by transmission electron microscopy. Modern surface characterization of the implants correlates with the histological reactions. Applications of the results to a variety of orthopaedic prostheses show promise in animal experiments. Biomechanical analyses of interfacial bonding between bioceramic prostheses and tissues are presented.

Soft tissue response to a series of dense ceramic materials and two clinically used biomaterials, W. C. Richardson, Jr., S. F. Hulbert, J. J. Klawitter, and B. W. Sauer, *SP415,* pp. 37-44 (May 1975).

Key words: biocompatibility; ceramic implants; histological evaluation; implant characterization.

Disc-shaped implants of spinel, alumina, mullite, zircon, a cast Co-Cr-Mo alloy, and ultra-high molecular weight polyethylene (UHMWPE) were implanted in the paraspinalis muscle of twelve adult, male, White New Zealand rabbits. Prior to implantation the implants were charac-

terized with respect to size and shape, weight and surface roughness. After periods of 1 month, 2 months, and 4 months the rabbits were sacrificed and the tissue specimens were retrieved with the implants still intact. Histological examination of the tissues surrounding the implants along with changes in the size and shape, weight, and surface roughness of the implants were used as criteria for evaluating these materials for implant purposes.

No surface degradation of any of the materials was detected using scanning electron microscopy. Fibrous tissue seems to adhere to the UHMWPE implants more than any other material used in this study. Large amounts of fibrous tissue were also found to adhere to the cast Co-Cr-Mo alloy implants.

The histological results indicated that within the limits of this investigation, the biocompatibility of the ceramic materials used in this study compares favorably with the clinically used cast Co-Cr-Mo alloy implants and the UHMWPE implants.

Engineering and biological studies of metallic implant materials, N. D. Greene, C. Onkelinx, L. J. Richelle, and P. A. Ward, *SP415*, pp. 45-54 (May 1975).

Key words: corrosion; inflammatory response; metallic implants; systemic effects.

The aim of this investigation is the development of improved alloys for short term (0.5 to 5 years) orthopaedic implants. The program is interdisciplinary in nature—simultaneous studies of corrosion, inflammatory response, and systemic effects of iron, nickel, cobalt, titanium, and tantalum base alloys are being determined. Corrosion tests under *in vitro* and *in vivo* conditions have been performed via linear polarization and other electrochemical methods.

The inflammatory responses of various implant alloys are being determined by both *in vivo* and *in vitro* experiments. *In vitro* chemotactic assays on rabbit neutrophilic granulocytes and mononuclear cells are performed in the presence and absence of appropriate metal ion concentrations. Corrosion rate data described above are employed to select the proper concentrations.

Systemic effects of metallic corrosion products have been determined via radioisotope and analytical techniques. Radioactive metallic salts at appropriate concentrations are injected intravenously in rats of known age and sex. Following this, the concentration of metallic products is determined as a function of time in various biological samples (plasma, urine, feces, etc.). These data permit the establishment of models which can predict the distribution of individual elements released from continuously corroding metal implants.

Materials characterization of implantable porous electrodes, R. B. Beard, J. F. DeRosa, S. F. Dubin, L. Sturm, R. M. Koerner, and A. Miller, *SP415*, pp. 55-61 (May 1975).

Key words: implantable hybrid cells; pacemakers; palladium black; platinum black; polarization; porous electrodes.

Porous platinum and palladium black electrodes have been used as cathodes for reducing body oxygen in implantable hybrid cells supplying energy to pacemakers. The power-generating capabilities of a cell are greatly decreased under load, i.e., increased current density, due to polarization at the electrode interface. A greatly increased surface area of the porous electrodes, i.e., number of sites for the electrode reaction, permits a greater current density with lower overpotential or polarization. Similarly, at the pacemaker stimulating electrode and at electrodes used in making electrical impedance measurements there is polarization and a consequent loss of energy in a charge transfer at the electrode interface. Porous electrodes in these cases have also greatly reduced the overpotential. The physical electrochemical properties of the porous electrodes have been characterized by specific adsorption, i.e., BET measurements; scanning electromicrographs; galvanostatic and potentiostatic measurements; and electrical impedance measurements. Histopathological studies have been made in order to determine the biocompatibility of the tissue-electrode interface.

Properties of fibrous biomaterials with statistically dispersed orientation, E. Y. Robinson, *SP415*, pp. 63-74 (May 1975).

Key words: biomaterial properties; biomechanics; composites; fiber orientation; fibrous biomaterials.

Many factors influence the interaction between bone or soft tissue and implanted synthetic biomaterials, e.g., biocompatibility, implant configuration, functional requirements, bone and tissue structure, and relative mechanical properties. Of the many active factors, one aspect is considered here: the theoretical consequences of the fibrous-lamellar structure of bone, and of the degree of fibrous orientation present in the individual lamellae. This orientation is known to be statistically dispersed about certain preferred directions in each layer, with possible large orientation changes from layer to layer. Analysis of this type of structure is presented with graphical illustration of the effects of orientation and of statistical dispersion of orientation on conventional engineering material parameters.

New biomaterials are being evolved which combine fiber reinforcement with polymer resin matrices (e.g., graphite fibers/polyethylene matrix). Such materials may be tailored to yield certain specific properties by controlling fiber orientation and quantity. Materials of this type are of interest in implants which may be required to behave in a similar fashion to adjacent bone tissue (as in bone splints, hip prostheses, etc.). The analysis presented here provides a rapid and convenient basis for calculating the effect of controlled and dispersed fibrous orientation on material properties.

The methods described lay a base for first approximations and show certain directions which should be followed in further investigation. Graphical results include examples for both fibrous bone tissue models and synthetic types of fiber-reinforced biomaterials.

A simple *in vitro* test for screening the blood compatibility of materials, H. Kambic, T. Komai, R. J. Kiraly, and Y. Nosé, *SP415*, pp. 75-82 (May 1975).

Key words: blood coagulation; blood compatibility; blood platelet consumption; kinetic clotting test.

An *in vitro* blood compatibility test was developed to evaluate thromboresistant properties of materials. This method is called the closed-cell kinetic blood coagulation test. A closed cell system eliminates any air-blood interface. The blood is withdrawn directly from the animal into the cell, minimizing the exposure to foreign surfaces other than the one being studied and eliminating the use of anticoagulants through the process.

The technique includes the simultaneous blood filling of eight cells with the test materials, and eight cells lined with a control material. As a control material we have selected silicone rubber, which has reasonably good thromboresistant properties, is widely accepted, and commercially available. The cells are opened at different predetermined times, and the clot formation is then measured by two complimentary methods: weighing the clot and colorimetry of the unclotted blood. The two methods correlate and can differentiate between red and white thrombus.

The results are presented as clot formation curves versus

time for the material under test and for the control. The variability of blood properties makes this control curve essential.

Detailed analyses of the curves will offer a new approach to the understanding of the mechanism of thrombus formation on various types of materials. Results will be presented for tests conducted on Hydron®, segmented polyurethane, purified natural rubber, as well as chemically treated tissue.

Conformation of adsorbed blood proteins. B. W. Morrissey, L. E. Smith, C. A. Fenstermaker, R. R. Stromberg, and W. H. Grant, *SP415*, pp. 83-90 (May 1975).

Key words: adsorbed protein conformation; blood protein; protein conformation.

The likelihood that surface-induced blood coagulation results from specific interactions between proteins and materials has led to a study of the conformation of adsorbed blood proteins. Infrared difference spectroscopy was used to determine the bound fraction, i.e., the fraction of carbonyl groups of an adsorbed molecule directly interacting with a silica surface, and ellipsometry was used to measure the average extension (thickness) of adsorbed protein films. *In situ* measurements were made on serum albumin, fibrinogen, and prothrombin as a function of the amount adsorbed, time of adsorption, and surface energy.

The bound fraction results obtained for serum albumin and prothrombin indicate that the internal bonding of these globular proteins is sufficient to prevent changes in conformation while adsorbed, even at low surface population. The bound fraction of fibrinogen increases with increasing adsorbance, suggesting possible interfacial aggregation. The conformation of all three proteins was found by both I.R. difference spectroscopy and ellipsometry to be independent of the time of adsorption. In addition, the ellipsometric studies show that while the adsorbance of fibrinogen and prothrombin does not vary for a number of surfaces, their extensions increase with decreasing surface energy.

Studies of cross-linked and denatured serum albumin have shown that changes in conformation concomitant with adsorption of the native protein, if they occur, are small.

A nerve implant prosthesis for facilitating peripheral nerve regeneration. Part I. Development of the prosthetic device and system of repair, W. E. Kuhn and J. L. Hall, *SP415*, pp. 91-98 (May 1975).

Key words: neurorrhaphical procedures; peripheral nerve repair; tubular prosthesis.

The design rationale and requirements of a system of sutureless nerve repair employing a special thin walled porous stainless steel tube and a vacuum technique for applying the tube and approximating the nerve ends will be outlined. A description of the tubular prosthesis, its fabrication, the surgical instruments and neurorrhaphical procedures will be presented.

A slurry dipping process has been developed for the production of uniform "green" tubes in quantity. These are sintered in a hydrogen atmosphere to impart the strength required to retain their tubular configuration under the forces imposed by the surgical procedures and the vacuum pressure. Placing the porous tube on the nerve and drawing the nerve ends into approximation is both simple and rapid.

A nerve implant prosthesis for facilitating peripheral nerve regeneration. Part II. Development of the prosthetic device and system of repair neuroanatomical aspects. J. L. Hall and W. E. Kuhn, *SP415*, pp. 99-101 (May 1975).

Key words: histological evaluation; nerve axons; surgical procedure.

The principal neuroanatomical aspects of peripheral nerve repair are the approximation of the severed ends and the minimizing of trauma during the approximation. The method of using vacuum to draw the severed ends down a porous tube seems to take these two factors into consideration. The porous tube provides a shielded environment for the regenerating nerve to grow into the approximated distal end. The porosity allows for the escape of edematous fluids, prevents the invasion of scar tissue and provides for the flow of nutritional fluids.

Histological and statistical results of the procedures are presented. In most instances the axons of the regenerating nerve grow across the gap and occupy the intact neurilema sheaths of the degenerating distal segments.

SP416, 1976 Edition. **Attacking the fire problem: A plan for action—1976 Edition,** F. B. Clarke and D. W. Raisher, Eds., (Supersedes NBS Special Publication 416, 1975 Edition) *Nat. Bur. Stand. (U.S.), Spec. Publ. 416, 1976 Edition,* 41 pages (Jan. 1976) SD Catalog No. C13.10:416, 1976 Ed., $1.00.

Key words: building design; consumer protection; fire control; fire detection; fire research; fire spread; flammability.

The mission of the Center for Fire Research is to insure the development of the technical base for the standards and specifications needed in support of the National goal to reduce fire losses by 50 percent over the next generation. A systems approach to accomplish this mission is described. The Center consists of four basic programs in the area of Fire Science and five applied research programs in the area of Fire Safety Engineering. Each applied program addresses an aspect of the Fire Problem, using fundamental information supplied by the basic research function. Active participation by staff members in voluntary standards organizations is the principal means of making this technology available for codes and standards needed to reduce the Nation's fire loss.

SP417. **Directory of United States standardization activities,** S. J. Chumas, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 417, 228 pages (Nov. 1975) SD Catalog No. C13.10:417.

Key words: codes; consensus system; directory; Federal Government—standardization; industry standards activities; national standards activities; recommended practices; specifications; standardization activities; standards; states—standardization activities; test methods.

This Directory serves as a guide to standardization activities in the United States. It supersedes a Directory of the same title, issued in 1967, as National Bureau of Standards Miscellaneous Publication 288. Included in the Directory are summaries of the standardization activities of trade associations, technical and other professional societies representing industry and commerce, and state and Federal governments. For the first time this Directory covers nonengineering and nonindustry organizations. SP417 contains current descriptive summaries of more than 580 organizations.

Criteria for inclusion are that the organizations have standardization activities such as standards-writing groups, that they assist in the development of standards, or that they issue standards or disseminate standards information.

The standardization activities summaries are grouped into three sections: associations, states, and agencies of the Federal Government. In each section, the summaries are arranged alphabetically by organization. Two types of indexes are included in SP417 to assist the reader in identifying an activity: (1) a subject of index key words taken from the summaries; and (2) a listing of organizations classified into 24 subject areas. Supersedes NBS Misc. Publ. 288.

SP418. **National Bureau of Standards. Annual Report**, E. P. McGehan, M. King, and R. S. Franzen, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 418, 32 pages (Apr. 1975) SD Catalog No. C13.10:418.

Key words: annual report; computer; energy; environment; health; product safety; research; science and technology; standards.

This document describes how resources were utilized during fiscal year 1974 and highlights major achievements as a result of work performed at the National Bureau of Standards. Using the theme, "Standards for daily living," the book presents brief discussions of accomplishments within major program areas. The report serves as 1) an annual account of NBS activities and 2) promotional information about NBS. The Table of Contents includes: From the Director: Standards for Daily Living: Historical Pioneer, Catalyst for Change, Information Programs; The Year in Review: Expanding Measurement Capabilities, Toward Solving the Energy Problem, Improving Man's Environment, Striving for Safer Products, Aiding Health Care, Advancing Computer Technology; Interaction is the Key: Public Interest, Government Projects, Industry Cooperation, Information Services; Funds and Facilities; Organization; People.

SP419. **Selected topics on hydrogen fuel**, W. R. Parrish, R. O. Voth, J. G. Hust, T. M. Flynn, C. F. Sindt, N. A. Olien, and J. Hord, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 419, 212 pages (May 1975) SD Catalog No. C13.10:419.

Key words: conservation; conversion; cost; cryogenics; economics; embrittlement; energy; hydrogen; industrial; instrumentation; liquefaction; literature; materials; production; solar; storage; transmission; transportation; utilities.

The National Bureau of Standards played a vital role in developing hydrogen technology for the space age and is now engaged in efforts to adapt and improve this technology for the commercial use of hydrogen fuel. This document is a summary report on selected hydrogen-fuel topics and was prepared to identify cost and technical barriers to the commercial use of hydrogen fuel and to generate reference data for policy-planning, decision-making and design. Cryogenic hydrogen fuel technology is emphasized in the economic and systems analyses reported herein. Using the best available technical and economic data, hydrogen fuel is not currently cost competitive with alternate fuels; however, we must not reject hydrogen on the basis of current economic comparisons. Increased efficiencies of production, liquefaction, and energy conversion may drastically change these comparisons-of-today as will increased fossil fuel prices and more stringent environmental and pollution constraints. Hydrogen appears currently marketable in certain integrated utility systems, in transoceanic transport of energy produced far at sea, and is a necessary element in a wide variety of growing industrial processes and in the liquefaction of coal. This publication identifies research and development needs within selected areas of NBS competence and future research plans are outlined.

SP420. **International Bureau of Weights and Measures 1875-1975**, C. H. Page and P. Vigoureux, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 420, 257 pages (May 1975) SD Catalog No. C13.10:420.

Key words: base units; centennial volume; history of SI; International Bureau of Weights and Measures; International System of Units; measurements; SI; Treaty of the Metre.

This is the English version of the Centennial volume of the International Bureau of Weights and Measures (BIPM) translated from the French. Metrology—the science of measurement—is traced from man's earlier efforts to the world's most modern, uniform, and coherent measurement system, the International System of Units (SI). Detailed accounts are given of the 1875 Treaty of the Metre—to which 18 nations, including the United States, were signators—and the work of the International Bureau of Weights and Measures which was created by the Treaty and now the international province of 44 nations. Historical reviews are given of the development of the base and derived units of the SI, specifically mass, length, gravimetry, manobarometry, thermometry, electricity, photometry, radioactivity, x and gamma rays, and neutron measurements.

SP421. **A guide to methods and standards for the measurement of water flow**, G. Kulin and P. R. Compton, Nat. Bur. Stand. (U.S.), Spec. Publ. 421, 97 pages (May 1975) SD Catalog No. C13.10:421.

Key words: flow measurement, water; instruments, flow measurement; open channel flow measurement; pipe flow measurement; standards, flow measurement.

Selected information sources on methods and standards for making measurements of water and wastewater flow in the field are listed and described. Both closed conduit and free surface flows are treated, but emphasis is on open channel flow measurements needed in water resource engineering and in water pollution control. Instruments and methods covered include weirs, flumes, current meters (and velocity traverse methods), dilution techniques, pipe flow instruments, acoustic meters and others. In addition to summarizing the basic properties of each instrument or method and referring users to the best available sources of detailed information on performance and field application, potential sources of error are described and quantified where possible.

SP422. Volume I and II. **Accuracy in trace analysis: Sampling, sample handling, analysis.** Proceedings of the 7th Materials Research Symposium held at the National Bureau of Standards, Gaithersburg, MD, Oct. 7-11, 1974, P. D. LaFleur, Ed., *Nat. Bur. Stand. (U.S.), Spec. Pub. 422, Vol. I,* 645 pages, *Vol. II,* 636 pages, (Aug. 1976) SD Catalog No. C13.10:422/vol. I and II, $20 per 2-part set.

Key words: accuracy; analysis; analytical chemistry; sample handling; sampling; trace analysis.

This book is the formal report of the proceedings of the 7th Materials Research Symposium: Accuracy in Trace Analysis. This volume contains the invited and contributed papers presented at the Symposium, and which treat problems of sampling and sample handling as well as the usually-discussed analytical methodology. Many important techniques and methods are described, and extensive references are presented.

o give deeper insight into the problems of obtaining accurate esults in trace analytical chemistry. Accordingly, this volume hould not only stimulate greater interest in research in these reas but should provide a valuable guide for everyday analytical roblems. *These proceedings include the following papers (in-dented):*

The need for accuracy in a regulatory agency, A. C. Kolbye, Jr., *SP422*, pp. 3-8 (Aug. 1976).

Key words: accuracy; drugs; foods; regulation; regulatory agency.

A discussion of the need for accuracy in the food and drug industries is presented. Problems involved in sampling, sample handling, and methods of analysis are discussed as well as the establishing of permissible limits of contaminants and additives.

Accuracy and trace organic analyses, R. G. Lewis, *SP422*, pp. 9-34 (Aug. 1976).

Key words: concentration; detectors; extraction; gas chromatography; isolation and clean-up; mass spectrometry; organic trace analysis; qualitative accuracy; quality control; quantitative accuracy; reference materials; sampling.

Accuracy in trace organic analysis presents a formidable problem to the residue chemist. He is confronted with the analysis of a large number and variety of compounds present in a multiplicity of substrates at levels as low as parts-per-trillion. At these levels, collection, isolation, identification and quantification are all very difficult. Sample contamination and substrate interferences can also lead to large errors. Obtaining accurate qualitative data is often more of a problem than accuracy of quantitative data. Retention times and peak height measurements from gas chromatography coupled with highly sensitive, but nonspecific, detectors are most commonly used in residue analysis. Although dual column and/or dual detector determination, partition values and chemical derivatization are often employed, lack of good reference standards, interferences and poor detector specificity frequently cast doubt on the qualitative and quantitative accuracy of data upon which regulatory decisions may be made. Mass spectrometry and Fourier transform spectrophotometry offer partial solutions to qualitative accuracy where this instrumentation is available. However, less expensive and more sensitive specific detectors for gas chromatography are most needed. Means of quantitating residues from such complex industrial mixtures as polychlorobiphenyls and toxaphenes are far from adequate. Finally, collection systems for environmental media often lack efficiency, especially for volatile organic compounds in air.

Accuracy and quality control in trace element analysis, J. H. Boutwell, *SP422*, pp. 35-40 (Aug. 1976).

Key words: accuracy and precision; clinical chemistry; quality control; surrogate specimens; trace elements.

Trace element analysis, not uniquely, but to a unique degree, is affected by the problems associated with contamination of the specimen during the process of collection, as well as by the contamination of reagents and the environment during the process of analysis, which will be discussed in other presentations.

The quality control of accuracy in trace element analysis must therefore cover all phases of the analytical process, including collection. Such an extension makes it necessary to use surrogate specimen material with defined trace element(s) content beyond the laboratory, that is, in the sphere of specimen collection in the field, on a regular, protocol-directed basis. The protocol for using such surrogate specimens for accuracy control should be directed to the exposure and display of any variations in systematic bias which may occur. Such bias, or error, may be either positive or negative and may arise from defects or alterations in collection materials or in procedural errors in the collection process.

The nature of the surrogate specimens required for accuracy control depends upon both the type of specimens to be collected and analyzed and the details of the analytical process itself.

The role of the National Bureau of Standards Standard Reference Materials in accurate trace analysis, J. P. Cali and W. P. Reed, *SP422*, pp. 41-63 (Aug. 1976).

Key words: accuracy; accurate measurement system; precision; reference methods; standard reference material; systematic errors.

A meaningful measurement process is capable of producing numerical values of the property(ies) under test or measurement that are compatible throughout the measurement infrastructure. By this we mean that all the measurement laboratories within a given industry or technological or scientific area are capable of and, in practice do, produce measurement values for a given property on a given material that are identical and immediately comparable within some agreed on uncertainty. Such measurement compatibility results when accurate measurements are the basis upon which the work is founded. When a measurement system is accurate, then the numerical values produced are free of systematic errors and are also precise. We will show that, in practice, a certain degree of precision must be obtained before assertions of accuracy can be realistically tested experimentally.

One mode by which accuracy may be transferred to all laboratories within a measurement infrastructure is through the use of reference materials used in conjunction with reference methods. At NBS reference materials are called Standard Reference Materials (SRM's). They are well-characterized materials (in terms of accurately determined properties) useful for the calibration and/or assessment of a measurement system. When SRM's are used in conjunction with a reference method, i.e., one of demonstrated accuracy, then it becomes possible to transfer accuracy throughout an entire measurement infrastructure. How this is accomplished will be discussed.

Obviously the assurance of the "built-in" accuracy of the SRM is critical. How this is done at NBS will be discussed. Finally, currently available SRM's useful in trace analysis will be considered, as well as work now in process and future plans for additional trace SRM's.

Interpretation of accuracy of trace element results in biological materials, G. H. Morrison, *SP422*, pp. 65-77 (Aug. 1976).

Key words: accuracy; biological materials; data interpretation; standard materials; trace elements.

With the recent realization that trace elements have a very important role, either beneficial or harmful, in man, trace element analysis has become an increasingly important field of research in clinical medicine, biology, nutrition, and environmental studies. Many researchers have investigated the amounts of various elements in man, animals, plants, and types of tissues.

The interpretation of trace analytical results for biological

materials is discussed from the viewpoint of their accuracy. Interpretation of results of an analysis of an unknown sample depends to a great extent on prior evaluation of the analytical method employed. The accuracy of the method is best determined by the analysis of standard samples. In the absence of standard samples of a similar nature to the unknown samples, the results of the method are compared with those obtained by other methods of analysis. Both of these approaches are discussed. An evaluation of published results for the determination of the 15 trace constituents in the standard reference material Orchard Leaves is presented from the viewpoint of accuracy.

A case history is presented to illustrate the problems associated in the development of a method for a biological sample and the evaluation of the accuracy of the method.

Precision and accuracy in silicate analysis, S. S. Goldich, *SP422*, pp. 79-89 (Aug. 1976).

Key words: accuracy; analytical bias; reference samples; silicate analysis.

The precision and accuracy of analytical results in geological publications range widely. High-quality analyses are typical of the research in geochronology and in other areas of isotopic investigations, and this work has resulted in substantial improvement in the data that are now evolving in more routine geological investigations. The trace elements Rb, Sr, Ba, and the rare earth elements are widely used in petrological investigations, and accurate results are obtained routinely by isotope-dilution techniques and mass spectrometric measurements. It is now commonplace for the results from different laboratories to agree within 1 to 2 percent of the amount present. In contrast, the results from atomic absorption, x-ray fluorescence, neutron activation, and optical spectrographic methods are much more variable and are less reliable. The increasing availability of reference samples is easing some of the problems of the instrumental analyst, but the reference samples have some problems of their own. The lack of well-characterized reference samples is a major barrier to better quality instrumental analyses.

Use and interpretation of water quality data, W. T. Sayers and W. R. Ott, *SP422*, pp. 91-107 (Aug. 1976).

Key words: accuracy; data interpretation; monitoring; water; water quality.

Water quality data are collected by State and Federal pollution control agencies to characterize baseline quality, identify trends, detect and document violations in quality standards and discharge permit conditions, develop mathematical models for determining present and future pollution control requirements, and characterize the movement, fate, and effects of specific pollutants entering the water environment. This information is used in formulating and implementing water quality management goals, strategies, and plans and in evaluating the effectiveness of resulting local, State, and Federal pollution abatement efforts. The kinds of interpretations to be made from water quality data, the interpretive methods to be used, and the level of reliability desired of the results must all be decided before an effective sampling program can be designed. These considerations dictate the number and spatial arrangement of stations, the parameters to be evaluated, sampling frequencies, and the duration of the sampling program. Because of supportive relationships among parameters, data on a given parameter are seldom evaluated independently of the data on the other parameters measured. Results are grouped in various combinations and displayed in any of a number of ways for interpretation, depending on the objectives in mind. Statistical procedures are an important tool in the interpretive process, but should never be used as a substitute for judgment. The economic and other impacts of management/legal decisions based on the data require that proper consideration be given to data reliability measures and the confidence levels of the results obtained, in addition to the results themselves.

Interpretation of clinical laboratory data, D. S. Young, *SP422*, pp. 109-122 (Aug. 1976).

Key words: accuracy, precision and specificity of analytical methods; biological and genetic variability; clinical laboratory data; specimen collection; specimen handling.

The central role of the clinical laboratory in the diagnosis of some diseases is discussed as well as some of the potential consequences of misinterpretation. Examples of the influence of both *in-vivo* and *in-vitro* factors on the interpretation of results are presented.

The genetic background and biological variability of the individual influences the data, even when he is healthy. The disease process may have a greater or lesser effect on laboratory data. In general, physicians usually request those tests to be performed that they anticipate being abnormal, so that the influence of disease on the test performed in the clinical laboratory is usually quite large. Other *in-vivo* influences include the mode of collection of specimens for analysis. Outside the patient the preparation of the specimen for analysis may affect the analytical results. Finally, the accuracy, precision and specificity of the analytical procedures in the clinical laboratory affect the data. It is only this group of factors that the clinical chemist is able to control and yet knowledge of both laboratory and patient factors is essential for the correct interpretation of data.

The analyst and accuracy, F. P. Byrne, *SP422*, pp. 123-126 (Aug. 1976).

Key words: accuracy; analytical chemistry; standard reference material; statistics; syndrome.

It sometimes happens that an analytical chemist, in evaluating the accuracy of his analysis, subconsciously obtains highly precise and accurate analyses, when in fact, the method and techniques he uses cannot possibly yield such results. This can happen even when he uses standard reference materials or carries out a series of repetitive analyses. Examples of these are discussed along with examples of other human foibles that may leave the analyst with a false impression of his accuracy and precision.

Detection of systematic errors by the analysis of precision, K. Heydorn, *SP422*, pp. 127-139 (Aug. 1976).

Key words: accuracy; analysis of precision; *a priori* error; *a priori* precision; *a posteriori* precision; chi-square test; precision; precision of analytical method; ultratrace level.

The extension of accuracy in trace element analysis to the ppb level cannot be based directly on the study of Standard Reference Materials because most of these are certified only at the ppm levels. Control of accuracy at such low levels may be achieved by an analysis of precision which serves to detect unknown sources of variation in replicate measurements. This approach was used to locate errors in connection with the determination of arsenic in human serum by neutron activation analysis. Successive applications of the analysis of precision led to the detection of two unknown sources of variation. In addition, the analysis of precision indicated that the current evaluation of

small photopeak areas was not entirely unbiased. The apprehension of these errors led to changes in the methodology which in turn yielded both better precision and improved accuracy at the ppb level of concentration.

Detection of systematic error in routine trace analysis, D. E. ing, *SP422,* pp. 141-150 (Aug. 1976).

Key words: analytical performance; between-run; calibration; precision; quality control; systematic error; Youden plot.

The Youden technique has been modified in order to monitor systematic error between runs. When a laboratory appears to have systematic error problems, it is important to know whether or not this is typical of the routine operation. The procedure to be described examines the sum and difference of the results obtained on each of two control samples. Simple statistics permit long-term analysis of the results of such control analyses to separate within-run, or random effects, from the systematic effects occurring between runs. This simple sum/difference approach has been applied in a wide variety of water and wastewater analytical procedures. The blank determination in trace analysis has been implicated, in many cases, as the most significant source of systematic error.

The application of cluster analysis to trace elemental concentrations in geological and biological matrices, E. W. Stromberg nd J. L. Fasching, *SP422,* pp. 151-162 (Aug. 1976).

Key words: air particulates; blood; chemistry; computer graphics; geochemistry; medicine; pattern recognition; trace elements.

In the past it has been difficult to accurately interpret the information provided by trace elemental analysis, especially when concerned with biological and geological studies where there may be many variables involved other than simple elemental distributions. Utilizing a combination of hierarchical cluster analysis, factor analysis, and canonical correlation, data is presented showing how these three statistical methods may be combined to study the relationships of trace elemental concentrations in geological and biological matrices. Clusters of elements are found which are not readily apparent from examination of either raw data or simple correlation matrices.

Individual variation of trace metal content in fish, J. R. Montgomery, S. E. Kolehmainen, M. D. Banus, B. J. Bendien, J. L. Donaldson, and J. A. Ramìrez, *SP422,* pp. 163-172 (Aug. 1976).

Key words: atomic absorption spectroscopy; fish analysis; sample size variations; trace analysis; trace metals.

Fifty herring *Opisthonema oglinum* (Le Sueur) were collected from Boquerón Bay, Puerto Rico in one gill net haul. Each whole fish was wet-digested and analyzed as a separate sample in triplicate for Fe, Zn, Pb, Cd, Cu, and Mn using atomic absorption spectrophotometry. Results were correlated to the size of the fish. The concentration of Fe, Zn, Cd, and Cu was significantly higher in the pooled small fish as compared to the pooled large fish. The Pb concentration showed no detectable difference between the size classes. However, the Mn concentration was significantly higher in the pooled large fish as compared to the pooled small fish. The mean concentrations of these metals were statistically compared to the results of a pooled sample of fish collected and analyzed identically and to a pooled sample of thread herring collected in another location at a different time. No significant difference was found between these two pooled samples of medium size fish or between the trace metal values for the individual medium size fish. A determination of the sample size necessary to detect a 15, 20, and 25 percent difference between two significantly different means showed that a minimum sample size to detect that magnitude of difference would be 124, 70, or 50 fish respectively.

Accuracy of chemical analysis of airborne particulates—results of an intercomparison exercise, F. Girardi, *SP422,* pp. 173-188 (Aug. 1976).

Key words: accuracy; activation analysis; airborne particulates; air filter analysis; atomic absorption; emission spectroscopy; environmental pollutants; intercomparisons; multi-element analysis; trace element analysis; x-ray fluorescence.

Since suitable standard reference materials for chemical analysis of airborne particulates are not available, an intercomparison exercise was carried out among 40 interested laboratories in order to evaluate the accuracy of various trace analysis techniques for this specific application. Six hundred grams of airborne particulates were collected from the inlet filters of the air conditioning installation of a hotel in the center of Milan. The sample was sieved to remove coarser particles, thoroughly mixed, and distributed in 1 to 5 gram aliquots. The homogeneity was checked by relative measurements carried out by three independent techniques. For 40 elements no inhomogeneity was found to exceed the analytical error, which was estimated to be approximately 10 percent. The data of the analytical exercise are being collected and evaluated. Results are available for 56 elements, but to date only 33 have been determined by more than one technique. Activation analysis, emission spectroscopy, atomic absorption, x-ray fluorescence and various wet chemical methods contributed to the intercomparison. No result was received from mass spectroscopic methods and, although analyses were specifically encouraged, very few results were received on the organic components. From a first approximate evaluation a good agreement was found for Al, Fe, Zn, Mn, Ca, Pb, Cl, S, Si, Ti, Mn, while for the other elements no definite conclusion can yet be drawn. An attempt will be made to interpret important cases of systematic errors, a few of which are already evident.

The estimation of accuracy in trace analysis. Results obtained from intercomparisons organized by the I.A.E.A., L. Górski, J. Heinonen, and O. Suschny, *SP422,* pp. 189-197 (Aug. 1976).

Key words: accuracy; activation analysis; air filter analysis; analytical quality control; atomic absorption spectrometry; environmental analysis; fresh water analysis; intercomparisons; precision; round-robin experiments; trace element analysis.

The 1972 and 1973 I.A.E.A. round-robin exercises concerning trace analysis in environmental problems are reported. Paper filters simulating air filters were spiked with known amounts of salts of: As, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, V, and Zn, in the order of micrograms of an element per one filter. Only Fe and Pb were present in the order of 200 μg. Twenty-two laboratories returned 922 analytical results obtained by 6 different methods—mostly neutron activation analysis and atomic absorption spectrometry. Tables summarizing the results for each element are presented with special emphasis on the difference between the true value and the reported results. The need and the utility of the Analytical Quality Control programme

of the Agency is also discussed.

Accuracy assurance in the analysis of environmental samples, R. K. Skogerboe and S. R. Koirtyohann, *SP422,* pp. 199-210 (Aug. 1976).

Key words: accuracy; anodic stripping voltammetry; arc emission spectroscopy; atomic absorption; environmental analyses; interlaboratory tests; neutron activation analysis; plasma emission; round robin; x-ray fluorescence.

Three soils, two freeze dried blood pools, two (NBS) plant leaf samples, and one (NBS) freeze dried liver sample were analyzed in an interlaboratory program undertaken by NSF(RANN). Three independent methods produced agreement within ± 20 percent for the soils and pooled blood. The values for the plant leaves were within the experimental error as estimated by the standard deviations given for the round robin results. The liver results showed excessive scatter.

Subsequent tests included the use of NBS reference samples, the preparation of secondary reference materials, resubmission of previously analyzed samples, and the use of several methods for the same determination. Methods used for cross checking included atomic absorption with and without chemical separation, nonflame atomic absorption, arc emission spectroscopy, plasma emission, anodic stripping voltammetry, neutron activation analysis and x-ray fluorescence. In most cases the agreement between methods was good, but enough problems were identified and subsequently corrected to establish the value of the program.

The steps taken in the two laboratories represent an adequate, yet practically attainable program to assure accurate results in a centralized analytical support laboratory for a university or other large research organization.

Four-laboratory comparative instrumental nuclear analysis of the NBS Coal and Fly Ash Standard Reference Materials, J. M. Ondov, W. H. Zoller, I. Olmez, N. K. Aras, G. E. Gordon, L. A. Rancitelli, K. H. Abel, R. H. Filby, K. R. Shah, and R. C. Ragaini, *SP422,* pp. 211-223 (Aug. 1976).

Key words: analytical methods; coal; environmental samples; environmental standards; fly ash; instrumental neutron activation analysis (INAA); instrumental photon activation analysis (IPAA); natural radioactivity; standard reference materials; trace elements.

The NBS coal and fly ash Standard Reference Materials (SRM 1632 and 1633) were analyzed for 37 elements in coal and 41 elements in fly ash mainly by the use of instrumental neutron activation analysis (INAA), augmented by instrumental photon activation analysis (IPAA) and direct counting of natural γ-ray activity. For most elements measured, there was excellent interlaboratory agreement between the four participating laboratories and with the National Bureau of Standards values for elements measured by them and in this work. In cases of most elements for which comparisons can be made, instrumental nuclear methods used in a round-robin study of the standards provided more accurate average concentrations and smaller interlaboratory dispersions of values than the other major techniques used, atomic absorption spectrometry and optical emission spectroscopy.

Trace element studies of a selected portion of the Mahoning River system, I. Mahadeviah, E. Mooney, and R. Munteau, *SP422,* pp. 225-230 (Aug. 1976).

Key words: atomic absorption analysis; Californium-252; Mahoning River: neutron activation analysis; pollution; sediment; trace elements; water; wet chemical analysis.

The Mahoning River flows through a highly industrial ized section of eastern Ohio. It is used as a dumping ground for both solid and liquid wastes by both industry and mu nicipalities along its banks.

Both water and sediment samples were collected a predetermined sites on a section of the Mahoning River running from its headwaters into and beyond one of the in dustrialized areas. The water samples were analysed fo trace elements by neutron activation analysis (NAA) em ploying Youngstown State University's 10 mg Californium 252 neutron source, wet chemical techniques, and atomi absorption (AA). Certain trace elements, Ca and Mg, in th water samples were detected by all three methods. Com parison of results showed good agreement between NA and wet chemical analysis for most samples. AA data, fo the most part differed considerably from both NAA an wet chemical analysis. Subsequent tests have shown tha organics, which are plentiful in the Mahoning River, ar responsible for erroneous results in AA analysis.

Neutron activation analysis was shown to be the simples of the three methods for trace element analysis and the loca tion of possible sources of pollution.

Analysis of 11 elements in biological material. Comparison o neutron activation analysis and atomic absorption analysis, H Wesch and A. Bindl, *SP422,* pp. 231-238 (Aug. 1976).

Key words: atomic absorption spectroscopy (AAS); com parison between NAA and AAS; neutron activation analy sis (NAA); time of analysis in NAA and AAS; trace ele ment content in liver biopsies; trace element content i tumor bearing animals; Wilson's disease.

Seven trace elements (Co, Cu, Fe, Mn, Mo, Se, Zn) an four bulk elements (Ca, K, Mg, Na) were analyzed by mean of neutron activation analysis and flame or flameless atomi absorption analysis.

The organic material was destroyed by wet or low tem perature ashing. Four different possibilities of analysi result from this arrangement. Time of analysis, accuracy reproducibility and real, not theoretical, detection limit wi be reported for each arrangement. The analyses were ca ried out with the 1577 NBS liver standard and our own live standard. The techniques will be discussed in reference t clinical and research applications. The reported results wi be based on analysis of liver biopsies and animal exper ments.

Determination of zinc in environmental matrices: A com parison of results obtained by independent methods, M. Ga lorini and E. Orvini, *SP422,* pp. 239-245 (Aug. 1976).

Key words: accuracy; atomic absorption; environmen neutron activation analysis; precision; x-ray fluorescenc

Zinc determination results in environmental matrices a reported by different laboratories in some recent inte laboratory comparisons, seems to have large biases. I order to achieve a better solution of the problem, an evalua tion of four different methods for the determination of zin content in environmental matrices is underway in ou laboratory.

The suggested methods are: a) XRF x-ray fluorescenc b) NAA(I) instrumental neutron activation analysis, c NAA(RC) neutron activation analysis, via radiochemica separation, and d) AAS atomic absorption spectrometry Each of these techniques give information on some critica step typical of each different method. SRF and NAA(require no sample treatment or dissolution or chemic procedures, and insure no loss of any component and n danger of contamination. Unfortunately some interferenc

due to some matrix content may occur, affecting in both ways the accuracy of the results. NAA(RC) techniques give results free from interferences from contamination, but require wet dissolution of samples or high temperature treatment which may affect the analytical results. AAS analysis may be affected by contamination from reagents and by the difficulties related to the sample dissolution. A critical evaluation of results acquired through these different methodologies on a dust sample is discussed.

Reliability of trace metal determination in freshwater by ameless atomic absorption (graphite tube atomization) in comarison with other chemical and physical methods, R. Vagemann, *SP422*, pp. 247-265 (Aug. 1976).

Key words: accuracy; flameless atomic absorption; freshwater; interlaboratory comparison; method evaluation; trace metal analysis.

An interlaboratory study of trace metal analyses involving seven different laboratories has been carried out, using river water samples and "synthetic" standards. The analytical precision for the flameless atomic absorption with graphite tube atomization was also established for eight different metals at various trace concentrations. The flameless atomic absorption method with graphite tube atomization is compared with 16 other techniques and methods used in the interlaboratory study, and the conclusion is reached that for a number of commonly determined metals the flameless atomic absorption method of measuring trace concentrations in dilute fresh water is as accurate a method as other more established methods. The relative standard deviation for interlaboratory determination of traces of zinc is consistently large, which indicates that this metal is relatively more difficult to measure accurately than most other metals that were investigated. The available analytical data for arsenic is small but sufficiently discrepant to indicate that arsenic is a most difficult metal to measure accurately at trace levels by most of the methods tried.

The accuracy of determination for most of the metals investigated would appear to lie within 20 to 45 percent, at the concentration levels prevalent in unpolluted fresh water.

The preparation and certification of trace mercury in water standard reference materials, J. R. Moody, P. J. Paulsen, T. C. Rains, and H. L. Rook, *SP422*, pp. 267-273 (Aug. 1976).

Key words: atomic absorption spectrometry; isotope dilution analysis; mercury in water, trace analysis; mercury in water, stabilization of; neutron activation analysis; spark source mass spectrometry.

The study of mercury in natural water supplies requires a Standard Reference Material (SRM) with a certified concentration at the 1 ng/g level. NBS SRM's have been prepared with nominal mercury concentrations of 1.5 μg/g and 1.2 ng/g. Confirmation of these values was obtained by neutron activation, atomic absorption, and isotope dilution-spark source mass spectrometry (IDSSMS). Nitric acid and trace amounts of gold were added to achieve a stable mercury concentration. The precautions observed for cleaning the glass and Teflon containers, preparation of mercury solutions, and the packaging of the SRM's are given. As an example of the care needed in the analysis of mercury at these levels, specific details are presented for the chemistry required to prepare samples for the spark source mass spectrometer (SSMS).

The influence of limits of laboratory accuracy and precision on the interpretation of blood lead analyses for industrial lead hygiene control, A. C. Eckert, Jr., *SP422*, pp. 275-282 (Aug. 1976).

Key words: accuracy; blood lead analyses; clinical chemistry; industrial lead hygiene; interlaboratory correlations; lead hygiene control; occupational exposure standard criteria; occupational health control; precision; trace element analyses.

Good laboratory accuracy in blood lead analyses can be obtained under some conditions but evaluation of the consistency of analyses of blood samples feasibly obtained from workers in industrial lead plants continues to present significant problems. The need for accuracy in blood lead analyses for industrial lead hygiene control is misunderstood because more than 45 years ago, long before there was any knowledge of blood lead levels, control of clinical lead cases had been achieved, and by 1949, 20 years of successful maintenance of such control was reported. The desirability of having an objective criterion, such as a maximum allowable blood lead level, for protection of the health of industrial lead workers is evident. However, adequate consistency of trace element analyses, even in relatively simple inorganic materials, is often not experienced even under some of the best conditions. Therefore, those who are concerned with reducing the lead hygiene control process to a routine, that can be administered in part by paramedical or nonmedical personnel, and those who are concerned with attempts to establish and enforce maximum allowable blood lead levels urgently need a clear statement that specifies the limits of the capability of the present technology to demonstrate the accuracy that would be essential to meet these objectives.

Sampling and sample preparation at the Geological Survey of Canada—The what, why, and how, J. A. Maxwell, *SP422*, pp. 285-297 (Aug. 1976).

Key words: contamination; geological sample; rocks and minerals; sample preparation; sampling; trace analysis; water sampling.

The landmass of Canada, with half of its 4 million square miles underlain by the Precambrian Canadian Shield, encompasses most of the main geological regions of North America, and presents the geoscientist with a wide diversity of geological terrains of varying degrees of complexity, economic interest and inaccessibility.

Among the chief concerns of the Geological Survey of Canada is that of providing a comprehensive inventory and understanding of the geological framework through its extensive field and laboratory studies, with emphasis upon those regions having high potential for the occurrence of additional economic mineral deposits.

Many factors influence the nature of a sampling program, which may vary from the taking of single "grab" specimens to the collection of large numbers of samples on the basis of a sampling pattern laid out according to a statistically devised plan, but the primary consideration is always to obtain a sample that will yield the best answer to the question being asked. Rocks, minerals, stream and lake sediments, soils, glacial deposits, water samples from lakes, streams, springs, muskeg and other sources, all of these have their use as a source of compositional, petrographic, isotopic, mineralogical, textural and other information.

Because of the often unique nature of a sample, the difficulty of obtaining additional samples, the succeeding extensive and frequently costly work to be done on the prepared material, and the conclusions that will be derived from the resulting data, it is of paramount importance that the sample be correctly prepared. Again, various factors

must be considered in the choice of method to be used, but the overriding concern must be to ensure that the sample prepared for study is truly representative of the sample submitted.

Sampling of biological materials, A. Speecke, J. Hoste, and J. Versieck, *SP422,* pp. 299-310 (Aug. 1976).

Key words: biological materials; chromium; cobalt; contamination; manganese; sampling; serum.

As many so-called essential elements are present in biological fluids and tissues in the subnanogram/gram range, contamination-free sampling and storage prior to the actual analysis is primordial. This is particularly the case when an essentially blank-free method like activation analysis is applied.

The used surgical equipment and storage vessels must be checked for their content of elements to be determined and adequate cleaning procedures must be adopted. As the tendency of liquid (or wet) samples to pick up contaminants from the vessel walls is much greater than that of dry samples, a drying (lyophilization) step should be enforced as early as possible after collection. (This will also prevent to a great extent the loss of traces to the vessel.) All samples should also be protected from dust as in an urban, industrial or laboratory environment airborne particles are important pollutants. All sample treatment and storage must be done in a dust-free room.

A typical example (the collection of human blood) will be discussed *in extenso,* together with the design of a dust-free room of simple conception and reasonable cost.

The adequacy and success of these procedures with continuous discipline is illustrated by the very low concentrations in serum obtained for Cr, Mn, and Co, respectively 0.15, 0.5 and 0.1 ng/ml. Furthermore as these elements are essential and the samples practically uncontaminated, the results present a Gaussian frequency distribution with a small standard deviation.

Accuracy in air sampling, J. P. Lodge, Jr., *SP422,* pp. 311-320 (Aug. 1976).

Key words: accuracy and precision; air; air particulates; air pollution; analysis of air; atmosphere; gaseous pollutants; sampling air.

The physical act of sampling the atmosphere for the subsequent determination of its trace composition is complicated by the fact that the atmosphere is not an equilibrium system. It contains numerous species that are mutually incompatible with one another, but that survive to be measured because of their extreme dilution. These arise from many point sources, many of them sporadic in nature, and hence the atmosphere is poorly mixed, even on a relatively small scale. This leads to serious problems in attempting to isolate a small portion of atmosphere in a form that may be carried back to the laboratory for subsequent analysis—or even analyzed *in situ.*

The planning of atmospheric sampling is further complicated by the statistical properties of the system. Simultaneous or sequential measurements, for example, within a city are not independent numbers, but tend to be highly autocorrelated. As a result, statistical judgments as to the number of necessary measurements to define mean levels within acceptable limits of accuracy have generally been misleading. In point of fact, most measurement networks have been designed around an available budget rather than around statistical ideality, and frequently without a clear notion of the purpose of the resulting data.

The reduction of orders of magnitude errors in lead analys of biological materials and natural waters by evaluating and co trolling the extent and sources of industrial lead contaminatio introduced during sample collecting, handling, and analysis, C. C. Patterson and D. M. Settle, *SP422,* pp. 321-351 (Au 1976).

Key words: accuracy of atomic absorption analytic techniques; accuracy of isotope dilution analytic techniques; errors in lead analyses; lead; lead contaminatio evaluation and control; lead in animals and plants; pollutio lead; sampling techniques; trace analysis of lead; water lead in.

Most present analytical practices for lead cannot reliab determine lead concentrations at the 1 ng/g level because a universal lack of familiarity with lead contamination du ing sample collecting, handling and analysis. Consequentl the great mass of published data on lead in plant and anim tissue and in water is associated with gross positive erro which obscure the meaning of most work dealing with lea at the few μg/g level.

It can be stated unequivocally that for lead concentratio in the μg/g range or less the investigator must know wi certainty the magnitude of the contribution of lead fro each individual reagent, from air exposure, and from co tainer walls; furthermore he must know the yields for ea step in the chemical separation procedure so that he c modify the contamination contribution at any given st caused by yields of less than 100 percent in the precedi step.

Techniques for the collection of uncontaminated sampl of fresh water, snow, sea water, and animal tissue a described. A clean laboratory for low level lead analyses also described and other sources of lead contamination a discussed and means of control evaluated.

Sampling for clinical chemistry, F. A. Ibbott, *SP422,* p 353-361 (Aug. 1976).

Key words: accuracy and precision; analysis of body fluid clinical analysis; clinical chemistry; clinical sampling; e zyme analysis; storage of clinical samples.

Three requisites must be satisfied for a physiological sa ple to be acceptable for analysis in the clinical chemist laboratory. If any of these three requisites is not met, t acquisition of a reliable and meaningful result is jeopardize

To begin with, at the time the sample is collected, the p tient must be in a physical state appropriate for the conte plated assay. Some of these physical requirements a reasonably apparent such as observance of being fasting, supine, and avoidance of hyperventilation. An example th is less obvious concerns the interference by radioacti material already present in the patient's blood upon radioimmunoassay.

The second requirement is for the blood drawn from t patient to be truly representative of that in the circulatio This implies circumvention of trauma to body tissu avoidance of damage to the blood cells and alertness to t possible introduction of contaminants.

Finally, the specimen must be maintained in a manner th preserves its composition with regard to the parameter to measured. While certain analytes remain stable for lo periods, others require the use of chemical preservatives that the sample be frozen. In some instances, no practi method of preservation has been developed.

High-purity reagents for trace analysis, M. Zief and J. H vath, *SP422,* pp. 363-375 (Aug. 1976).

Key words: analytical blanks; analytical reagents; contamination control; high-purity reagents; membrane filtration; mercury cathode electrolysis; prepurification; purity definition; reagent contamination; ultrapurification.

Determination of ultratrace (<1 μg/g) metal content in diverse matrices requires high-purity reagents for dissolution, preconcentration and supporting electrolytes. Trace impurities in these reagents fluctuate not only with the degree of contamination during purification and containment by the manufacturer but also with the care exercised by the analyst.

Particulates are a prime source of ultratrace impurities in inorganic salts. Most of the Fe, Pb and Cu in water soluble sodium and potassium reagents can be removed by submicrometer filtration under pressure. These impurities can be further reduced by mercury cathode electrolysis.

Although liquids are more easily purified, they are not stored as easily as solids. Accelerated aging studies for liquids, particularly the mineral acids, in leached glass or plastic containers are necessary to insure the integrity of the product. After the chemical has been purified and stored, it must be equilibrated with its container and analyzed under contamination-free conditions. Until full, accurate disclosure of procedural details for ultratrace measurements are published by suppliers and the laboratory analyst, inaccuracies attributed to systematic errors can be expected. Improper handling of high-purity reagents is frequently observed. For example, there is no point to use an expensive reagent when the container is allowed to collect dust on an open shelf or in the fume hood of a heavily contaminated laboratory.

Contamination of atmospheric particulate matter collected at mote shipboard and island locations, E. J. Hoffman, G. L. offman, and R. A. Duce, *SP422,* pp. 377-388 (Aug. 1976).

Key words: analytical blanks; atmospheric sampling; coastal sampling; contamination of atmospheric particulate samples; sample handling; shipboard atmospheric sampling.

As part of a study of the chemistry of marine aerosols, atmospheric particulate samples have been collected simultaneously on the bow and on the stern of the University of Rhode Island oceanographic vessel TRIDENT to determine the degree to which particulates generated or modified by the ship itself can influence the chemistry of ambient air particulates. Samples have been analyzed for a variety of trace elements, including Na, Mg, Ca, K, Fe, Cu, Mn, Al, and Pb. The results indicate that certain elements are most subject to this form of contamination.

It is possible to use meteorological parameters to determine whether or not samples are contaminated by local sources. Atmospheric particulate samples have been collected from coastal towers in Hawaii and Bermuda. The composition of the particulates at the Hawaii tower is dependent not only on meteorological conditions at the time of collection, but also on conditions *(e.g.,* wind direction, rainfall, *etc.)* 24 hours previous to sample collection. Detailed meteorological information is thus critical in remote locations to determine whether or not the sample collected is representative of the ambient atmosphere.

Sampling and analysis for sulfur compounds in automobile exaust, E. R. Blosser, L. J. Hillenbrand, J. Lathouse, W. R. ierson, and J. W. Butler, *SP422,* pp. 389-400 (Aug. 1976).

Key words: automobile exhaust; catalytic oxidation converter; dilution tunnel; isopropanol; particulate filtration; sulfate; sulfur dioxide; sulfur trioxide; sulfur trioxide condensation.

Fuel sulfur is oxidized to the dioxide and trioxide in automobile engines. Adding an oxidation catalyst for emission control may alter the SO_3/SO_2 ratio in the exhaust.

An engine, a current production V-8 equipped with 1975 emission controls including an oxidizing catalytic converter (but without exhaust-gas recirculation), was run at steady operating conditions on an engine dynamometer. The exhaust was passed through a conventional exhaust system to a 23-in-diameter, 36-ft-long dilution tunnel.

Samples were withdrawn from before and after the catalytic converter, from the tailpipe, and from before and after filters sampling the diluted exhaust in the tunnel. Material balances for the fuel sulfur were carefully checked to ensure that valid data were being obtained.

Experiments were conducted with several catalysts, at two levels of fuel sulfur content. The results indicate less than 1 percent conversion to sulfate when the catalyst is not used, but substantial conversion to sulfate with the catalyst in use at the operating conditions of the experiments. A large increase in particulate mass is observed with the catalyst; the increase has been shown to be largely sulfuric acid and associated water.

Considerable care must be exercised in the sampling and analysis of exhaust sample if errors are to be avoided. Details of the overall method, and reasons for the precautions taken will be presented, with data supporting the conclusions.

Preparation, analysis, and sampling constants for a biotite, C. O. Ingamells and J. C. Engels, *SP422,* pp. 401-419 (Aug. 1976).

Key words: biotite stoichiometry; geochemical standards; geochronological standards; K-Ar dating; sampling a biotite; sampling constants; standard biotite.

A 99.9+ percent pure 40-60 mesh biotite, intended primarily as a K-Ar dating standard, but useful in other applications, has been exhaustively analyzed. About 8 kilograms have been prepared for distribution.

Sampling constants K_s (*i.e.*, the weights of samples necessary for 1% sampling error) have been determined for potassium (0.005 g), for sodium (1 g), for total iron (0.005 g), for calcium (2 g), for aluminum (0.001 g), and for some other elements. Nonuniformity with respect to potassium, sodium, and calcium may be partly due to diadochic substitution: nonuniformity with respect to calcium may be caused in part by 0.02 percent of apatite impurity. There is evidence that the biotite is geochronologically inhomogeneous; it behaves as a mixture of two biotites of different K-Ar ages. The sampling constant for radiogenic argon is about 0.05.

Possibly the greatest value of this standard material will lie in its demonstration of the principles which ought to be observed during the preparation and distribution of geochemical standards. We hope that may be the first in a series of International Standard rocks and minerals which may be used with confidence to calibrate and control geochemical analysis.

An approximate method of computing errors in trace analysis due to sampling heterogeneous solids, F. J. Flanagan, *SP422,* pp. 421-427 (Aug. 1976).

Key words: analytical error; geochemical variance; particle size distribution; particle size errors; sampling errors; trace analysis.

An approximate method of computing errors in the determination of trace elements in silicate rocks, errors that may be attributable to the size distribution at the sample grains,

has been derived using the Poisson distribution and assuming no covariance between minerals and grain sizes. Standard deviations of trace-element analyses decrease as particle size decreases and as number of particles increases. Before a crushed rock is sampled, the analyst should ensure that the number of particles is so large that the relative error due to the number of grains in the portion for analysis will always be a magnitude or two less than other errors he may make in the analytical procedure.

Sampling and analysis of carbon contained in the primary coolant of pressurized water reactors, S. A. Meacham, *SP422*, pp. 429-438 (Aug. 1976).

Key words: analysis; carbon; crud; filtration; pressurized water reactors; primary coolant; sampling; water.

A portable high pressure in-line filtration device, developed by the Westinghouse Analytical Laboratories, was installed in a pressurized water reactor (PWR) primary coolant sample line and the suspended solids removed by filtration.

The filtration medium was a 47 mm diameter silver filter having a porosity of 0.45 μm. Collection times of 8 hours with an average flow rate of 2.66 liters per minute (42.1 gal h^{-1}) were made. Total volume of primary coolant processed per run was 1,275 liters and resulted in the collection of 3.3 milligrams of suspended solids; more commonly known as crud. This corresponded to a concentration of 2.6 $\mu g\,\ell^{-1}$ or 2.6 ppb in the coolant.

After sufficient crud has been collected, the pre-tared silver filter is removed from the high pressure housing, dried, and reweighed. Eleven millimeter diameter discs are cut from the filter and placed in a preconditioned quartz combustion system and heated to 1150 °C within 30 minutes. An additional hour at 1150 °C is required to ensure complete reaction of the crud sample with the oxidizing atmosphere. The quantitative liberation of carbon dioxide is collected in a trap cooled with liquid nitrogen and subsequently released and measured by gas chromatography. Provisions are made for blank determinations on an unused silver filter with appropriate corrections and aliquot size determined by gamma spectroscopy.

The method developed for this analysis is applicable in the range of 1 to 200 micrograms of carbon. The accuracy and precision of the sampling method and the analytical procedure are discussed.

Sampling and sample handling for activation analysis of river water, S. H. Harrison, P. D. LaFleur, and W. Zoller, *SP422*, pp. 439-455 (Aug. 1976).

Key words: filtering water; river water; sampling water for trace elements; suspended particulates in water; Teflon water sampler; trace elements; trace elements in water; water.

A complete preanalysis scheme for determining trace elements in river and estuarine water by instrumental neutron activation analysis is described. The design, operation and evaluation of a new Teflon water sampler is included in the presentation of the preanalysis scheme. The evaluation of this water sampler consists of replicate sampling experiments and a comparison with a commercial sampling bottle (Van Dorn). The water sampler described allows for filtration of the sample as it is transferred from the sampler to a storage container. Lyophilization (freeze drying) is used as the preconcentration technique for the dissolved species, *i.e.*, liquid portion of the sample. Normalization of suspended particulate data to the element scandium is presented as a useful technique for locating man-made heavy metal input sources.

Homogeneity considerations in trace analyses using the nuclear track technique, B. S. Carpenter and G. M. Reimer, *SP422*, pp. 457-459 (Aug. 1976).

Key words: detector techniques; nuclear track analysis; sample homogeneity.

Nuclear track results are compared to those obtained by other analytical methods using different quantities of homogeneous material.

Two different approaches are used to make the nuclear trace analysis of a sample more representative of the larger sample. Sample homogenization methods and detector manipulation are discussed.

Problems in sample treatment in trace analysis, C. W. Sill, *SP422*, pp. 463-490 (Aug. 1976).

Key words: ashing (wet and dry); chemical errors; contamination; dissolution techniques; fusion dissolution; radiochemical analyses.

One of the most important—and most neglected—parts of any analytical procedure is the initial decomposition of the sample. Not only must the sample matrix be dissolved but the element sought must be converted reliably to the proper ionic form before chemical reactions characteristic of that element can be obtained. Complete dissolution is especially difficult with the quadrivalent and pentavalent elements which form very refractory oxides, carbides, *etc.*, particularly after having been heated. For example, the plutonium in the ash remaining from dry ashing large samples of soft tissue requires much more powerful treatment for its complete conversion to the ionic state than merely boiling with nitric acid. Fusion with molten potassium fluoride is one of the simplest and most effective methods for dissolving metallic as well as siliceous refractories because of the stability of the fluoride complexes and the high reaction rates available at its melting point of 846 °C. Inclusion of a small quantity of potassium nitrate even permits rapid and complete dissolution of refractory carbides such as Carborundum. The cake can then be transposed either with sulfuric acid to a pyrosulfate fusion with simultaneous volatilization of both hydrogen fluoride and silicon tetrafluoride, or with nitric and boric acids to give a solution free of sulfate. Color slides of the entire process will be shown to demonstrate that the procedure is neither difficult nor time-consuming as is generally supposed.

Extremely serious problems can be introduced by evaporating solutions of quadrivalent elements to dryness or by neutralizing them to too high a pH. Powerful sequestering agents can be produced from orthophosphates in the sample that will completely change the course of the analysis unless recognized and provided for. Standardizations are frequently carried out in a careless and inaccurate manner. Contamination is one of the greatest problems in trace analysis and needs to be avoided by good management and understanding of the causes. Preservation of both samples and standards can be vastly improved by application of a little more fundamental chemistry. Many other important "details" will be discussed which are frequently ignored or overlooked because of preoccupation with the more glamorous facets of the procedure, such as elegant separations or measurement techniques employed.

Dissolution of organic materials, T. T. Gorsuch, *SP422*, pp. 491-507 (Aug. 1976).

Key words: ashing techniques; dissolution; dry ashing; organic materials analysis; trace element analysis; wet ashing.

The initial stage in the determination of trace elements, the destruction of the organic matter, is likely to introduce more errors than all the other stages put together.

There are two main families of decomposition methods, those involving air or oxygen and carried out at relatively high temperatures and those involving relatively large quantities of liquid reagents and carried out at temperatures limited by the boiling points of the liquids. Each of them has its advantages and disadvantages. The dry methods generally being characterized by high and relatively less controlled temperatures and with little or no separation of the required elements and the other solid components of the system, while with regard to the wet methods, the temperature is generally lower and there is separation at all times between the required elements and the solid components of the system. The technique using activated oxygen falls into a separate class of its own.

The problems during the decomposition stage are of two kinds, losses of the required elements, or contamination of the sample with extraneous material. The losses can be due to volatilization or to fixation on the solid components of the system and such losses are generally less serious with wet methods than with dry. Contamination on the other hand is often related to the quantities of reagents added and in this instance the dry methods are probably superior to the wet.

The problems encountered, particularly with regard to losses, will vary greatly with the element to be determined and the nature of the sample in which it is to be determined. Elements such as mercury and selenium are always difficult and samples containing chlorine in any form generally pose problems.

The role of the analytical blank in accurate trace analysis, T. J. Murphy, *SP422*, pp. 509-539 (Aug. 1976).

Key words: accuracy; analysts; apparatus; blank; contamination; environment; purity; reagents.

The inability to control the analytical blank, *i.e.*, contamination from all sources external to the sample, has seriously affected the accuracy of low level trace determinations. Most of the sources of the blank are variable and it is this variability that determines the uncertainty of the blank correction and, therefore, the lower limit of trace element concentration that can be determined with reliability. To improve both the accuracy and lower limit of trace determinations, it is imperative to control the variability of the analytical blank. The only practical way to accomplish this is to reduce the size of the blank itself by controlling the sources of the blank.

The analytical blank is composed of contamination from four principal sources, namely: the environment the analysis is performed in, the reagents used in the analysis, the apparatus used, and the analyst performing the analysis.

Environmental contamination is caused by particulates and gaseous compounds in the ambient air. Methods for reducing the blank from this source by the use of isolation chambers or "absolute" filters are described.

While commercially available high-purity reagents have helped the analyst to control the blank from reagents, they are frequently not low enough in trace element concentration and must be purified before use. Methods for the preparation of high-purity reagents, especially water and the mineral acids, are reviewed.

Contamination from beakers, containers, mortars and other apparatus can seriously affect the blank. Techniques for controlling this type of contamination are described with emphasis on the purity of materials.

The last source of contamination is that caused by the analyst during the analysis due to carelessness or poor technique. Suggestions are given to aid the analyst in this regard.

The analysis of surfaces and microstructural detail, F. Bacon and E. Lifshin, *SP422*, pp. 541-573 (Aug. 1976).

Key words: Auger spectrometry; electron microprobe analysis; ESCA; ion scattering; secondary ion mass spectrometry; surface analysis.

The spatial distribution of trace elements detected by bulk chemical analysis can be as important a factor in determining the properties of any material as its overall composition. In structural materials such as steel, for example, the presence of certain impurities below the 100 parts per million level, segregated to grain boundaries, can cause intergranular failure while a uniform distribution of the same concentration might have a negligible effect on mechanical properties. Similar examples can readily be cited regarding the influence of minor or trace constituents on electrical properties, corrosion, oxidation, adhesion and catalysis behavior.

New instruments for chemical analysis of fine structure and surfaces include electron and ion microanalyzers, as well as Auger, photoelectron and ion scattering spectrometers. It will be the purpose of this paper to review the present status and limitations of these techniques for local chemical analysis and discuss how they complement each other and more traditional methods of bulk chemical analysis.

The effects of container composition, storage duration, and temperature on serum mineral levels, G. L. Fisher, L. G. Davies, and L. S. Rosenblatt, *SP422*, pp. 575-591 (Aug. 1976).

Key words: atomic absorption spectrophotometry; calcium; container effects; copper; magnesium; potassium; serum minerals; serum storage effects; sodium; temperature effects; trace elements; zinc.

To evaluate the effects of various storage parameters on serum mineral levels, blood-bank pooled, human serum was stored in Erlenmeyer flasks of five different compositions at three temperatures. The samples were analyzed by atomic absorption techniques for calcium, magnesium, copper, zinc, sodium, and potassium at 0, 1, 2, 4, 8, 16, 32, and 50 days of storage. Container effects were highly significant for Zn, K, and Na, but were small with maximal container differences of 2 to 3 percent. To 16 days of storage, temperature effects were not significant, and at later times temperature was highly significant at room temperature for Ca, Mg, and Zn. The effect of storage time was highly significant for all elements: Zn showed a 20 percent decrease after 2 days; Ca, Mg, and Cu had 10 percent decreases at 2, 4, and 8 days, respectively; K and Na showed maximal decreases of 2 percent and 3.5 percent with storage time. For the elements Zn, Ca, Mg, and Na, decreases were observed after 4 days of storage with near return to the original values on day 8. The patterns of mineral change in serum suggested at least two mechanisms: (1) pH change and (2) at later times, bacterial growth. To test these hypotheses, two subsequent studies were initiated. In one study, pH of f shly pooled human serum was measured, and streak plates were counted for bacteria at the time of each elemental analysis under various storage conditions. In another study, serum pH changes were accelerated by physical techniques that accelerated the loss of CO_2. The data indicate that factors that influence serum pH levels appear to affect elemental concentrations.

Biological sample contamination due to quartz container in neutron activation analysis, B. Maziere, A. Gaudry, J. Gros, and D. Comar, *SP422*, pp. 593-604 (Aug. 1976).

Key words: biological analysis; container blank; neutron activation analysis; wet-ashing blank.

Activation analysis is not dependent on the purity of chemical reagents because these are used only after irradiation. However, in the analysis of biological samples a new source of "contamination" appears, due to the container in which the sample is irradiated. For this reason it is often necessary to separate the irradiated sample from its irradiation container before recording the activity. Since the quartz of the container is partly dissolved, it is necessary to eliminate contamination due to impurities adsorbed on the surface of the quartz ampoule. The values of the so-called "analytical blank" are given for some 15 elements, certain of which have a recognized importance in biology.

Preparation of biological materials for chromium analysis, W. R. Wolf and F. E. Greene, *SP422*, pp. 605-610 (Aug. 1976).

Key words: biological materials; biological standards; chromium; flameless atomic absorption; volatile chromium compounds.

In flameless atomic absorption spectrometry, introducing biological materials directly into a graphite furnace leads to a lower response than if the samples are pre-ashed. The decrease is due to organically bound chromium. Since few biological standards are available with reliable data as to chromium content, it is necessary to use inorganic standards of known chromium content and prepare the biological materials in such a way as to destroy the chemical history of the chromium. Studies were carried out on the NBS Standard Reference Material SRM-1577 (Bovine liver), looking at a variety of sample digestion and ashing procedures. An order of magnitude variation in chromium content was seen depending upon the type of sample preparation procedure used. The existence of volatile compounds of chromium that are lost during ashing or digestion steps has been postulated for an explanation of these different results.

Stability of chromium ions at low concentrations in aqueous and biological matrices stored in glass, polyethylene, and polycarbonate containers, V. D. Anand and D. M. Ducharme, *SP422*, pp. 611-619 (Aug. 1976).

Key words: adsorption losses; biological systems; chromium; stability; storage containers.

Low-concentration solutions of chromium (< 50 μg/dl), in either aqueous or biological matrices, frequently need to be stored for short or long term studies. Storage at low temperatures is usually considered the best available precaution against changes in concentration through adsorption or leaching or evaporation of water. Polyethylene containers are not appropriate for storage of aqueous chromium standards of low concentration. Borosilicate glass containers are preferred for the storage of low-concentration aqueous standards for up to 6 months. The stability of serum and plasma chromium concentration ($< 0.2 - 0.5$ μg/dl) is maintained in polyethylene vessels, if stored frozen at below -10 °C. Polycarbonate tubes were found adequate for storage of serum and plasma for up to 2 weeks, under refrigeration at 4 °C.

A possibility of state analysis of plasma spectrometry, S. Hanamura, *SP422*, pp. 621-625 (Aug. 1976).

Key words: plasma spectrometry; preliminary analysis; specimen decomposition; specimen evaporation.

This report describes a new method of state analysis b plasma spectrometry which is found to be very useful fo preliminary analysis of natural samples. An induction fur nace or an electric heater is used for the vaporization of thi solid sample and the resulting gas is introduced into th plasma torch. The vaporized sample enters the plasma flam in the order of height of boiling point and depends upon th temperature gradient of the furnace.

Preparation and analysis of aquatic-related samples, N. M Ferguson, J. R. Lund, R. R. Rickard, and L. T. Corbin *SP422*, pp. 627-632 (Aug. 1976).

Key words: aquatic insects; atomic absorption; clean room fish; mini-computer; sample preparation; toxic metals trace determination.

The use of a special room in which to prepare sample and high-purity reagents has become standard now. How ever, without adopting and judiciously following specia operating procedures to cope with those factors which af fect the accuracy of trace analyses, the analyst may en counter serious problems.

Special operating procedures have been followed withi the sample preparation laboratory to provide representativ aliquots of aquatic-related samples (fish, aquatic insects water, and water sediments) to other analysts for multipl element determinations. Procedures or preparatio techniques employed for aquatic-related samples have bee directed toward the final use of NAA, SSMS and AA fo the desired determinations. Criteria have been establishe to aid in the selection of applicable analytical methods Consideration is given to determining what degree of accu racy is adequate and to the expense necessary to achiev this accuracy. By following sound sample preparatio procedures in the sample preparation laboratory and by tak ing great care in making the final determination or measure ment, significant reductions in analytical costs can be real ized without compromising the accuracy of the analysis.

Stability of metal ions in aqueous environmental samples, A Rattonetti, *SP422*, pp. 633-648 (Aug. 1976).

Key words: filtration losses; metallic ions; pollution moni toring; rainwater analysis; sample stability; surface wate analysis.

The time lapse between the collection of aqueous en vironmental samples and the analysis affects the origina ionic concentration. Studies have proven the nonionic spe cies in a water sample have more of an effect on the veracity of an analysis than the "container wall" effect, and that ad justment to a pH of 2 at sample collection time is a "Pyrrhic victory." Lead, for example, will commonly increase a order of magnitude when unfiltered samples are adjusted t a pH of 2 upon collection. This effect is greatest when ele mental ions are present in the ng ml^{-1} range and lessens a the original ionic concentration increases.

Data is presented that behooves filtration of stream wate and rainwater samples prior to any acidification step. Th need to acidify the resulting filtrate is also discussed. Lithi um, sodium, potassium, cesium, magnesium, calcium, stron tium, manganese, iron, copper, silver, zinc, cadmium, alu minum, indium, and lead are examined. The insoluble phas retained on the filter can be digested with acid and also analyzed. The separate analysis of the filtrate and filter wil give a true representation of the occurrence of these metal in nature. Flame and flameless atomic absorption and emis sion are used to perform the trace analyses.

Resin-loaded papers—sampling and trace analysis using neutron activation and x-ray spectrography, S. L. Law and W. J. Campbell, *SP422*, pp. 649-658 (Aug. 1976).

Key words: ion exchange; sampling; x-ray fluorescence.

Resin-loaded papers, composed of approximately 50 weight percent cellulose and 50 weight percent resin, provide an ideal medium for sampling large volumes of solution, then determining the concentrated elements by either fluorescent x-ray spectrography or neutron activation. This combination of chemistry and spectrography offers a versatile quantitative approach to the determination of trace elements in the ppm-ppb range. Standards and unknowns are prepared by either multiple filtration of solutions through two or more papers to measure the collection efficiency or a radiotracer is added to the solution to serve as a collection monitor. Reagent and paper blanks are incorporated into the analytical procedure. Papers containing strong acid or base resins collect a wide range of ions. Specific ions are collected by either chemical processing of the solution prior to filtration through the resin-loaded paper or by the use of papers loaded with chelating resins having high specificity.

Advantages of the resin-loaded paper approach prior to spectrography are: Improved analytical accuracy as the standards and unknowns are present in similar matrices; sampling errors are reduced and sensitivity significantly increased by concentration of the elements from a large volume of solution; and x-ray and gamma-ray spectral interferences are greatly reduced compared to bulk analysis. Also standard papers can be reused and stored indefinitely for x-ray applications.

Examples of published applications to a wide range of industrial, environmental, and health problems are summarized together with applications by the Bureau of Mines to metallurgical and mining problems. Potential applications of new ion exchange resins and reagent-loaded papers are also considered.

Losses, interferences, and contamination in trace metal analysis—some examples, F. Amore, *SP422*, pp. 661-668 (Aug. 1976).

Key words: analysis; ashing; blood lead; contamination; dairy products; digestion; interferences; losses; mercury; trace metal.

The three main problems confronting the analysts in trace metal determinations are losses, interferences, and contamination. These problems occur at all stages of the analysis. Procedures requiring a minimum amount of sample manipulation are, therefore, desirable. Examples such as losses of copper, cadmium, lead and chromium in dairy samples routinely surveyed fr these elements in both a dry ashing and wet digestion procedure are discussed. Examples and discussion of interference problems and sources of contamination are also given. The use of blanks and spiking and continuous monitoring practices are emphasized.

Sampling problems and the determination of mercury in surface water, seawater, and air, H. A. Das and H. A. van der Sloot, *SP422*, pp. 669-699 (Aug. 1976).

Key words: activation analysis; adsorption isotherm; environmental samples; mercury; preconcentration; trace elements.

Analysis of surface water for mercury comprises the determination of both ionic and organically bound mercury in solution and that of the total mercury content of the suspended matter. Eventually, metallic mercury has to be determined too. These determinations require a sampling procedure which meets the following requirements: a) the concentration of suspended matter is not affected, b) the separation of the solid fraction from the sample is performed immediately after sampling without losses from the aqueous phase due to absorption and losses from the solid phase due to desorption at a too low pH, and c) the aqueous phase is processed immediately to prevent losses due to absorption on the wall of the container. A method for the routine determination of mercury in surface water and seawater was developed and applied to Dutch surface waters. The total sample volume is 2500 ml. About 500 ml is used for the determination of the content of suspended matter and the total amount of mercury in the water. The sample is filtered through a bed of previously purified active charcoal at a low flow-rate. The main portion ($\simeq$ 2000 ml) passes a flow-through centrifuge to separate the solid fraction. One liter is used to separate "inorganic" mercury by reduction, volatilization in an airstream and adsorption on active charcoal. The other liter is led through a column of active charcoal to collect all mercury. The procedures were checked with ^{197}Hg radiotracer both as an ion an uncorporated in organic compounds. The mercury is determined by thermal neutron activation, followed by volatilization in a tube furnace and adsorption on a fresh carbon bed. The limit of determination is $\simeq$ 1 ng l^{-1}. The rate of desorption from and adsorption on suspended material has been measured as a function of the pH of the solution for Hg^{+2} and various other ions. It can be concluded that only the procedure mentioned above does not disturb the equilibrium. The separation of mercury from air is obtained by suction of 1 m^3 through a 0.22 μm filter and a charcoal bed. The determination is then performed as in the case of the water samples.

Control of blanks in the analysis of phthalates in air and ocean biota samples, C. S. Giam and H. S. Chan, *SP422*, pp. 701-708 (Aug. 1976).

Key words: air analysis; analytical blank; gas chromatography; ocean biota analysis; phthalate trace analysis.

For the trace characterization of phthalates, gas chromatographs equipped with electron-capture detectors have been found to be more sensitive than those with flame-ionization detectors in the order of about 10^2. But the response (measured by peak height) of phthalates to electron-capture detectors are in the order of 10^2 less sensitive than that of chlorinated hydrocarbons (DDT, DDE, PCBs, *etc.*). The response of phthalates to electron-capture detectors is not constant and normally as little as 0.5 nanogram of di-2-ethylhexyl phthalate (DEHP) can be detected.

The following factors limit the detection of phthalates at ultra-low levels (parts per billion to parts per trillion in biota samples) with acceptable accuracy: 1) contamination from solvents, reagents and materials used in the analysis; 2) limitation from the size of the samples; and 3) polychlorinated biphenyls (PCBs) and DEHP contamination in the laboratory and their strong adsorption to glass surfaces.

This paper will describe the problem of background contamination from various sources—reagents, solvents and materials used in the laboratory—the procedure for the removal of these contaminants and the methods for the isolation and separation of phthalates in air and open-ocean biota samples.

Mass spectrometric analysis for fractional ppb atomic content of boron in trichlorosilane, J. A. Baker, *SP422*, pp. 709-714 (Aug. 1976).

Key words: boron measurements; mass spectrometry; semiconductor grade silicon; trichlorosilane.

$HSiCl_3$ is used to make semiconductor grade silicon. This silicon must have a boron content in the low ppb atomic range as measured by resistivity analysis; thus, purity of the raw material $HSiCl_3$ must be known in advance. A mass spectrometric technique was developed to analyze quantitatively the boron content in the $HSiCl_3$ relative to the observed boron deposited in the silicon.

A fixed volume of $HSiCl_3$ was evaporated and hydrolyzed onto a cleaned silicon electrode; the electrode surface area was approximately 20 square mm. A point silicon counter electrode was scanned over the surface of the coated large area electrode to spark the "deposited" residue. To obtain a limit of detection of 3 ppb atomic in the bulk analysis of a solid it is necessary to spark and produce a 300 nanocoulomb exposure on the analyzing photoplate. The evaporation and hydrolysis of $HSiCl_3$ produces a concentration factor as later determined of approximately 1000; thus, a surface exposure of 3 nanocoulomb will give a limit of detection of 0.3 ppb atomic. Experiments were performed on 8 samples covering a wide range of boron content and 16 samples at or near the limit of detection. Mass spectrometric analysis of each $HSiCl_3$ sample was performed and silicon poly rods were grown from each $HSiCl_3$ sample. The poly rods were float zoned 1 and 10 pass to determine by resistivity the boron and donor concentrations in the poly. A calibration curve was then constructed comparing the mass spectrometric boron concentration and the boron as determined by resistivity. The concentration factor of approximately 1000 was thus obtained for the mass spectrometric analysis of boron in $HSiCl_3$. The observed boron content thus refers to the boron deposited in polycrystalline silicon by the $HSiCl_3$ and not the boron content in $HSiCl_3$. This distinction is necessary; to demonstrate that one analytical technique is producing correct results it is necessary to calibrate it against a known standard technique. The measurement of boron in silicon by resistivity is an accurate technique is producing correct results it is necessary to validated. Thus, an analytical technique has been developed to measure impurity concentrations (in this case boron in $HSiCl_3$) in the fractional ppb atomic range in liquids with great accuracy.

The challenge of getting the lead out, E. Berman, *SP422*, pp. 715-719 (Aug. 1976).

Key words: atomic absorption spectrometry; blood analyses; contaminations; flameless methods; lead; lead blood analyses; methodology; trace element analyses.

Developments in spectroscopic instrumentation over the last decade have enabled determinations of the lead content in blood, other biological fluids, and tissues to become routine analyses in clinical laboratories serving metropolitan centers. Though not a technically difficult procedure in itself, maintaining the quality of lead analyses presents a few challenges. One must be cognizant of the pitfalls of a specific method and of the limits of its accuracy and precision. Instrumental limits, the matter of possible extraneous lead contaminants on the subject of analysis, the labware, the in-the-laboratory environment, the reagents, *etc.* must all be considered.

Factors influencing the integrity of lead determinations in the clinical laboratory, from sample collection to interpretations of analytical results with confidence, will be discussed.

Rapid homogenization and drying of biological material, I. Y. Donev, *SP422*, pp. 721-726 (Aug. 1976).

Key words: biological materials; homogenization; lyophilization; noncontaminating; sample preparation.

The determination of chemical trace elements in biological material presents many methodological difficulties. The most important difficulties of the sample's homogenization and enrichment are connected with the elimination of contamination with other elements or losses of the latter. Another problem is tissue lyophilization.

The paper describes the procedure for a relatively rapid drying and fine homogenization of biological materials for trace element research by means of nondestructive neutron activation analysis. Data are given on a double homogenizer and vacuum drying installation at liquid nitrogen temperatures. Wet homogenization of tissues is carried out in the inner homogenizer. This homogenizer is put into a second one, the lower part of which is utilized for fine mincing.

Each homogenizer has a capacity of up to 15 cm^3. The humidity taken away during the drying is approximately 75 to 90 percent, and depends especially on the tissue state.

The procedure was applied with success on serum, blood plasma and other biological materials.

The total installation allows the simultaneous drying of 13 homogenates. The total time for the drying and homogenization of 13 samples carried out by one trained laboratory assistant, is about 6 to 7 hours.

Problems in trace analysis of nitrosamines in foodstuffs, E. A. Walker and M. Castegnaro, *SP422*, pp. 727-736 (Aug. 1976).

Key words: carcinogens; food; nitrosamines; trace analysis.

Methods in general use are briefly reviewed. Epidemiological research in the region of the Caspian Littoral has demonstrated certain trends in the distribution of incidence of oesophageal cancer. Samples of typical foodstuffs from both high and low incidence areas have been analyzed for traces of N-nitrosamines. After extraction from the food, the nitrosamines were analyzed by oxidation to nitramines which were then separated by adsorption chromatography and determined by gas chromatography using an electron capture detector. Initial results suggested a correlation between levels of nitrosodimethylamine and oesophageal cancer incidence. However, the presence of nitrosamines could not be confirmed by mass spectrometry. As a result, the clean-up procedure was modified by inclusion of a further adsorption chromatography stage where some interfering material was eliminated and all levels of nitrosamine were reduced below the 1 $\mu g/kg$ level. The work demonstrates that even for screening analysis, clean-up procedures must be rigorous when carrying out trace analysis to avoid misleading results.

Effects of storage conditions on residues of 2,4-D and 2,4-DCP in potatoes, D. Bristol, *SP422*, pp. 737-745 (Aug. 1976).

Key words: gas chromatography; potatoes; residues, dissipation of; residues, in potatoes; residues, metabolic; residues, total; residues, volatilization; storage effects; 2,4-dichlorophenol; 2,4-dichlorophenoxyacetic acid.

Red potatoes grown in North Dakota are treated with low dosage rates of 2,4-D (2,4-dichlorophenoxyacetic acid) at tuber set to improve market quality and yield. Tuber residues of 2,4-D and 2,4-DCP (2,4-dichlorophenol) in potatoes treated at a total rate of 2 ounces of active ingredients per acre were found to range from 0.068 to 0.15 and from less than 0.002 to 0.012 ppm, respectively. Samples were analyzed both with and without an acidic tissue hydrolysis step which preceded solvent extraction to deter-

mine total and free residue levels, respectively. Conjugated residues of 2,4-D could not be detected in significant quantities.

The stabilities of 2,4-D and 2,4-DCP in stored samples were found to be very dependent upon both the manner in which field samples were processed and the temperatures used for storage. Residue levels of metabolically incorporated 2,4-D in treated potato samples stored whole at 4 °C decreased over a period of 15 months to less than 0.005 ppm but those of 2,4-DCP remained constant. The observed dissipation rate of 2,4-D was approximately first order with a half-life of about 10-14 weeks. In contrast to these results, obtained under conditions used for commercial storage, the stabilities of 2,4-DCP were reversed in tuber samples which were sliced, fortified and processed immediately after harvest and stored at − 20 °C. Recoveries of 2,4-D from frozen samples were constant over a 15-month period, but those of 2,4-DCP decreased slowly from 88 to 47 percent. These contrasting results point out the utility and necessity of incorporating dissipation experiments into residue studies conducted on samples stored for significant periods of time.

Sampling problems in the investigation of high purity metals, I. Radwan, L. Walis, and H. Jaskólska, *SP422*, pp. 747-755 (Aug. 1976).

Key words: high purity metals; inhomogeneity; microsegregation; sampling; surface contamination.

One of the vital problems in the determination of trace elements in metals is their inhomogeneous distribution in the matrix. Elements which dissolve in the metal matrix at elevated temperatures often concentrate during the crystallization process at the grain boundaries, or inside the grain. Elements which do not dissolve occur in the form of nonmetallic inclusions. The distribution of such inclusions is generally irregular, and obtaining results which are representative for the whole ingot is practically impossible. The error involved can be reduced, if the type and range of segregation of the element to be determined in the alloy is known and taken into account on sampling. Several examples are given.

Analytical methodology for accurate determination of trace constituents in highly pure materials, P. Albert, *SP422*, pp. 759-772 (Aug. 1976).

Key words: contamination; gas analysis; high purity; materials analysis; neutron activation analysis.

High purity materials analysis is a difficult problem and different analytical methods are used. This paper is devoted to the discussion of the principles of analytical methodology in two ways: 1. the accurate determination of one or a few trace elements in a high purity material, and 2. the accurate determination of the "complete analysis" in a high purity material with the purpose of defining the true number of "nines," at the level of six or seven "nines," in the conventional definition in percent purity. In the first case the ultimate goal of analytical measurement is a numerical result of known accuracy. The necessary conditions for the accurate and precise analytical determination of an element in a high purity material are discussed and the calibration, the "blank" and the "clean rooms," surface contamination, chemical recovery, and finally the need of certified purity reference materials are debated. In the second case the main problem is to make a selection of some complementary multielement trace analysis methods.

Discussion includes identifying and resolving the problems and identifying what areas require further research. Conclusions are made on general philosophy and attitude concerning the necessity of a general approach to guarantee the accuracy of trace analysis.

Analytical methodology—rocks and ores, H. Onishi, *SP422*, pp. 773-790 (Aug. 1976).

Key words: accuracy and precision; comparison of trace analytical methods; contamination; rocks and ores; sample preparation; trace element analysis.

To Goldschmidt we owe early knowledge of trace element geochemistry. He analyzed a variety of geomaterials by emission spectrochemical analysis during 1930-37. Colorimetric (spectrophotometric) procedures have been developed beginning with Sandell since 1936. Studies in trace element geochemistry have been greatly advanced by means of neutron activation analysis since approximately 1950. Isotope dilution mass spectrometry is gaining a central position as a reliable trace element analysis method; this has become possible through scrupulous control of blanks.

The blank can be related to the constituent in question and the interfering (positively or negatively) substances. Correction for contamination during sample preparation is usually very difficult. The blank is affected by reagents, vessels, and atmosphere or environment, all of which require the close attention of the analyst. Ways for reducing blank values are briefly mentioned.

Methods recently described for determination of trace elements in geomaterials are: spectrophotometric and fluorimetric, emission spectrochemical, atomic absorption and flame emission, x-ray fluorescence, nuclear (activation, nuclear track, *etc.*), electrochemical, mass spectrometry, and gas chromatography. Examples of comparison of methods are given. The following are to be considered in choosing the proper analytical technique: objective of analysis, sensitivity and detection limit, accuracy, precision or reproducibility, determination of single element or multielements, time and cost, and analyst.

The past, present, and future of the analysis of atmospheric particulates, R. K. Skogerboe, *SP422*, pp. 791-803 (Aug. 1976).

Key words: atmospheric particulates; direct analysis techniques; emission spectroscopy; particulate analysis; particulate characterization; sampling methods; X-ray fluorescence.

The determination of the composition of airborne particulate matter is a major task of escalating importance. The general requirements imposed on the analytical methods are typical: The multielement composition must be determined accurately and precisely over a wide concentration range. These accurate results are to be generated by the analytical method even though there may be major variations in the general composition of the particulate samples or in their "preparative" histories. Other emerging requirements include the determination of composition on a continuous basis in the field even at exceedingly low concentrations and/or the specification of composition as a function of particle size.

A comparative evaluation of the various analytical methods used for characterization of particulates is presented from the perspective of these requirements. The state of the art for several competitive analytical methods is summarized and their advantages and limitations defined. A synopsis of ongoing research is presented and potentially fruitful directions for analytical development are indicated.

Analytical chemistry of natural waters, D. E. Robertson, *SP422*, pp. 805-836 (Aug. 1976).

Key words: accuracy; analytical chemistry; contamination; errors; natural water; sample storage; sampling.

Analysts who have had more than a casual experience in trace element analysis of natural waters will unanimously agree that achieving accurate and precise results is indeed a difficult task. The reasons for these difficulties are numerous and begin with the collection of the sample. Many of the factors which govern the accuracy and precision attainable by present techniques and instrumentation for the measurement of trace element analysis of waters, from the sampling through the actual analysis, are discussed. Several case studies are presented which illustrate the parameters which must be carefully evaluated to ensure sufficient accuracy and precision in water analysis.

Analytical methodology for accurate analysis in clinical chemistry, S. S. Brown and F. L. Mitchell, *SP422*, pp. 837-850 (Aug. 1976).

Key words: accuracy; clinical analysis; clinical chemistry; health; precision.

Methods of measurement in clinical chemistry need to be continuously assessed to determine the degree of accuracy and precision required to ensure their optimum value for clinical purposes. Constant review is necessary since improvements in technology often show that much of what was once thought to be biological variation within and between individuals can be laboratory error. When biological variation is clearly known, it is pointless to provide measurements which may be costly when done beyond the required degree of accuracy and precision. In many cases however, that degree is not yet attainable in routine work.

Once determined, these levels of efficiency must be maintained and comparability of results ensured between laboratories and nations. Only comparatively recently have the principles which are required to achieve this, been formulated and understood. The first stage was the elimination, as far as possible, of human error by the large-scale introduction of automation and electronic data processing, then when precision was thus brought under control, it became possible to investigate accuracy.

Work in this direction using special reference technology, is proving that many of the well established techniques are far from satisfactory. New substances are required to be measured increasingly, and often, a technique may be accurate and not precise or *vice versa*, only an ability to monitor and maintain accuracy and precision with confidence in the clinical chemistry laboratory, will ensure continued progress in the use of clinical measurement in medicine. Ways of doing this will be discussed.

Trace level determination of triclosan by gas chromatography, F. H. Marquardt, J. Schulze, and D. Smith, *SP422*, pp. 851-859 (Aug. 1976).

Key words: bacteriostats; blood analysis; gas chromatography; trace analysis; triclosan; 2-hydroxy-2′,4′,4-trichlorodiphenyl ether.

The triclosan (2-hydroxy-2′,4′,4-trichlorodiphenyl ether) content in various substrates, for example, blood, can be determined by extraction into hexane, formation of the acetyl derivative, and gas chromatography over OV-17 with an electron capture detector, either with or without aldrin as internal standard. The precision and accuracy of this method is discussed.

Electrochemical trace analyses based on Faraday's Law, D. J Curran, *SP422*, pp. 861-869 (Aug. 1976).

Key words: automatic titrations; coulometric titration current integration; digital timing; epinephrine; linea sweep voltammetry; manganese; micrometer cell; thin laye electrochemistry; vanadium.

Thin layer electrochemical measurements and constan current coulometry can provide useful absolute methods fo trace analysis.

The difficulty to distinguish the coulombs consumed b the Faradaic process from the total coulombs consumed i the experiment can be minimized by the use of a null co cept with constant current coulometry. After adjustment the system to the null point, for example potentiometric, th sample is added and the system returned to the null by cou lometric titration. The electrochemical potential of th system is the same before and after passage of the electroly sis current, no charge can be lost or gained from charging o discharging of the double layer. Several examples of deter minations based on this concept are presented.

The coulometric method involves the use of an elec trogenerated titrant in almost all cases. A more direct ap proach to the use of Faraday's Law is provided by thi layer methods, where direct electrochemical conversion o the species of interest is carried out stoichiometrically Corrections for background coulombs must be made wit these techniques. Very small volumes of solutions as dilut as $10^{-5}M$ can be handled and several examples ar presented. In addition, it is possible to combine thin laye methods with electrochemical preconcentration technique to yield a versatile tool for trace analysis.

The non-faradaic background in pulse polarography, R. A Osteryoung and J. H. Christie, *SP422*, pp. 871-879 (Aug 1976).

Key words: background correction; differential puls polarography; dropping mercury electrode; electroanalysis pulse polarography; trace analysis.

The dropping mercury electrode, with its continuall renewed fresh surface, offers advantages for real sampl analysis. However, continuous expansion of the electrod drop requires a continuous non-faradaic current to maintai the charge density on the electrode surface. The technique of pulse polarography attempt to minimize this non-faradai component by differencing currents flowing before and afte application of a potential step to the drop. Nevertheless since these currents are measured neither at the same poten tial nor at the same time in drop life, the difference curren will contain a non-faradaic contribution, which is *nonlinear* function of a potential.

Extensive computer simulations of the effect of the non faradaic background on the analytical utility of puls polarography at trace concentrations indicate that inaccu rate results may be obtained if the true baseline is not know (as is likely for a real matrix). The magnitude of th background limits the amount of analyte that may be de tected and the nonlinearity of the background determine the accuracy with which the superimposed faradaic signa may be measured.

Recognizing that the double layer charging current is de pendent only on the potential and the time in drop life a which the current is measured while the faradaic current de pends on the history of the entire drop, we have devise three variants of pulse polarography which compensate fo the non-faradaic background current. These variants c pulse polarography are: 1. alternate drop pulse polarog

raphy. The output current is the difference in current for a drop whose potential is changed late in drop life and a drop maintained at the step-to potential throughout its life. 2. Twin electrode pulse polarography. The current output is the difference in current between two matched drops, both in the test solution, one of which is pulsed while the other is maintained at the step-to potential.

Improved anodic stripping voltammetry for accurate trace analysis, M. Ariel and J. Wang, *SP422*, pp. 881-897 (Aug. 1976).

Key words: anodic stripping voltammetry; background current compensation; differential anodic stripping voltammetry; electrochemical analysis; twin electrode balancing.

The unfavorable "signal to noise" ratio obtained during measurements carried out in very dilute metal ion solutions sets the lower concentration limit in anodic stripping voltammetry (ASV) determinations. The noise, deriving largely from the background current during the stripping step, is composed of a capacity current and a faradaic current contribution. DASV (differential ASV) and ASWC (anodic stripping with collection), carried out with *in situ* mercury film formation at rotating glassy carbon disc or ring-disc electrodes respectively, efficiently reduce residual current interference and significantly improve the reliability of ASV methods, as applied to real sample analyses.

DASV is carried out at identical twin working electrodes balanced against each other and immersed in the sample solution, to which Hg^{+2} ions have been added. Preelectrolysis, carried out at both electrodes at the same potential but for different deposition periods, is followed by a stripping step during which the oxidation currents are substracted.

In ASWC, a rotating ring disc electrode is employed; conventional ASV at the disc is supplemented, during the stripping step, by simultaneous redeposition at the ring, kept at a suitably cathodic constant throughout the stripping scan, allowing unequivocal quantitative evaluation of collection current peaks. Very rapid scan rates may be employed during the disc stripping steps, resulting in improved sensitivity without any loss in accuracy.

The method, combined with thin film ASV, with the mercury film co-deposited *in situ* with the trace metals present on a glassy carbon ring disc electrode, yields excellent results in the analysis of trace metal solutions in the ppb (and lower) range.

Monitoring dissolved copper in seawater by means of ion-elective electrodes, G. K. Rice and R. J. Jasinski, *SP422*, pp. 99-915 (Aug. 1976).

Key words: adsorption; copper; cupric ion; flow cell; ion-selective electrode; seawater analysis.

The application of an ion-selective electrode method for continuously monitoring Cu^{++} in seawater, without sample pretreatment, is described.

The necessary sensitivity of the Cu^{++} selective electrodes was achieved by preconditioning the electrodes and by use of a flow cell configuration. Response times, even at trace concentrations, were found to be adequate for monitoring small changes in the Cu^{++} concentration of seawater.

Evaluating the effects of solid materials on the chemistry of Cu^{++} in seawater was simplified by the speed and convenience of the ion-selective electrode technique. In addition to the adsorption of metal ions on solid surfaced, Cu^{++} electrode analysis indicated that contaminants from some solid materials form complexes with Cu^{++} in solution. Other materials apparently introduce cations such as Fe^{+++} which can liberate Cu^{++} from some complexes. It was also found that changes in chemical properties such as pH measurably affect the distribution of Cu^{++} in seawater.

Operation of a trace sampling and analysis system aboard a ship is complicated by chemical and electrical effects of the ship's hull on the continuous seawater flow stream. A method was found for minimizing electrical "noise" in the flow stream and to distinguish the Cu^{++} potential of chemical contamination due to the ship from the ambient background of natural seawater.

The results indicate that it should be practical to develop trace analytical methods which require little or no sample pretreatment for true *in situ* analysis thus avoiding many of the problems of sampling and sample handling.

Electroanalytical determination and characterization of some heavy metals in seawater, M. Branica, L. Sipos, S. Bubic, and S. Kozar, *SP422*, pp. 917-928 (Aug. 1976).

Key words: Adriatic Sea; cadmium; copper; electrochemical analysis; heavy metals; lead; seawater analysis; speciation; stability of water samples; zinc.

Anodic stripping methods have been widely applied during the last 10 years for determination of some heavy metals in natural water systems. However, relatively little has been done on the physicochemical characterization and determination of species actually present in aquatic systems, which is of special importance for elucidation of respective biogeochemical cycle and fate of radioactive or industrial waste.

The experience on application of electroanalytical techniques is presented and discussed with regard to: 1) direct determination of concentrations of some metal ions; 2) characterization of the species actually present; 3) study of chelation, hydrolyzation and other interactions between metallic ions and organic ligands in natural aquatic system.

Anodic stripping voltammetry (ASV) with rotating glassy carbon electrode was used for determination of Cd, Pb, and Cu and slowly dropping mercury electrode was used for determination of Zn in the North Adriatic. The reproducibility of measurements, behavior of electrodes, the role of cell and storage bottle materials and sampling procedures are discussed.

A new method for characterization of the ionic state of metals at very low concentrations (10^{-9} to $10^{-8}M$), based on voltammetric measurements with accumulation at various constant potentials, is proposed.

The accurate determination of lead in biological and environmental samples by isotope dilution mass spectrometry, L. A. Machlan, J. W. Gramlich, T. J. Murphy, and I. L. Barnes, *SP422*, pp. 929-935 (Aug. 1976).

Key words: accurate and precise analysis; biological and environmental samples; blanks; homogeneity of lead content; isotope dilution mass spectrometry; lead analysis.

The accurate determination of lead in biological and environmental samples has become of great interest due to health considerations. Isotope dilution mass spectrometry (IDMS) has proven to be precise and accurate to within 0.15 percent. The IDMS method has permitted the accurate determination of trace quantities of lead in samples of biological and environmental interest as well as determining the inhomogeneity of the lead content.

IDMS has been utilized to provide certified lead values in Standard Reference Materials used by the fuel industry (coal, fuel oil and fly ash). These materials are to be used for comparison standards, quality assurance and developing or

verifying analytical methods. The lead content of a series of blood samples has also been determined by IDMS to provide accurate values in the development of a clinical reference method.

The method consists of taking a weighed aliquot of the sample, adding a known amount of separated isotope, decomposing the material with suitable acids, separating the lead by anion exchange, purifying the lead by electrodeposition, determining the lead isotope ratios by thermal ionization mass spectrometry and calculating the lead content of the sample.

Rare earth element analysis by isotope dilution, G. N. Hanson, *SP422*, pp. 937-949 (Aug. 1976).

Key words: analytical techniques; fractional crystallization; geochemistry; isotope dilution; partial melting; rare earth elements; trace element models; volcanic rocks.

At Stony Brook we have been analyzing igneous rocks, granites through gabbros, basalts, and ultramafic rocks for rare earth elements (REE) as well as the other major, minor, and trace elements in order to determine the origin of these rocks utilizing quantitative trace element models. For rare earths we are using the analytical procedure of J. G. Arth, USGS, Reston, Virginia, which utilizes two Dowex 50Wx8 cation columns, one for nitric acid to get a group separation of the REE and the other for hydrochloric acid to separate the specific REE. The rare earth elements La, Ce, Nd, Sm, Eu, Gd, Dy, Er, Yb, and Lu can usually be analyzed in three to four mass spectrometric runs with a total time for analysis of about 8 hours. The number of REE analyzed should not be reduced or the great advantage of the REE, the regular but not consistent variation from element to element, cannot be fully utilized in an interpretation. Precision is about 1 percent for all elements except for Lu and Gd. The uncertainty in the accuracy is somewhat greater.

Much of the REE data in the literature has uncertainties of about 5 percent or greater, and for gross comparison of rock types this data is adequate. REE data, however, with uncertainties much greater than 10 percent are no longer acceptable, as they are not useful even for gross comparisons of rock types.

In a detailed study of a magmatic sequence in order to distinguish differentiated fractions *versus* different original parents and to determine which residual or fractionating minerals are involved, then high precision on the order of 1 percent is absolutely necessary. In such a sequence, since it is only necessary to compare samples with each other, high precision is adequate as one can normalize all samples to a sample in the sequence. In order to compare data with other laboratories, however, high accuracy is also necessary. The uncertainty in the accuracy is mainly in not having adequate rare earth standards.

An accurate determination of electrolyte concentrations in blood serum by isotope dilution mass spectrometry, E. L. Garner, L. A. Machlan, J. W. Gramlich, L. J. Moore, T. J. Murphy, and I. L. Barnes, *SP422*, pp. 951-960 (Aug. 1976).

Key words: accurate; blood; concentrations; determination; dilution; electrolyte; isotope; mass spectrometry; serum.

Concentrations of the electrolytes Li, Mg, Cl, K and Ca were determined in three different lots of blood sera by isotope dilution mass spectrometry. Descriptions of the chemistry, mass spectrometry, and some of the precautions necessary to obtain an accurate measurement are given. An internal normalization technique which eliminates a systematic bias component due to variable isotopic fractionation between different analyses, was used to significantly improve the accuracy of the magnesium measurement. The experimental values for the three lots of sera followed a pattern of low, intermediate and high concentration levels for each electrolyte. The magnesium values in $\mu g/g$, for example were 8.546 ± 0.064, 24.52 ± 0.08, and 41.27 ± 0.10. The estimated limit of error for a single analysis, based on the 95 percent confidence limit and the effect of sample impurities ranged from 0.75 percent for magnesium in one lot of serum to 0.2 percent for the potassium concentrations.

Spiking isotope dilution and its application to fluorine determinations, H. A. Das and T. Wals, *SP422*, pp. 961-982 (Aug. 1976).

Key words: absorption isotherm; environmental samples; fluorine; isotope dilution; radionuclides; substoichiometry.

Isotope dilution is based on the isolation of a constant substoichiometric amount. This method can be completed by a group of techniques in which this amount is a function of the concentration to be determined. This approach enables the routine analysis of aqueous samples. The practical difference with normal isotope dilution is twofold: a) the activity is added as a spike to both the standard and the sample solution and b) the count rates obtained for the fractions isolated from the standard solutions, are plotted against the concentration in such a way that a linear calibration curve is obtained. Some methods which can be used in the application of this principle are discussed and compared to "classical" isotope dilution. Expressions are derived for the relative statistical error and the limit of detection. As a practical example of these techniques, the determination of fluorine is discussed. The radionuclide used is ^{18}F ($T\ 1/2 = 110$ min) which is prepared carrier free by irradiation of Li_2CO_3. The substoichiometric amount is taken by either absorption on glass beads or by imperfect liquid-liquid extraction with $(CH_3)_3SiCl$ dissolved in benzene. The glass beads or the organic extract are counted integrally. The reciprocal of the count-rate is a linear function of the concentration to be determined. The limit of detection is usually 0.01 $\mu g/ml$ while the limit of determination is $\simeq 0.05$ $\mu g/ml$. The method is applicable to both F^- and $SiF_6^=$ and is not sensitive to appreciable NaCl concentrations. The error is depending on counting statistics and on the ratio reagent amount to be determined. The method can be extended to dried plant material by ashing and dissolving the sample using ^{18}F-tracer for chemical yield determination.

The determination of small amounts of nitrogen (0 to 20 ppm) in plain carbon steels, H. F. Pronk, J. de Boer, and N. Butter Bijwaard, *SP422*, pp. 983-1003 (Aug. 1976).

Key words: atmospheric contamination; blank value; indophenol blue reaction; Kjeldahl digestion technique; limit of detection; nitrogen in steel.

The paper describes the results of a thorough experimental investigation into the original and reduction of the blank during sample handling and sample analysis in the determination of the total nitrogen content in plain carbon steel at levels of 0.002 percent and less. Attention is paid to atmospheric contributions to the blank and to their prevention. The possible harmful effect of nitrite or nitrate compounds on the analytical result is pointed out. Finally a method is recommended which is especially adapted for the determination of very low levels of nitrogen.

Trace element analysis of nickel and nickel-base alloys—review of current methods, C. M. Davis, *SP422*, pp. 1005-101 (Aug. 1976).

Key words: atomic absorption spectrophotometry; emission spectroscopy; nickel; nickel-base alloys; polarography; spectrophotometry; x-ray fluorescence spectroscopy.

Trace element analysis has been a frontier in the field of analytical chemistry for many years. Twenty years ago 0.01 percent was considered a "trace." Today, specifications require certain nickel-base alloys to have no more than 0.00003 percent (0.3 ppm) of some elements. The everchanging definition of the word "trace" has made trace element analysis a continuing challenge to the analytical chemist. This paper reviews the various approaches to this elusive problem and outlines potential solutions. The emphasis is on elements categorized as being detrimental to the mechanical properties of nickel-base alloys since these are of the greatest concern.

Among the methods reviewed are spark source mass spectrometry, emission spectroscopy, x-ray fluorescence spectroscopy, spectrophotometry, polarography, and atomic absorption spectrophotometry.

Nonuniform distribution (both micro and macro) of trace elements in high-temperature alloys, O. H. Kriege and J. Y. Marks, *SP422*, pp. 1017-1022 (Aug. 1976).

Key words: high-temperature alloys; intergranular segregation; macro-segregation; sampling problems; trace elements.

Because low melting metals such as bismuth, lead, selenium, tellurium and thallium can have a harmful influence on the mechanical properties of high-temperature alloys, the accurate determination of 0.3 to 10 ppm of these metals is of considerable importance. In developing reliable methods for the determination of trace elements in complex, high-temperature alloys, major sampling problems were encountered. Significant variations in trace metal concentrations were frequently noted in different parts of the same casting. For example, marked variations were sometimes observed between the top and bottom of small cast parts, other specimens had significantly different amounts of trace metals at the surface than at the center of the coating, while the concentration of certain trace metals was a function of wall thickness in some hollow parts. The common practice of sample selection by removal of material from noncritical regions of a casting to preserve the part can evidently lead to serious errors in cases when macro-segregation of trace elements exists. Various production practices which have produced analytically important macro-segregation are summarized in detail.

In addition to macro-segregation, significant intergranular segregation has been observed in high-temperature alloys. There is a pronounced tendency for certain trace elements to concentrate at grain boundaries rather than at the center of grains. With the increased commercial importance of directionally solidified and other large grain cast materials, the importance of this micro-segregation is increased, particularly when methods are used which involve the analysis of very small amounts of sample. Techniques for proper sampling of nonuniform, high-temperature alloys are reviewed.

In addition, those methods which are currently used to determine low concentrations of trace metals in high-temperature alloys are reviewed.

Monitoring of an atomic absorption spectrophotometer using umulative sum statistical control charts, J. R. Montgomery, *P422*, pp. 1023-1033 (Aug. 1976).

Key words: atomic absorption; cadmium; copper; lead; manganese; sensitivity; spectrophotometry; statistical methods; zinc.

A method has been devised to monitor the reproducibility of an atomic absorption spectrophotometer utilizing statistical control charts. Standard curves for five elements, Cu, Pb, Zn, Mn, and Cd have been monitored to determine if the cumulative sum type control charts with "V" mask can detect incipient changes in sensitivity of the atomic absorption spectrophotometer caused by alteration in lamp output, fuel, air mixtures and electronic gear. The cumulative sum chart is easily computed and allows the operator to quickly detect significant changes in the sensitivity of the machine.

Signal characterization and measurement in microsample atomic absorption spectrometry, R. S. Vogel and A. M. Hartley, *SP422*, pp. 1035-1043 (Aug. 1976).

Key words: atomic absorption; background correction; Delves Cup; lead; spectrophotometry.

Some of the errors encountered in atomic absorption spectrometry are broadband absorption due to light scattering by particles and absorption by molecular species originating from the sample matrix. Instrumentation for microsample techniques have been developed for typical volumes of 50 μl or less. The resultant transient absorbance signals are from one to several orders of magnitude greater than the same concentration in the 1-ml or more sample volume typically required by conventional solution aspiration methods. Background signals associated with the microsample methods are sometimes a major fraction of the total absorption signal. Literature dealing with these methods has emphasized the ubiquitous nature of background absorption and so-called "smoke" peaks. Specific absorption by atomic species might be mistaken for nonspecific background absorption resulting in significant errors. An example is given of this potential problem and how mistakes can be avoided.

Absorption signals characteristic of those from nebulizer-burner systems, as well as those from microsample systems are discussed. The conclusion drawn on the basis of the experimental evidence is not that the "smoke" peak attributed by others to nonspecific absorption is actually due to atomic absorption, but rather, when in the use of the microsample atomic absorption techniques, sequential absorption peaks are observed. Each of these peaks must be studied objectively or serious analytical errors may occur.

An intercomparison of flame and nonflame systems in atomic absorption spectrometry, T. C. Rains and O. Menis, *SP422*, pp. 1045-1051 (Aug. 1976).

Key words: atomic absorption spectrometry; nonflame graphite furnace; sensitivity *vs.* precision and accuracy; Standard Reference Materials.

In atomic absorption spectrometry (AAS) the nonflame devices for producing atomic vapor have recently received wide attention. In comparison to the traditional flame technique they offer increased sensitivity for many elements. On the other hand they seemed to suffer from poorer precision. In this study several of the parameters affecting the precision of the carbon furnace were evaluated and data were compared with NBS Standard Reference Materials (Fly Ash, Coal, and Orchard Leaves). Operating conditions, such as the sample volume, and the temperatures of the drying, ashing and atomization controlled the precision and accuracy of the measurement. The main advantage of the graphite furnace was the elimination of the preconcentration step and its inherent problem of larger blanks.

Atomic absorption spectrophotometry of air filter paper tape samples, F. J. Muñoz-Ribadeneira, M. L. Nazario, and A. Vega, *SP422*, pp. 1053-1061 (Aug. 1976).

Key words: air sampling; atomic absorption spectrophotometry; high temperature ashing; trace elements.

Several techniques for the preparation of air paper tape samples for trace metal analysis by Atomic Absorption Spectrophotometry (AAS) have been investigated. Known amounts of Cr, Mn, Co, Ni, Cu, Zn, Cd, and Pb were used to study the recovery of each under the effects of several preparative and digestion procedures. Conclusions obtained by means of a statistical analysis of the results are given. Statistical analysis of data obtained from the application of the most successful techniques when applied to natural air particulate samples are also presented.

Analysis of cadmium in fish tissue by flameless atomic absorption with a tantalum ribbon, E. R. Blood and G. C. Grant, *SP422,* pp. 1063-1072 (Aug. 1976).

Key words: atomic absorption; bluegills; cadmium; fish; heavy metal; tissue; trace element analysis; water pollution.

Bluegills *(Lepomis machrochirus)* of the same age and approximately the same size after acclimation were exposed to known amounts of cadmium (ppm level), sacrificed at selected time intervals and frozen whole in plastic bags until dissection and analysis. The heart, liver and kidney were removed entirely and portions of skin, muscle, gill, gut and bone were taken at the same time. Analyses were made by atomic absorption, following wet digestion in concentrated acid. All results are expressed as micrograms cadmium per gram of wet tissue. Typical values reported are in the range of 0.2 to 20 μg Cd per gram of wet tissue with a typical precision of 10-15 percent rsd for repetitive aliquots from the same organ. Corresponding organs from different fish, however, gave mean values differing from one another by as much as a factor of five.

Methodological considerations in western Lake Superior water-sediment exchange studies of some trace elements, J. E. Poldoski and G. E. Glass, *SP422,* pp. 1073-1088 (Aug. 1976).

Key words: anodic stripping voltammetry; flameless atomic absorption; interstitial water; Lake Superior chemical analysis; trace element water analysis; water filtration; water sampling apparatus.

Trace element measurements on western Lake Superior water were taken as a function of geographical area and distance above and below the water-sediment interface. The objective of detecting gradients of certain constituents in the system, however, required an extensive examination of required methodology. Investigations of this methodology indicate that the values obtained from a particular sample type are constrained by a number of uncertainties and operational definitions. Data were taken using different methods and experiments were conducted at various points in the analytical scheme to determine the influence of sample collection, handling and analysis steps. Results were of aid in determining where emphasis should be placed to improve the end result.

Accuracy in determining trace element concentrations in marine sediments, E. D. Wood and N. A. Cintron, *SP422,* pp. 1089-1102 (Aug. 1976).

Key words: accuracy; Atomic Absorption Spectrometry; Caribbean; precision; Puerto Rico; replicates; sediments; standard; trace elements.

When sampling the environment, one desires not only an accurate analysis of a particular sample, but also an analysis which is representative of the region sampled and one that can be repeated within reasonable limits. Replicate sediment samples were collected in the course of mapping a portion of the sea floor on the west coast of Puerto Rico. The location is in the discharge region of the Guanajibo River. Ten replicate grab samples were taken by independent positioning of the ship. The samples were stripped with hydrochloric acid and the resulting solutions analyzed by atomic absorption spectrometry (AAS) for Ca, Cd, Co, Cr, Cu, Fe, Mg, Ni, Pb, Sr and Zn. The standard deviations of replicate analysis of individual samples were generally less than for the individual samples themselves. Chemical standards prepared in our laboratory were used to determine the value of the samples. Particle size and homogeneity are factors considered with respect to the number of replicates required and sample size. The average concentrations for several elements in a set of 10 samples with confidence limits for 95 percent level as determined by AAS are as follows: Cd, 0.840 ± 0.011; Co, 56.5 ± 0.2; Cr, 696 ± 8; Cu, 30.7 ± 0.4; Fe, 60000 ± 1010; Mn, 827 ± 5; Ni, 487 ± 5; Pb, 17.2 ± 0.2; and Zn, 70.3 ± 0.8 μg/g dry sediment. A composite sample from this location was prepared for use as a standard in future sediment analysis.

Significant improvement of accuracy and precision in the determination of trace rare earths by fluorescence analysis, L. Ozawa and H. N. Hersh, *SP422,* pp. 1103-1107 (Aug. 1976).

Key words: fluorescence method analysis; rare earths, as an internal reference; rare earths, determination of trace amounts.

Most of the rare earths in yttrium, gadolinium and lanthanum oxides emit characteristic fluorescent line spectra under irradiation with photons, electrons and x rays. The sensitivity and selectivity of the rare earth fluorescences are high enough to determine the trace amounts (0.01 to 100 ppm) of rare earths. The absolute fluorescent intensities of solids, however, are markedly affected by the synthesis procedure, level of contamination and crystal perfection, resulting in poor accuracy and low precision for the method (larger than 50% error). Special care in preparation of the samples is required to obtain good accuracy and precision.

It is found that the accuracy and precision for the determination of trace (less than 10 ppm) rare earths by fluorescence analysis is improved significantly, while still maintaining the sensitivity, when the determination is made by comparing the ratio of the fluorescent intensities of the trace rare earths to that of a deliberately added rare earth as reference. The variation in the absolute fluorescent intensity remains, but is compensated for by measuring the fluorescent line intensity ratio. Consequently, the determination of trace rare earths (with less than 3% error) is easily made by a photoluminescence technique in which the rare earths are excited directly by photons. Accuracy is still maintained when the absolute fluorescent intensity is reduced by 50 percent through contamination by Ni, Fe, Mn or Pb (about 100 ppm). Determination accuracy is also improved for fluorescence analysis by electron excitation and x-ray excitation. For some rare earths, however, accuracy by these techniques is reduced because indirect excitation mechanisms are involved. The excitation mechanisms and the interferences between rare earths are also reported.

The advantages of x-ray fluorescence analysis for trace elements in silicate rocks, B. M. Gunn, *SP422,* pp. 1109-1118 (Aug. 1976).

Key words: mineral analysis; trace analysis; x-ray

fluorescence.

X-ray fluorescence (XRF) analysis has been successfully used to analyze over 1000 rock, cement and ore samples per year for elements including F, Na, Mg, Al, Si, P, S, Cl, V, K, Ca, Ti, Mn, Fe, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Ba, Cs, Ce, La, Pb, Th, and U. Detection limits are never greater than 10 ppm and optimally are as low as 1 ppm for 60 second counting times. Accuracy is mainly limited by the accuracy of available standards which for major and minor elements are not known to better than 0.1 to 0.01 percent. Data reduction and matrix corrections are made by computer and programs have been developed in both FORTRAN IV and FOCAL-11 language.

Monitoring of smog aerosols with elemental analysis by accelerator beams, T. A. Cahill, R. G. Flocchini, R. A. Eldred, P. J. Feeney, S. Lange, D. Shadoan, and G. Wolfe, *SP422*, pp. 1119-1136 (Aug. 1976).

Key words: aerosol; California aerosol monitoring program; elemental analysis; ion beam analysis; monitoring; particle sizing; time resolution.

The California Air Resources Board has operated an aerosol monitoring network of up to 15 stations since January 1973, using impactors to collect size segregated samples and ion-excited x-ray emission to perform the subsequent elemental analyses. Two-stage Lundgren-type rotary drum impactors with afterfilters collect particles in the 0.1 to 0.6 μm, 0.6 to 5 μm, and 5 to 20 μm size ranges. Alpha beams from an isochronous cyclotron, possessing energies of 18 MeV, are used to excite x-rays in the aerosol samples, which are then detected by a Si(Li) x-ray detector. On-line data collection and reduction codes generate aereal densities for elements between sodium and uranium, with sensitivities in the nanogram per cubic meter range for most elements. During the first year of operation, about 12,000 analyses were performed as part of this program. Each analysis normally included between 15 and 25 elements. In order to insure that all results were accurate, extensive programs were undertaken in quality assurance. The first concern involved proper operation of the aerosol collection systems. Uranene dye studies were able to generate information on the particle size cuts induced by the impactor slits, as well as indicate the importance of nonoptimum collection effects such as bounce-off from the drum surfaces. However, extensive studies with real aerosols were required before the problem of bounce-off for dry, silicious aerosols was solved by coating the drums with 530 $\mu g/cm^2$ mylar upon which was deposited about 50 $\mu g/cm^2$ paraffin. Penetration of the Nuclepore final filter contributed important corrections to the smallest size range, based upon the work of Spurney and Lodge. Operation of the collection system was verified through extensive comparisons on an element by element basis with high-volume filter samplers, and a nominal collection error of $\pm$ 15 percent was assigned from these causes. Absolute accuracy of the analysis system was established through the use of 28 gravimetric thin film standards, and confirmed by numerous interlaboratory and inter-method comparisons, all of which showed that the nominal analytical accuracy of $\pm$ 10 percent was quite conservative. Major corrections for light elements, loading effects, which limited accuracy to $\pm$ 30 percent for sodium in the worst case.

Characteristics of environmental airborne fissionable materi-
l, B. M. Center, K. E. Jackson, and F. H. Ruddy, *SP422*, pp. 132-1142 (Aug. 1976).

Key words: alpha particle tracks; fission radiography; solid dielectric track recorders; ^{239}Pu track.

Methods are reported for performing a quantitative assay of environmental air samples for fissionable material. Determination of size characteristics using the nuclear track technique is given and a comparison is made with size characteristics obtained from an aerodynamic (cascade impactor) separation. Special emphasis is placed on the important problem of detection of plutonium in the environment.

Analytical design in activation analysis: The role of accuracy and precision, D. A. Becker, *SP422*, pp. 1143-1155 (Aug. 1976).

Key words: accuracy and precision; activation analysis; analytical design; irradiation procedures; radioactivity detection systems; radiochemical separations; sampling and sample handling.

In order to obtain maximum utilization of the technique of activation analysis, a logical and systematic method for the evaluation of alternate analytical procedures is required, especially for analyses requiring a high degree of accuracy and precision. The activation analysis procedure can be separated into the four basic areas: A) sampling and sample handling; B) irradiation procedures; C) radiochemical separations; and D) detection systems. Each of these areas can then be divided into a number of individual options, each option with its own characteristics, including an uncertainty value.

The resulting analytical design results when these options are fused to form a procedure which will adequately meet the requirements. This paper outlines many of the options available in each area and discusses some of their inherent limitations and uncertainties.

A search for accuracy in activation analysis of trace elements in different matrices, S. Meloni, M. T. Ganzerli-Valentini, V. Caramella-Crespi, V. Maxia, L. Maggi, U. Pisani, R. Soma, and P. Borroni, *SP422*, pp. 1157-1164 (Aug. 1976).

Key words: accuracy; activation analysis; copper; gold; hafnium; palladium; platinum; precision; radiochemical separations; silver.

Different factors may affect accuracy in activation analysis of trace elements. The evaluation of these factors often requires a number of time consuming experiments, but the statement of accuracy in activation analysis is of great value to cast some light on the overall reliability of the method itself. It can be pointed out that accuracy is often inversely proportional to the number of steps of the whole analytical procedure, from sampling to calculation of results. Several techniques of activation analysis were developed and applied to the determination of trace element content in standard reference materials and in samples chosen for intercomparison among laboratories. Emphasis was put on limiting the number of steps to improve the accuracy and on achieving the best of precision. Results are presented and discussed, together with the criteria for the choice of the most appropriate separation technique. Other sources of systematic errors, such as the reliability of the content of the reference standards and dead-time corrections when short-lived isotopes are involved, were taken into account and discussed.

Surface effects on accuracy in activation analysis, G. Revel and M. Federoff, *SP422*, pp. 1165-1171 (Aug. 1976).

Key words: accuracy; activation analysis; charged particle irradiation; diffusion; etching; metals; neutron irradiation; recoil; surface effect.

One of the main advantages of trace activation analysis is the possibility of eliminating surface contamination by

post-irradiation removal of the superficial layers of the sample. In some cases this advantage is lost by noneffective removal, leading to inaccurate results. We discuss the main causes of ineffective removal of surface contamination. In neutron activation analysis the surface contamination takes place during sampling and irradiation. The main causes of ineffective removal of this contamination are redeposition during chemical etching and large diffusion during irradiation. For the determination of light elements (O,C,N) performed by charged particle or photon irradiation, the surface contamination is increased through the diffusion of impurities by recoil and channeling. Chemical etching, used as the only method, is not convenient for a number of metallic samples—often the thickness of the dissolved layer varies along the surface due to heterogeneities in purity, crystalline structure and localized oxidation made by nonhomogeneous incident beam. Several examples investigated by tracer and metallographic methods are given. A procedure for accurate surface contamination removal is suggested.

A study into the accuracy of a remote-controlled system for multielement determination in foodstuffs using NAA, R. Schelenz and J. F. Diehl, *SP422*, pp. 1173-1180 (Aug. 1976).

Key words: biological material; biological standards; data evaluation; distillation; food composition; gamma spectrometry; inorganic separators; isotopic exchange; multielement determination; neutron activation; radiochemical separation; trace elements.

More accurate information on the trace element composition of foodstuffs is important in the field of nutrition. An appropriate approach to this problem is the application of neutron activation analysis for simultaneous multielement determination using high resolution gamma spectrometry.

A system has been developed permitting determination of at least 28 elements, utilizing remote controlled radiochemical processing of irradiated biological samples. The reliability of the method has been ascertained by participation in inter-laboratory comparisons organized by the International Atomic Energy Agency (IAEA). Results for multielement determinations are given for potatoes (peeled), milk powder, fish solubles and algae.

Neutron activation analysis of elements extracted into organic media, R. Stella and N. Genova, *SP422*, pp. 1181-1187 (Aug. 1976).

Key words: chlorine effect; counting corrections; gamma intensity attenuation; neutron flux depression; organic liquid sample irradiation; palladium distribution ratios; platinum distribution ratios.

It is sometimes worthwhile, especially in solvent extraction studies by radiochemical techniques, to neutron irradiate the organic phase after extraction and directly count the same. Problems arise in comparing gamma activities in the corresponding aqueous phases, eventually irradiated after extraction, and in aqueous standards. Many factors may affect, though in a different way, both the neutron activation and counting steps: the former being a function of neutron absorption in the organic medium that may be especially relevant in the case of chlorine containing solvents and of the different neutron thermalizing properties of the same.

To test these effects, tributyl phosphate in various diluents as an extractant for the chlorocomplexes of some noble metals, namely Pd, Pt, Ir, Os and Au, was used.

The effect of different thermalizing power of the media by comparing the activities of irradiated aqueous and organic obtained on identical samples by other analytical methods like colorimetry, atomic absorption and mass spectrometry.

Estimation of primary reaction interferences in fast particle activation analysis by calculations using cross section data, V. Krivan, *SP422*, pp. 1189-1214 (Aug. 1976).

Key words: accuracy; activation analysis; analytical chemistry; charged particle activation analysis; cross sections; excitation functions; fast neutron activation analysis; fast particle activation analysis; interferences; primary interference reactions; systematic errors; trace analysis.

Since the primary interference reactions may be a considerable source of systematic errors in fast particle activation analysis, their evaluation is of principal importance. These interferences can often be avoided or at least reduced to a negligible degree by the choice of the optimum projectile energy. In certain cases the interfering nuclear reactions cannot be avoided; then their extent must be evaluated quantitatively and corresponding corrections applied.

For the evaluation of the primary interference reactions by calculation, in addition to the appropriate projectile flux parameters, the cross section data must be known. A critical picture is provided of the present state of the cross section data required for this purpose with regard to their accuracy and completeness. Compilations from which the cross section data can be obtained are surveyed and discussed. A survey of systematics enabling the possibility to estimate unknown cross section data is given. The consequences of the uncertainty in nuclear data for the evaluation of primary reaction interferences are discussed and demonstrated by using practical examples. Handling of nuclear interferences in activation with 14 MeV neutrons, with fast neutrons of intermediate energy and with charged particles is considered.

In most cases, the cross section data needed for these calculations are, at present, already available. Generally, the accuracy suffices to make calculations for assessing the significance of the interferences and to choose the optimum projectile energy. The application of calculations to obtain the actual correction factors is possible only in cases where the cross section data have been critically evaluated and their accuracy is well known.

Activation analysis with charged particles of intermediate energy: Performances and applications, J. N. Barrandon and J. L. Debrun, *SP422*, pp. 1215-1232 (Aug. 1976).

Key words: activation analysis; charged particle; cyclotron; method evaluation; multielemental analysis.

The subject of this communication is activation analysis with intermediate energy protons (10 to 15 MeV) and $_2{}^3$He(10 to 20 MeV) with an emphasis on nondestructive multielemental analysis, but results obtained for single element determination after radiochemical separations are also reported.

Precision, accuracy, selectivity and sensitivity of the methods are discussed, as well as the possibilities of application in various areas including mainly metallurgy, geology, solid state physics and archeology.

In the case of nondestructive analysis with 10 MeV protons, we will present experimental activation yields for over 130 radioisotopes corresponding to more than 50 elements. Calculated sensitivities for the determination of these elements will be compared with experimental sensitivities obtained in actual analysis of various matrixes like Ag, Al, Au, Co, Ir, Nb, Rh, Ta, rocks and graphite.

For destructive analysis with higher energy protons and $_2{}^3$He, our experimental results will be compared with results obtained on identical samples by other analytical methods like colorimetry, atomic absorption and mass spectrometry.

Organomercury and total mercury content of environmental matrices as determined by neutron activation analysis, E. Orvini and M. Gallorini, *SP422*, pp. 1233-1240 (Aug. 1976).

Key words: environmental matrices; extraction yields; mercury; neutron activation analysis; organomercury; solvent extraction.

Neutron activation analysis and the gas-chromatographic techniques are used in the determination of organomercury compounds and of total mercury in environmental matrices. In this work the benzene-cysteine separation procedure of Westôô was coupled to neutron activation analysis. In this way both the total mercury content and the organomercury fraction can be evaluated in one sample and during one radiochemical separation process. The activity of ^{197}Hg from the inorganic mercury content of the samples has been evaluated with a well-known combustion separation technique, carried out on the residual sample after benzene extraction. The activity of ^{197}Hg from organomercury compounds of the samples has been evaluated after extraction and purification with cysteine acetate from benzene fraction. The total mercury content was checked on an untreated portion of the same sample. Szilard-Chalmers reaction on the chemical bond between mercury and the organic radical seems to have a very low yield, down to 3 to 4 percent.

Determination of elements in standard material (Bovine Liver SRM 1577), I. Y. Donev and L. M. Marichkova, *SP422*, pp. 1293-1304 (Aug. 1976).

Key words: errors of analysis; homogenization; neutron activation analysis; sample preparation; standard materials; trace element analysis.

Investigations for quantitative determination of the elements: bromine, chromium, copper, iron, calcium, sodium, manganese and zinc in standard material Bovine Liver SRM 1577 have been carried out. Nondestructive neutron activation analysis was utilized. Gamma spectrometry was carried out with a 10 cm^3 Ge(Li) detector connected to a 4000 channel pulse height analyzer. In addition, some methodological procedures concerning the preparation of the standards are communicated, especially on the manipulation and origin of individual or systematic errors. Quantitative evaluations of these errors are given. Analytical results of trace element determinations, before and after cleaning, of Bulgarian polyethylene film, used as packaging material, are given.

A short description is also given of the procedure for rapid homogenization and drying of biological material at liquid nitrogen temperature for about 6 hours, where the water removed is about 85 percent. This enrichment is sufficient for investigations with the neutron activation analysis method. It is also important that the drying is carried out at 30 °C, so the danger for losses of different elements such as arsenic, selenium, silver, *etc.*, is reduced.

Evaluation of error in the instrumental activation analysis of rocks, R. J. Rosenberg, *SP422*, pp. 1241-1256 (Aug. 1976).

Key words: comparative analyses; error evaluation; geological materials; instrumental-neutron activation analysis.

In this paper, the overall error in instrumental activation analysis of rocks with a TRIGA Mark II reactor and the magnitude of its components, are evaluated. The analysis of lanthanides in the USGS standard rocks G-1 and W-1 is used as an example. In view of these results the possibility to decrease the error is discussed.

The average precision of the individual results obtained in this work is 11.6 percent and the average deviation of the mean is 4.6 percent. According to a comparison of values found in the literature the average error of results obtained in different laboratories is 11.8 percent and the average deviation of the results obtained in this work from the average of all results is 7.3 percent evenly distributed on both sides of zero.

The possible components of the error have been investigated partly experimentally and partly theoretically and the following was found to give noticeable contributions when 200 mg samples were used: The flux gradient causes an average error of 5.2 percent and thermalization in aquatic standards causes a negative error of 2.2 percent. Differences in counting geometry in measurements with the sample on the detector cause an error of 2.5 percent and differences in gamma-ray absorption cause an error that varies between 2.5 percent and below 1 percent. This error is negative when aquatic standards are used. Counting statistics causes an error that varies between 1 percent and 38 percent. The mean errors calculated from these data give a total error that varies between 9.0 and 42 percent with an average of 10.8 percent. A comparison between 10.8 percent and the average precision 12.8 percent of all results obtained in this work indicates that all errors of any importance are considered here. The mean error without counting statistics is 8.9 percent.

By rotating the samples during irradiation, counting with a few cm distance between sample and detector and by using rock-standards the total error can be decreased to the level of counting statistics. The same results can be obtained by decreasing the dimensions of the samples.

Neutron activation analysis for some nonstoichiometric constituents in a large number of natural and synthetic beryl samples, S. M. Ristic, *SP422*, pp. 1257-1274 (Aug. 1976).

Key words: cesium and scandium content; natural and synthetic beryls; neutron activation analysis.

About 100 natural beryls from very different locations were analyzed. An appreciable content of all five alkali metals was present, so that determination with a good precision was an important crystalochemical as well as geochemical problem. The trace amounts of Cr, As, Sc, Mn, Eu, and Dy in some natural samples, as well as Co, Ni, Fe, Mo, Sc, Cs and Na were measured in a gamma-spectrometric arrangement with a 500-channel pulse height analyzer, without chemical treatment (*i.e.*, in a nondestructive NAA procedure). The results obtained were partly controlled and compared by emission spectrography, flame spectrometry, and atomic absorption spectrometry, in order to determine the general reliability, as well as precision and accuracy in various analytical procedures and different samples.

Control of sample configuration as an aid to accuracy in instrumental neutron activation analysis, R. E. Heft, *SP422*, pp. 1275-1281 (Aug. 1976).

Key words: gamma counting efficiency; germanium detectors; instrumental neutron activation analysis; particulate sample geometry; trace elements in polyethylene powder.

Errors associated with the basic calculation common to all instrumental neutron activation analyses are discussed. The sample thickness of particulate or powdered samples contained in vials or cups is likely to be nonuniform and difficult to measure. To improve the accuracy of the counting efficiency determination, a procedure was developed for potting the samples in polyethylene to form cylindrical

disks of polyethylene completely containing the sample material, uniformly distributed throughout the volume of the disk. Typically, 100 milligrams of sample is intimately mixed with 1 gram of polyethylene powder by gentle grinding in an agate mortar. The mixture is placed in a 2.54 cm diameter polycarbonate cylindrical cup and heated to 150 °C in a vacuum oven with a 3.81 cm long polycarbonate cylindrical rod of just under 2.54 cm diameter, in place, on top of the sample. At 150 °C the polyethylene melts and forms a highly viscous fluid which upon cooling forms a disk of fixed diameter with parallel faces and whose thickness is measurable to 0.05 millimeter. Blank corrections for the polyethylene are found to be small, and the disks serve as secure containers for the particulates during and after irradiation; and as counting samples of precise configuration for which counting efficiency can be accurately determined.

Observations on the quantitative electron probe microanalysis of particles, C. E. Fiori, K. F. J. Heinrich, R. L. Myklebust, and M. M. Darr, *SP422*, pp. 1283-1291 (Aug. 1976).

Key words: continuous radiation; electron probe microanalyzer; glass standard; lithium drifted silicon detector; Monte Carlo; particle analysis.

Elemental analysis of high accuracy with the electron probe microanalyzer is possible for flat specimens which are thicker than the depth of penetration of the electron beam. Existing data reduction procedures convert x-ray intensities to mass fractions of elements with typical accuracies of 1 to 2 percent (relative). These procedures will not work for specimens which are irregularly shaped and smaller than the range of the electron beam, such as dust particles. A Monte Carlo method is being developed to predict the expected x-ray intensity from particles of various shapes, sizes and compositions. We are also developing a method to measure the mass of a particle through the emitted continuous radiation. The expected end result of this work is an algorithm for quantitative microprobe analysis of particles. Experimental parts of this work include the manufacture and analysis of glass fibers and spheres of various diameters and widely varying composition.

SP423. **MFPG—Mechanical failure: Definition of the problem.** Proceedings of the 20th Meeting of the Mechanical Failures Prevention Group, held at the National Bureau of Standards, Washington, DC, May 8-10, 1974, T. R. Shives and W. A. Willard, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 423*, 228 pages (Apr. 1976) SD Catalog No. C13.10:423.

Key words: brittle fracture; economics of failure prevention; fatigue failure; mechanical failure; mechanical reliability; stress corrosion cracking.

These Proceedings consist of 20 submitted papers and discussions from the 20th Meeting of the Mechanical Failures Prevention Group held at the National Bureau of Standards, May 8-10, 1974. The central theme of the proceedings is the definition of the problem of mechanical failure, with emphasis on modes of failure, consequences of mechanical failure, and implications of mechanical failure. *These proceedings include the following papers (indented):*

What we can learn from the examination of service failures, J. A. Bennett, *SP423*, pp. 3-11 (Apr. 1976).

Key words: crack propagation; failure analysis; failure prevention; fracture; fractography; mechanical failure.

The study of metal components that have fractured in service provides information that can be of major importance in preventing future failures. The metallurgical and fractographic techniques used in such studies are described so as to permit an evaluation of the reliability of the results. Examples are given of some case histories in which the fracture studies were highly effective, and of others in which the information was ignored and further failures occurred.

Failure by fatigue, A. J. McEvily, *SP423*, pp. 13-24 (Apr. 1976).

Key words: crack initiation; crack propagation; fatigue crack growth; fatigue failure; metal fatigue.

The lifetime of manufactured items under intended service conditions is often limited by the processes of corrosion, wear and fatigue. Since such processes represent economic loss and perhaps a safety hazard to the consumer, much effort has gone into the understanding of these phenomena as well as into improved design procedures to guard against their occurrence. In the field of fatigue in particular a considerable advance in recent years has been made in the quantitative treatment of the fatigue process, especially with respect to the matter of fatigue crack growth. Improved understanding of the fatigue crack growth process is timely as in certain circumstances, as for example in the case of welded structures, it is not the initiation of cracks but rather the growth of cracks from preexisting defects which is the critical aspect in determining service lifetime. Other advances have been made in improving the resistance of materials to fatigue either through the control of chemistry or by control of processing variables. Such procedures are generally more important in affecting the crack initiation rather than the crack propagation stages. In this presentation a review of the current status of fatigue will be given from the mechanistic as well as the design viewpoints. Areas in need of further understanding such as corrosion fatigue, creep-fatigue, and fatigue under variable amplitude loading will also be considered.

Failure by stress corrosion cracking—Current approaches toward failure prediction, J. Kruger, *SP423*, pp. 27-40 (Apr. 1976).

Key words: corrosion; failure prediction; film rupture-metal dissolution; hydrogen embrittlement; stress corrosion cracking; stress-sorption.

Stress corrosion cracking (SCC) produces failures in a material when it is subjected to the combined effects of mechanical stress and reaction with an environment. All proposed mechanisms of SCC seek to explain how the combination of a given level of stress, a particular material, and a given environment can lead to the initiation and propagation of cracks. The three major categories of mechanisms that are generally proposed are (1) active path dissolution, (2) stress-sorption, and (3) embrittlement.

In recent years attempts to determine the mechanisms have been enhanced by new concepts and techniques that flow from the three major scientific disciplines that underlie the complex problem of SCC—chemistry, metallurgy, and mechanics. From chemistry have come two main currents: (a) increased awareness of the importance of characterizing the altered environment inside a growing crack, and (b) a recognition of the importance of the regrowth rate of a protective film on a bare surface exposed when that film is broken by stress. The main emphasis in the metallurgy of SCC has been on the crucial role played by structure in general, and particularly at the tip of a crack. Aiding this objective has been the use of the high voltage electron microscope which can directly look at the interaction of the

environment with structural defects, e.g., dislocations. Finally, the major thrust in the mechanics of SCC has been the application of the concepts and techniques of fracture mechanics.

The impact of these new concepts and measurement techniques on predicting and preventing SCC failure will be discussed.

Elastohydrodynamics in concentrated contacts, H. S. Cheng, *SP423,* pp. 41-54 (Apr. 1976).

Key words: contact lubrication; elastohydrodynamic contacts; fatigue; lubricant film thickness; scuffing; wear.

Typical geometrical features of elastohydrodynamic (EHD) contacts and major operating, lubricant, and material parameters governing lubrication in these contacts are described. Operating regimes for various machine components, such as gears, rolling element bearings, cams, and compliant bearings, are identified. A state-of-the-art survey is given to the predictability of major EHD characteristics based on existing analytical and experimental EHD research. The significance of film thickness, pressure fluctuations, friction, and temperature in affecting failures of concentrated contacts by fatigue, scuffing, and wear is discussed. Finally, suggestions are made to incorporate the EHD effects in predicting fatigue life, scuffing load, and wear rate.

Failure in gears and related machine components, R. A. Wilde, *SP423,* pp. 55-66 (Apr. 1976).

Key words: abrasive wear; adhesive wear; gear failure; machine component failure; mechanical failure; surface pitting.

Tooth breakage and abrasive wear are gear failure mechanisms that are well understood. Adhesive wear (scuffing and scouring) and surface pitting are more complex failure mechanisms.

When sliding is introduced into the rolling condition the rubbing between partially lubricated surfaces introduce high surface tensile stresses which result in adhesive wear and surface pitting. Neither of these failures will occur if a continuous oil film separates the metal surfaces.

Because these failures are the result of the interaction of many variables, a systems approach is required to understand the nature of the failure. The following variables have a direct effect on the thickness of the oil film and therefore on the amount of metal to metal contact: Surface roughness, direction of scratches relative to the sliding direction, oil viscosity, conjunction temperature, rolling speed, relative sliding speed, oil composition and load (Hertz stress). These variables will have significantly different effects when sliding is introduced to the rolling condition as occurs in gear applications.

Bearing damage analysis, R. L. Widner and W. E. Littmann, *SP423,* pp. 67-84 (Apr. 1976).

Key words: bearing failure; bearing loading; bearing lubrication; bearing misalignment; bearing temperature; mechanical failure.

Failure analysis of machine components is described with the major emphasis on tapered roller bearings and their interactions with other components of a system. Included in the discussion are the effects of loading, deflections, misalignment, lubrication, temperature, debris, water and electrical current on the type of damage and life of tapered roller bearings.

Anti-friction bearing design, inspection and recycling, K. M. Glaesner, *SP423,* pp. 87-91 (Apr. 1976).

Key words: aircraft engine bearings; antifriction bearings; bearing failure; bearing failure modes; bearing inspection; bearing reclamation; bearing recycling.

The paper will describe the ramification of failures of antifriction bearings related to aircraft applications, including engine bearings. The paper will endeavor to describe the problems of antifriction bearings in four categories:

I. Design of application. Here, the paper will describe the inherent design failures as noted in applications. The paper will also include parameters of bearing design which will best provide operational success and life expectancy.

II. Failure modes in bearing applications will be described and an outline of the most popular types of failure as detected in bearings, will be discussed.

III. A recovery process for the reclamation of bearings will be outlined and again limits for the acceptability of defects on bearings will be presented.

IV. New inspection techniques now under study will be outlined and the method of inspection will detail failure prevention once the bearing is mounted in the application.

Holographic NDI of P-3 wing plank splices, A. J. Koury, M. J. Devine, J. F. Erthal, and P. D. Bhuta, *SP423,* pp. 93-103 (Apr. 1976).

Key words: aircraft component failure; continuous wave holograms; crack detection; holographic techniques; pulsed laser holograms; stress corrosion cracking; ultrasonic inspection.

Continuous wave and pulsed laser holographic techniques were applied to inspect stress corrosion cracking in P-3 wing plank splices. Holographic results were compared with those of currently used ultrasonic inspection techniques. Holographic techniques successfully detected all the stress corrosion cracking areas that were identified by the ultrasonic inspection technique and, in addition, several other crack areas were located whose presence was later verified by dye penetrant inspection after careful disassembly of the panel joints. It was also shown that the holographic technique can locate areas of stress corrosion cracking without removal of paint and sealant materials. The currently used ultrasonic technique requires a paint and sealant stripping operation prior to inspection. Considerable savings in cost will be realized when inspection using holographic techniques is implemented. The holographic technique was demonstrated to Navy personnel at the Naval Air Rework Facility, Alameda, California, in an air rework environment. The concept of "structural signature" to verify structural integrity of complex aircraft structures is briefly described.

Economic considerations in failure prevention, H. E. Morgan, *SP423,* pp. 107-116 (Apr. 1976).

Key words: economic cost of failure prevention; frequency of failure; government action; life-cycle costing; marginal analysis; quality control; safety standards.

Economic considerations normally determine if product failure prevention is justified by a producing firm. Some failures are not worth preventing, even if prevention is technically feasible. Since the risk of failure is inherent in all products, the expected benefits of failure prevention should be compared with expected costs, both discounted to present value in a life-cycle context and compared with alternatives.

Producers and users of a product may evaluate the risk of failure and its economic cost differently. This may lead to in-

efficient and inequitable production decisions affecting the public interest. Consequently, externalities (third-party effects) may require that regulatory or other agencies of Government intervene to protect the public and to insure socially efficient and equitable allocation of resources to failure prevention.

Failures represent a gap between expectations and performance. Both involve measurement and standards technology which the NBS can provide. However, economic analysis should be used to determine the conditions under which failure prevention is desirable. Examples of economically desirable conditions for failure prevention are provided.

Economic impact of tribology, H. P. Jost, *SP423*, pp. 117-139 (Apr. 1976).

Key words: economic savings of failure prevention; friction; lubrication; mechanical failure; tribology; wear.

The emergence of tribology as a subject in its own right arose out of industrial need. In the early 1960's there was a large increase in reported failures of plant and machinery due to wear and associated causes. At the same time, technology was increasing the capital intensity of plant and the use of more continuous processes; thus breakdowns of such plant and machinery were becoming more costly.

In 1966 a U.K. Government investigation came to the conclusion that by application of tribological principles, very large savings were obtainable, in most cases without appreciable capital investment.

Tribology was defined as "the science and technology of interacting surfaces in relative motion and of subjects and practices related thereto." In other words, it deals with all aspects of rubbing, sliding and rolling surfaces and included the subjects of wear, friction and lubrication. Application of tribological principles would lead not only to greater operational reliability, efficiency and productivity, but also to conservation of materials and energy.

To gain the advantages outlined in the above Report, estimated at the time to be in the region of £515 million per annum (p.a.) ($1285 million approximately), the British Government set up the Committee on Tribology, to implement the recommendations in the education, research and industrial fields.

Actual savings already resulting to British industry are conservatively estimated to be in excess of £100 million p.a. ($230 million), and potential savings (allowing for inflation since the 1966 estimate) to over £1,000 million p.a. ($2,300 million).

In less than seven years, the new concept of tribology has been accepted by the majority of the industrial countries as part of their scientific and technological background in the field of obtaining greater plant efficiency, better performance, fewer breakdowns and significant savings in other directions.

Nuclear power plant safety, P. A. Morris, *SP423*, pp. 143-151 (Apr. 1976).

Key words: failure prevention; mechanical failure; mechanical malfunction; quality assurance; reactor systems and components; safety standards.

Protection against the potential radiological consequences of malfunction or mechanical failure of reactor systems and components in nuclear power plants is achieved by a combination of procedural and technical constraints. For routine operation, plants are to be designed and operated so that radioactive effluents are maintained as low as practicable. To assure that the probability of serious accidents is acceptably low requires conservative design, construction and operation using redundant and diverse systems and components and a rigorous program for quality assurance at all times.

Mechanical failures and public expectations of safe transportation, H. H. Wakeland, *SP423*, pp. 153-163 (Apr. 1976).

Key words: effects of mechanical failure on environment; failure prevention; government action; mechanical failure; safety standards; transportation safety.

Although, in the interaction between society and technology, it is desired to minimize the incidence of mechanical failure under all conditions, the practical ability to circumscribe and control failures in transportation (for example) varies widely. Depending upon identifiable variables in circumstances, society may effectively require a range of performance between complete freedom from failure and general acceptance of repeated failures of a life-threatening nature. An attempt is made to classify the variables of circumstance which seem to govern public expectation and to create a structure in which the degree of freedom from mechanical failure which will be tolerated by the public can be reviewed. The possibility of using this structure for estimating public reaction to failures is discussed.

Public safety and construction surety, J. Feld, *SP423*, pp. 165-170 (Apr. 1976).

Key words: construction safety; construction surety; degradation of safety with age and use; maintenance of safety; public safety; safety responsibility.

Structures are conceived, designed and constructed for use by man and located in proximity to other structures and open spaces occupied by man. How safe are these structures when first occupied, and what degree of safety can be expected of them with age?

Who is responsible for the original condition of safety of the structures, and for the degradation of safety with age and use?

Who is responsible for the maintenance of sufficient safety to permit continued use and occupancy?

In addition to the broad aspects of the problem, the paper will describe avoidable use of incompatible materials that caused local distress or failure of the structure.

Public safety and construction surety depend on proper control of each factor involved in the design, construction, maintenance, and use of a structure. Any deviation on the part of any one factor makes the structure vulnerable to damage or even collapse. Absolute safety is not obtainable. The historical record of structure behaviour indicates the high reliability of present techniques and procedures.

Responsibility for defects and for the small percent of structures that do not perform properly is a deterrent to proper control, but considerable pressure is needed to further reduce the number of failures to insignificant numbers. It is the duty of the professions involved to provide that pressure, since legal and political action has not been successful, and to control the proper performance of the work in every factor and so provide public safety and surety in the construction industry.

The people considerations of automotive service, F. J. Uhlig, *SP423*, pp. 171-178 (Apr. 1976).

Key words: automotive repair; automotive repair effectiveness; automotive service; customer-mechanic relationship; human factor considerations; universal symbol diagram approach.

The presentation will cover some of the human factor considerations in servicing automobiles at GM dealerships. Emphasis will be placed on the communication channel between customer and mechanic and possible attendant breakdown that can limit the effectiveness of repairs. Specifically, the repair challenge will be described relative to: (1) Vehicle relation and consumer expectations; (2) The customer item-service writer interface; (3) Technical service information for internal service shop communications.

In addition, the presentation will cover some recent developments of GM service research which address themselves to the above problems for example: (1) Service writer check sheet—a vehicle simulator oriented approach to customer order write up; (2) "STAR"—A computerized reading comprehension method for use in improving the readability of service manuals used by mechanics; (3) "USDA"—Universal Symbol Diagnosis Approach—that uses graphic symbols in a logic tree format to aid in vehicle system problem diagnosis; (4) Shop operation management system.

Mechanical failures: Implications for science; J. P. Hirth, *SP423*, pp. 181-191 (Apr. 1976).

Key words: continuum cracks; continuum mechanics; failure mechanisms; mechanical failure; microstructural effects on mechanical failure.

The early scientific advances by Griffith for continuum cracks and by Orowan, Taylor, Hall and Petch, and Hirsch and coworkers for effects of microstructure have contributed to our current understanding of mechanical failure. However, this understanding remains incomplete. Here, a brief historical account and survey of the present status of various fundamental aspects of the failure problem are presented. Specific unsolved problems and areas for needed research are suggested.

Implications for action for engineering, H. W. Paxton, *SP423*, pp. 193-197 (Apr. 1976).

Key words: environmental extremes; fail-safe operation; high strength materials; mechanical failure; potential service conditions; proliferation of specifications.

The demands on materials for fail-safe operation have increased enormously since the days of "Galloping Gertie" and Liberty Ships. The necessity to use higher strengths has increased demands on selection, design, acceptance testing, nondestructive evaluation of structures, and manufacturing methods. Extremes of temperatures, thicker sections, and environmental effects have all accentuated the tendency for mechanical failure. This paper will discuss the current status of selected problems, and by assessing our fundamental understanding of certain important engineering parameters, will examine prospects for improved materials and techniques.

Mechanical reliability—Implications for engineering, manufacturing and design, W. D. Compton, *SP423*, pp. 199-208 (Apr. 1976).

Key words: design engineering; material deterioration; mechanical failure; mechanical integrity; mechanical reliability; performance envelope; predicting product reliability.

The automobile is a complex assembly of some 15 000 different components in a network of functional subsystems and systems. The definition of the problem of mechanical performance is complicated by the absence of a fixed vehicle performance envelope. Control over use of the vehicle is in the hands of the individual driver. This is substantially different from military and aerospace hardware for which there are specified performance envelopes, and from many consumer products in which the performance follows a fixed pattern, almost independent of consumer preference. This situation imposes special implications for engineering and design, and for testing.

Improved methodologies for predicting component durability and lifetime under real-life conditions, when combined with information on material and structure properties derived under realistic test conditions, can be of great value in developing designs with improved mechanical properties. Likewise, the high volume production rates associated with automotive components involve consideration of material processing and manufacturing factors if the proper levels of mechanical performance are to be achieved.

Implications for action—Industry, J. E. Ryan, *SP423*, pp. 209-212 (Apr. 1976).

Key words: consumer products; marketing; mechanical failure; product performance; product reliability; product testing.

This paper will review product trends for industrial and consumer durables; the foreseeable environment of production and use of these products and systems; and the implications for preventive action in this industrial area based upon the growing body of knowledge of mechanical failure mechanisms and the increasing concern for economic and social consequences of mechanical failures.

The implications of mechanical failures for consumer product safety—Vice versa, L. M. Kushner, *SP423*, pp. 215-219 (Apr. 1976).

Key words: consumer product safety; failure prevention; government action; government responsibility; mechanical failure; safety standards.

In years past, manufacturing a safe product (rather than one that is simply marketable) for the consumer was regarded as a nice, but not necessarily imperative, thing for a manufacturer to do. Recent legislation, however, mandates consumer product safety, thereby putting additional responsibilities on product designers and engineers and the research scientists who support them. Experience in operating a regulatory product safety program discloses that materials failures, many of which are mechanical in nature, are an important factor in consumer product safety. A discussion will be presented of the implications of the Consumer Product Safety Act for materials engineers. Some specific examples of mechanical failures in consumer products that have created serious safety problems will be given.

Mechanical failure—A material matter, R. W. Roberts, *SP423*, pp. 221-225 (Apr. 1976).

Key words: conservation of material resources; failure prevention; government action; mechanical failure; mechanical reliability; safety standards.

The Federal Government has long been concerned with minimizing mechanical failures. This concern has come about for two reasons. First, the Federal Government purchases and operates a great deal of equipment, much of it, as in the space program and in the DOD, equipment of extreme technological sophistication. The Government, in purchasing, using, and maintaining this equipment, has often led the way in devising new approaches to mechanical reliability. The second reason involves areas of broad public

concern, such as safety. Here, Congress has granted Government agencies the authority to set mandatory standards that are designed to prevent mechanical failures in the private sector. It is clear that in the future both these activities will be continued.

In addition, several current national trends call for enhanced concern with mechanical reliability. These trends are related to the conservation of natural resources, the continuing need for new methods of improving product quality and maintainability in the face of rising labor costs, and the growth of new technologies, such as nuclear energy, requiring a new plateau of operating reliability.

These trends are analyzed in terms of future government policy and future modes of interaction between the government and the private sector.

SP424. **A contribution to computer typesetting techniques: Tables of coordinates for Hershey's repertory of occidental type fonts and graphic symbols,** N. M. Wolcott and J. Hilsenrath, *Nat. Bur. Stand. (U.S.), Spec. Publ. 424,* 173 pages (Apr. 1976) SD Catalog No. C13.10:424.

Key words: alphabets; COM; computerized typesetting; digital plotting; graphics; Hershey character set; plotting; type fonts; typesetting; vectorized characters.

These tables present coordinates from which it is possible to generate 1377 different alphabetic and graphic characters on either COM devices or on digital plotters. The tables, originally developed by Dr. A. V. Hershey of the Naval Weapons Laboratory, are augmented here by corresponding figures which show for each character the location of the tabulated points and the manner in which they are connected. The tables can be used with existing typographic systems to compose pages for scientific and mathematical publications of graphic arts quality either on COM devices or flat-bed plotters. Numerous applications are discussed and illustrated. The tables are also available on a magnetic tape in either BCD or ASCII format from the National Technical Information Service.

SP425, Volumes I and II. **Nuclear cross sections and technology.** Proceedings of a Conference held in Washington, D.C., March 3-7, 1975, R. A. Schrack and C. D. Bowman, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 425, Vol. 1, 487 pages, Vol. II, 553 pages (Oct. 1975) SD Catalog No. C13.10:425.

Key words: biomedical; conference; cross section; nuclear; standards; technology.

These proceedings are the compilation of 221 papers presented at the Conference on Nuclear Cross Sections and Technology held in Washington, D.C. on March 3-7, 1975. The Conference summarized the present status of nuclear cross sections and technology and discussed future cross section needs. Special emphasis is placed on reactor technology and biomedical applications of nuclear science and the measurement of standard cross sections. *These proceedings include the following papers (indented):*

The light water reactor industry-nuclear data needs, V. O. Uotinen, J. D. Robertson, and J. S. Tulenko, *SP425,* pp. 7-13 (Oct. 1975).

Key words: lattices; nuclear data; parameter; reactivity.

Radioactive-nuclide decay data in science and technology, C. W. Reich and R. G. Helmer, *SP425,* pp. 14-20 (Oct. 1975).

Key words: applications of decay data; ENDF/B-IV decay-data file.

The scope of ENDF/B has recently been expanded to include radioactive-nuclide decay data. In this paper, the content and organization of the decay data which are included in ENDF/B are presented and discussed. The application of decay data in a wide variety of nuclear-related activities is illustrated by a number of examples. Two items pointed up by the ENDF/B decay-data compilation effort are treated: the identification of deficiencies in the data; and the importance of a radioactive-nuclide metrology effort oriented toward supplying these needs in a systematic fashion.

Radioactive decay heat analyses, R. E. Schenter and F. Schmittroth, *SP425,* pp. 21-28 (Oct. 1975).

Key words: decay heat; $\bar{E}_\beta$; $\bar{E}_\gamma$; ENDF/B-IV; fission products; half lives; yields; ^{235}U; ^{239}Pu.

Calculations of decay heat from fission products have been made using the summation method for fast and thermal reactor systems. Results of these calculations for both "burst" and long exposure times are presented and compared with previous experimental results and summation calculations. In addition, uncertainty estimate calculations are given which used both exact and approximate summation method formulas. The above calculations require as input libraries containing data for each individual fission product nuclide. Our source of data has been ENDF/B-IV, where fission yield, cross section and decay data (half lives, β and γ energies, branching, etc.) for 824 fission product nuclides are contained in the fission product and fissionable isotope files.

Sensitivity of the afterheat from ^{235}U and ^{239}Pu thermal fission to errors in fission product nuclear data, C. Devillers, B. Nimal, C. Fiche, J. P. Noël, J. Blachot, and R. de Tourreil, *SP425,* pp. 29-38 (Oct. 1975).

Key words: afterheat; decay heat; error estimates; fission products; loss of coolant accident; sensitivity.

This paper presents calculational results on the decay heat associated with the thermal fission of ^{235}U and ^{239}Pu. Calculations are based on the summation of the energies which are released by individual fission products. Two cases have been considered: the first corresponds to one instantaneous fission, the other to a 900 days irradiation time. In both cases the sensitivities of the afterheat to respectively independent yields, half-lives, average beta plus gamma energies of 512 instable fission products have been derived. This information has been used to calculate the afterheat uncertainties from experimental and evaluated nuclear data errors, when available. Results relating to the instantaneous fission of ^{235}U and ^{239}Pu are compared to calorimetric measurements between 100 and 10^5 second cooling time. Errors in the afterheat corresponding to a 900 days irradiation time have been estimated for cooling times ranging from 1 to 1000 seconds which are appropriate for Loss of Coolant Accident analyses in light water reactors. The computer programmes which have been developed can be applied to any irradiation and cooling time condition.

Significance of nuclear data on the development of the LMFBR industry, N. C. Paik, *SP425,* pp. 39-44 (Oct. 1975).

Key words: data; flux; LMFBR; neutron.

The overall interaction of nuclear data, methods and nuclear performance predictions of an LMFBR is described. Areas of successful applications of the recent Evaluated Neutron Data File (ENDF/B) to an LMFBR design are shown to be numerous. Design areas where improvements in the Evaluated Neutron Data File would have significant impact on the development of the LMFBR industry are listed. Specific cross sections where improvements in the neutron data would be beneficial to the LMFBR industry are enumerated. In order to provide insight into why

these developments are required, an application of nuclear data to the determination of the intrinsic neutron source strength in an LMFBR are described in relation to the Ex-Vessel Low Level Flux Monitor system design.

Fast reactor safety, R. Avery, *SP425*, pp. 45-50 (Oct. 1975).

Key words: accidents; breeders; fast reactors; LMFBR; recriticality; safety.

The current state of knowledge with respect to the analysis of potential accident sequences in fast breeder reactors and the understanding of associated accident phenomena, as well as implications to reactor design, are reviewed.

After PHENIX, what is the importance of nuclear data programs for the FBR development?, J. Y. Barré, J. Bouchard, and J. P. Chaudat, *SP425*, pp. 51-61 (Oct. 1975).

Key words: FBR development; integral experiments; nuclear data; PHENIX.

In the fast reactor physics approach chosen in France, the integral experiments serve as a reference. The significance of differential nuclear measurements, in this philosophy, is presented.

The programs carried out on critical facilities and operating fast power reactors up to the end of this year will solve the last major problems arising from nuclear data inaccuracies for commercial plants. Results obtained on PHENIX during start-up and operation validate this approach. After the end of 1975, the nuclear data needs concern mainly safety, plant operation and fuel cycle analysis. Nonnuclear uncertainties largely dominate the effects of nuclear data uncertainties for these problems. Evaluations must be sufficient to reach the requested accuracies.

NE-213 neutron spectrometry system for measurements to 15 MeV, R. H. Johnson, B. W. Wehring, and J. J. Dorning, *SP425*, pp. 62-65 (Oct. 1975).

Key words: proton-recoil spectrometry; Pu-Be and ^{252}Cf neutron spectra; spectra unfolding.

A 5-cm by 5-cm NE-213 scintillator mounted on a 56AVP PM tube is used with a bridge utilizing two high voltage supplies and giving good linearity and good pulse shape discrimination. The cross-over timing method is used to discriminate against gamma-ray events. Measurements of a ^{252}Cf and a D-T source were used to test the linearity of the system. The ^{252}Cf measurement is in good agreement with earlier results and is fit by a Maxwellian distribution with a temperature of 1.43 MeV. A modified version of the COOLC unfolding code was used to obtain neutron spectra. This code, FORIST, optimizes the neutron energy resolution through an iterative process. A measured Pu-Be spectrum is used to demonstrate the benefits of the modified unfolding procedure. The Pu-Be spectrum is also in good agreement with earlier results. The 9.7 MeV peak of the Pu-Be neutron spectrum is resolved when the FORIST code is used, but not when the COOLC code is used with the window width data distributed with the COOLC and FERDOR code package.

Absolute calibration of neutron detectors in the 10-30 MeV energy range, J. A. Cookson, M. Hussian, C. A. Uttley, J. L. Fowler, and R. B. Schwartz, *SP425*, pp. 66-68 (Oct. 1975).

Key words: absolute efficiency of fast neutron detectors.

A central problem in fast neutron research is that of finding the absolute efficiency of neutron detectors. Using the associated particle method for this purpose, we have designed a chamber to count He particles from the D(d,n)^{3}He or the T(d,n)^{4}He reaction in coincidence with neutron events. The reactions take place in deuterium o tritium gas and a ΔE solid state counter at 80, 65, or 43° t the 2-10 MeV deuteron beam direction detects the He parti cles with 100 percent efficiency. To reduce background w allow the deuterons to pass out of the gas chamber throug a Ni window and stop the beam ~ 150 cm from the coun ters. With the D(d,n)^{3}He reaction we have obtained ~ 2 per cent efficiency calibration of the central portion of a liqui scintillator in the 9-10 MeV energy range. With the T(d,n reaction this calibration can be extended to ~ 27 MeV an the efficiency can be mapped out as a function of position i the scintillator.

A thick target measurement technique for determining nuclear reaction rates, N. A. Roughton, M. J. Fritts, R. J Peterson, C. J. Hansen, and C. S. Zaidins, *SP425*, pp. 69-72 (Oct. 1975).

Key words: astrophysics; cross sections; fusion; reactior rates; thick targets.

A technique for measuring nuclear cross sections using thick targets and an empirical approximation for energy loss has been developed by our group at the Nuclear Physics Laboratory of the University of Colorado. Over the past two years we have measured thick target yields of over thirty nuclear reactions of interest in astrophysics and CTR applications. From these yields we can derive average cross sections and thermonuclear reaction rates, $N_1 \langle \sigma v \rangle$. We will describe the technique and data analysis methods and give some examples of our results.

A black detector for 250 keV—1000 keV neutrons, G. P. Lamaze, M. M. Meier, and O. A. Wasson, *SP425*, pp. 73-74 (Oct. 1975).

Key words: detector; flux; Monte Carlo; neutrons; scintillators; time-of-flight.

A detector has been designed to have a greater than 95 percent efficiency in the range of 250—1000 keV neutron energy. The detector is modeled from a similar but larger detector by Poenitz. The efficiency calculations were made with a modified version of Carlo Black, which is a Monte Carlo calculation of multiple neutron scattering in a scintillator. The detector is a 12.6 cm × 17.78 cm cylinder of NE 110 with a 5.08 cm × 2.54 cm reentrant hole. The scintillator is mounted on an RCA 8854 photomultiplier tube which has been selected for low noise. Calculated efficiencies are presented as well as comparisons with experimental measurements.

Detector calibration with an associated particle apparatus, M. M. Meier, A. D. Carlson, and G. P. Lamaze, *SP425*, pp. 75-77 (Oct. 1975).

Key words: associated particle technique; neutron detector; neutron flux monitor; neutrons; neutron standards; T(p,n)^{3}He reaction.

An associated particle apparatus employing the T(p,n)^{3}He reaction is now in routine use at the NBS. The apparatus consists of two target chambers with ports at 10 and 25° which give a useful neutron energy range of 100 keV to 1 MeV for protons from the 3 MV Van de Graaff. Electrostatic deflection, fast energy discrimination and pulsed beam time of flight techniques are used to reduce background in the neutron-associated $^3He^{++}$ pulse height spectrum to less than 1 percent. Neutron fluxes in the associated cone range between 30 and 100 n/sec at the lowest and highest bombarding energies. The spatial profile of the neutron cone is broadened by coulomb scattering of the $^3He^{++}$ in the tritiated titanium target and has a width less than 12° (full

width at one-tenth maximum) for neutron energies above 300 keV. The apparatus has been used to calibrate a "black" detector described by Lamaze. The results of this calibration will be compared to a Monte Carlo calculation of the efficiency.

Use of gas proportional counters for neutron flux monitors at the NBS Linac, O. A. Wasson, *SP425*, pp. 78-80 (Oct. 1975).

Key words: counter; flux; hydrogen; monitor; neutron; proportional.

The use of a hydrogen filled proportional counter as a neutron flux monitor for standard neutron reaction cross section measurements at the 200 m flight path of the NBS Linac is described. Efficiency uncertainties approaching 1 percent are obtainable.

Fission cross section measurements on short-lived alpha emitters, J. W. T. Dabbs, N. W. Hill, C. E. Bemis, and S. Raman, *SP425*, pp. 81-82 (Oct. 1975).

Key words: fast ionization chamber; fission/alpha; spherical electrodes; σ_f; ^{245}Cm.

The large difference in initial ionization can be used to limit the size of alpha pulses relative to fission pulses in an ionization chamber, if the track lengths are both short. In parallel plate chambers this condition is not well met. We have developed a spherical plate chamber in which the ratio of maximum/minimum track length is 3. In the present (small sample) version, the maximum track is 6 mm, with deposit and neutron beam diameters of 1 cm. At optimum, with pure CH_4 gas, an electron collection time of ~ 22 ns is expected across the 2 mm gap. It is expected that the worst alpha/fission current pulse ratio will not exceed 1/14. Thus fissile isotopes with alpha half lives of 30 years or more (e.g., ^{243}Cm) may be studied with 1-2 nanosecond risetime current amplifiers; in addition, very small spontaneous fission branching ratios may be better determined. Comparisons of this new chamber with a parallel plate chamber and initial results on ^{245}Cm (~ 16 μg sample) will be presented. The ORELA pulsed neutron source permits measurements below 20 eV which are inaccessible to underground explosion experiments.

Systematic discrepancy in photoneutron cross sections for medium and heavy nuclei, T. Tomimasu and S. Sugiyama, *SP425*, pp. 83-88 (Oct. 1975).

Key words: calibrations of the NBS P2 chamber; comparison of shape and magnitude of photoneutron cross sections; nuclear reactions Cu, ^{63}Cu, Pr, Pb, ^{208}Pb, Bi(γ,n).

The shape and magnitude of the photoneutron cross sections for Cu, Pr, Pb, and Bi are compared to find out a systematic discrepancy between the cross sections obtained using the NBS P2 chamber as a bremsstrahlung beam monitor and those obtained by other experimental techniques such as the positron annihilation-in-flight. The former cross sections in general are observed to be systematically larger than the latter. The discrepancy of about 10 percent is demonstrated in the peak cross section values for medium nuclei. This may be explained in the good direction by a systematic discrepancy of 6 percent in the calibration constants of the NBS P2 chamber given at several laboratories, because the lowest values in these calibrations have been widely used to determine the photoneutron cross sections from measured neutron yield curves. The highest values can almost eliminate the 10 percent discrepancy. The definite discrepancy cannot be demonstrated for heavy nuclei because of the large discrepancies of 20 percent or more found in the cross sections obtained with γ-rays from positron annihilation-in-flight.

The 2-keV filtered beam facility at the NBS reactor, I. G. Schroder, R. B. Schwartz, and E. D. McGarry, *SP425*, pp. 89-92 (Oct. 1975).

Key words: capture gamma rays; cross sections; dosimetry; filtered beams; neutrons.

A scandium filter that views a manganese scatterer has been installed in a through tube of the National Bureau of Standards Reactor (NBSR). The use of a resonant scatterer eliminates unwanted core neutrons and core gamma rays. This produces a pure 2-keV neutron beam with only 3 percent higher energy neutron contamination and a 1 mR·hr^{-1} gamma-ray background. This should be compared with previously reported results in which the high energy contaminant was approximately 50 percent, thus severely limiting the utility of such a filter. Details of the filter construction, the use of titanium with the scandium to reduce background, the optimization of the beam for different types of experiments, and the application of 2-keV neutrons to neutron dosimetry, cross-section measurements and capture gamma-ray studies are discussed.

The Rensselaer Intense Neutron Spectrometer, R. C. Block, R. W. Hockenbury, D. S. Cramer, E. Bean, and R. E. Slovacek, *SP425*, pp. 93-96 (Oct. 1975).

Key words: measured Th fission and deduced $\bar{\Gamma}_f$ below 260 eV; measured ^{145}Nd(n,α); measured ^{238}U fission below 35 keV, deduced $\bar{\Gamma}_f$ of 6.7, 21 and 37 eV resonances.

The Rensselaer Intense Neutron Spectrometer (RINS) is obtained by driving a 75-ton lead slowing down spectrometer with the intense pulsed neutron source from the RPI 100-MeV electron linac. For the same linac beam power, RINS produces a useable neutron flux which is $10^3 \sim 10^4$ greater than that obtained with a conventional time-of-flight spectrometer. Fission measurements upon ^{238}U have shown strong subthreshold fission above 700 eV and have determined the fission widths of the 6.7, 21 and 37 eV resonances to be (10 ± 5), (70 ± 30) and (8 ± 6) neV respectively. No strong subthreshold fission was observed in ^{232}Th, and an upper limit of (15 ± 10) neV is obtained for $\bar{\Gamma}_f$ for the Th resonances below 260 eV. Measurements of ^{145}Nd (n,α) have shown that the RINS system is readily capable of measuring ~ μ eV partial widths with only several mg of sample.

A modular minicomputer multiparameter data gathering and virtual memory operating system for the NBS neutron standards program, R. A. Schrack, H. T. Heaton II, and D. Green, *SP425*, pp. 97-98 (Oct. 1975).

Key words: CAMAC; disc; minicomputer; modular; multiparameter; on-line.

The new aboveground neutron time-of-flight system has recently been completed at the National Bureau of Standards linear accelerator facility. A computer system has been developed that will permit the accumulation of multiparameter data simultaneously from several experiments, using an inexpensive minicomputer and a small moving head disc storage unit. The operating system is modular in form, allowing different experimenters to rapidly construct a software system to their requirements. Data gathering and analysis programs are interchanged between core and disc as required. Interfacing hardware has been modularized using the CAMAC system.

TUNL fast neutron cross section facility, D. W. Glasgow, F. O. Purser, J. C. Clement, G. Mack, K. Stelzer, J. R. Boyce, D. H. Epperson, H. H. Hogue, E. G. Bilpuch, H. W. Newson, and C. R. Gould, *SP425*, pp. 99-102 (Oct. 1975).

Key words: C(n,n), E=9-15 MeV, measured $\sigma(E_n,\theta)$; D(d,n)^{3}He and C(n,n) spectra; neutron TOF facility.

A fast neutron time-of-flight (TOF) facility has been constructed in order to measure neutron differential cross sections required for the CTR program. The facility combines the outstanding capabilities of the Cyclo-Graaff accelerator with those of a good energy resolution, high mechanical precision, very low background TOF spectrometer-goniometer. The facility provides the capability for measurements of scattering cross sections with magnitudes of a few mb/sr to ≈ 5 percent absolute accuracy in the energy range 6-15 MeV. The D(d,n)^{3}He source spectra at 0° are practically devoid of extraneous neutrons produced by deuteron reactions with the all-metal, ultraclean beam transport system.

A facility for studying neutron-induced charged particle reactions, F. P. Brady, N. S. P. King, M. W. McNaughton, J. F. Harrison, and B. E. Bonner, *SP425*, pp. 103-105 (Oct. 1975).

Key words: facility; neutron-induced reactions; ^{12}C data; 56 MeV.

Nearly monoenergetic beams of neutrons, variable in energy from below 10 to above 60 MeV are produced via intense beams of protons and deuterons from the sector focusing isochronous cyclotron at Crocker Nuclear Laboratory. The neutron production target and collimation system are connected to a scattering chamber containing detector telescopes, all in vacuum. ΔE, E and time-of-flight signals from each telescope are interfaced to a PDP15/40 computer via CAMAC and sophisticated on-line and off-line data processing can be carried out. There are a number of examples of the use of these cross sections: Neutron induced reactions on carbon have provided us with a better understanding of energy dependence of neutron detection efficiencies in plastic scintillators. Data from carbon and other tissue-resident elements are necessary for an understanding of microscopic dose distributions produced by neutrons.

After-pulse suppression for 8850 and 8854 photomultipliers, J. P. Lamaze, J. K. Whittaker, R. A. Schrack, and O. A. Wasson, *SP425*, pp. 106-107 (Oct. 1975).

Key words: after-pulse; detector; gamma-flash; photomultiplier; pulse suppression; scintillator.

Spurious pulses occurring after large light output events in a scintillator (after pulsing) have been observed in semiconducting first dynode photomultipliers (RCA 8850 series). The after-pulsing apparently has two components, an isochronous component occurring at a fixed time interval after the initial light pulse and an asynchronous component with a long duration lasting at least 40 μsec. The time interval between the isochronous bursts is related to the types of residual gases in the photomultiplier. In the RCA 8850 series tubes, the asynchronous after-pulsing consists of very low amplitude pulses and appears to be primarily due to single electron events, the number of these events being related to the main pulse amplitude. To obtain after pulse suppression, a fine stainless steel mesh was stretched tightly over the glass window of the photocathode. The mesh was then pulsed (FWHM = 250 ns) during the light flash to +300 volts relative to the photocathode potential. The isochronous and asynchronous after-pulsing was completely suppressed. Further details are presented.

A secondary standard neutron detector for measuring total action cross sections, K. K. Sekharan, H. Laumer, and F. Gabbard, *SP425*, pp. 108-111 (Oct. 1975).

Key words: absolute efficiency determination; cross section measurements; neutron detector.

A neutron detector has been constructed and calibrated for the accurate measurement of total neutron-production cross sections. The detector consists of a polyethylene sphere of 24 in diameter in which 8-$^{10}BF_3$ counters have been installed radially. The relative efficiency of this detector has been determined for average neutron energies, from 30 keV to 1.5 MeV by counting neutrons from ^{7}Li(p,n)^{7}Be. By adjusting the radial positions of the BF_3 counters in the polyethylene sphere the efficiency for neutron detection was made nearly constant for this energy range. Measurement of absolute efficiency for the same neutron energy range has been done by counting the neutrons from ^{51}V(p,n)^{51}Cr and ^{57}Fe(p,n)^{57}Co reactions and determining the absolute number of residual nuclei produced during the measurement of neutron yield. Details of absolute efficiency measurements and the use of the detector for measurement of total neutron yields from neutron producing reactions such as ^{23}Na(p,n)^{23}Mg are given.

Facilities for cross section measurements using Na-D photoneutron sources, J. C. Robertson, M. C. Davis, and J. C. Engdahl, *SP425*, pp. 112-115 (Oct. 1975).

Key words: calibration; construction; Na-D photoneutron sources; radiolysis; spectrum.

Photoneutron sources are a convenient source of neutrons in the intermediate energy range, and because of this they are often used to make absolute cross section measurements. In this paper, the construction of two sodium-deuterium sources is described. One of the sources uses deuterated polyethylene shells and the other utilizes heavy water. The methods used in the manipulation of the sources are outlined. The effects of radiolysis on the yields from the sources is discussed together with the unique features of the Michigan manganese bath system used in their calibration. The results of Monte Carlo calculations of the neutron spectra are given.

A 25-keV neutron beam facility at NBS, E. D. McGarry and I. G. Schroder, *SP425*, pp. 116-118 (Oct. 1975).

Key words: dosimetry; filtered beams; neutrons; spectroscopy.

An iron-filtered, neutron-beam facility that provides a well collimated source of 25-keV neutrons has been developed at the National Bureau of Standards (NBS) Reactor. For selected physics experiments and monoenergetic calibration of neutron dosimeters, the beam flux may be tailored to provide $5 \times 10^5 n \cdot cm^{-2} \cdot s^{-1}$ with 99 percent 25-keV neutrons. For other experiments, such as calibration of fast-neutron spectrometers, fluxes of $10^6 n \cdot cm^{-2} \cdot s^{-1}$ may be obtained with as many as 13 identifiable peaks in the energy range 25 keV to 1.5 MeV.

New experimental techniques and results in neutron spectroscopy, C. D. Bowman, *SP425*, pp. 119-128 (Oct. 1975).

Key words: neutron cross sections; new results; new techniques; review.

During the past several years there has been very little funding available for construction of new facilities for neutron measurements. The most important changes in the field have come through the development of new experimental techniques at existing facilities. These techniques and resulting measurements in the area of programmatic neutron data and neutron physics research will be discussed.

Measurement, analysis, and implications of the fission cross section of the important fissionable isotopes, M. S. Moore, *SP425*, pp. 129-138 (Oct. 1975).

Key words: calculated $<\sigma_f>$; deduced channel spectrum; E = 3-5 MeV; fission; nuclear reactions; Pu isotopes; U; $^{235}U(n,f)$.

Recent measurements on the resonance cross sections of isotopes of uranium and plutonium are reviewed, with the objective of determining average parameters suitable for calculations at higher energies. The average parameters obtained are useful in two ways: they provide the necessary input for statistical calculations of resonance cross sections in the unresolved region, and they provide a normalization point for the calculation of smooth cross sections above the unresolved region. The particular problem we address is the systematic trend of average fission cross sections from 3-5 MeV, which have been found to follow the equation $\sigma_f = -39.031 + 17.231\ Z^2/A^{3/2}$. We find that a very simple statistical model calculation, based on R-matrix parameters which adequately describe the total cross section from 20 keV to 20 MeV, can provide a qualitative understanding of this systematic behavior.

Neutron capture cross section measurement techniques, R. E. Chrien, *SP425*, pp. 139-148 (Oct. 1975).

Key words: activation; capture techniques; high resolution methods; Moxon-Rae; review; total absorption.

A review of currently-used techniques to measure neutron capture cross sections is presented. Measurements involving use of total absorption and Moxon-Rae detectors are based on low-resolution detection of the prompt γ-ray cascades following neutron captures. In certain energy ranges activation methods are convenient and useful. High resolution γ-ray measurements with germanium detectors can give information on the parameters of resonance capture states. The use of these techniques is described.

Nuclear models and data for gamma-ray production, P. G. Young, *SP425*, pp. 149-155 (Oct. 1975).

Key words: nuclear reactions ^{14}N, ^{27}Al, ^{56}Fe, Mo, ^{93}Nb, ^{181}Ta, W, ^{238}U, review selected (n,xγ) measurements, evaluations, $\sigma(E_n)$, $\sigma(E_\gamma)$; $^{93}Nb(n,x\gamma)$, E = 14.2 MeV, calculated $\sigma(E_\gamma)$; $^{181}Ta(n,x\gamma)$, E = thermal, calculated $\sigma(E_\gamma)$.

The current Evaluated Nuclear Data File (ENDF/B, Version IV) contains information on prompt gamma-ray production from neutron-induced reactions for some 38 nuclides. In addition, there is a mass of fission product yield, capture, and radioactive decay data from which certain time-dependent gamma-ray results can be calculated. These data are needed in such applications as gamma-ray heating calculations for reactors, estimates of radiation levels near nuclear facilities and weapons, shielding design calculations, and materials damage estimates. The prompt results are comprised of production cross sections, multiplicities, angular distributions, and energy spectra for secondary gamma-rays from a variety of reactions up to an incident neutron energy of 20 MeV. These data are based in many instances on experimental measurements, but nuclear model calculations, generally of a statistical nature, are also frequently used to smooth data, to interpolate between measurements, and to calculate data in unmeasured regions. The techniques and data used in determining the ENDF/B evaluations will be reviewed in this paper, and comparisons of model-code calculations and ENDF data with recent experimental results will be given.

Techniques for the determination of neutron induced charged particle reactions, H. Liskien, *SP425*, pp. 156-160 (Oct. 1975).

Key words: application; charged particle; cross section; emission; neutron; techniques.

Several fields of practical importance are existing for neutron induced charged particle reactions despite their low position within the cross section hierarchy. A survey is given on the experimental techniques employed to obtain information on cross sections, energy and angular distribution for this class of reactions. The obtainable accuracies are discussed and compared with the accuracies requested for the practical applications. The main areas of work, presently neglected, requiring future attention can be identified: (1) Reactions on medium mass nuclei not accessible by the activation method and (2) the neutron energy region between 6 and 12 MeV where suited neutron sources are not easily available.

Integral measurements to test shielding cross sections, L. Harris, Jr., J. C. Young, N. A. Lurie, D. K. Steinman, S. J. Friesenhahn, D. E. Bryan, W. E. Gober, and L. Schänzler, *SP425*, pp. 161-164 (Oct. 1975).

Key words: concrete and steel shield; gamma-ray spectrum unfolding; integral measurements; neutron spectrum unfolding; NE-213 detector; nitrogen cross sections.

The pulsed-white-neutron-source, time-of-flight method and an NE-213 detector have been used for two integral shielding measurements. Incident-neutron-energy-dependent measurements of scattered neutrons and secondary gamma rays from small samples of Be, C, N, H_2O and Fe have been performed. Results for N, including unfolded energy spectra of scattered neutrons and secondary gamma rays at 125°, are presented. Time-dependent measurements of leakage neutrons and secondary gamma rays from a thick concrete and steel shield are described, and some data are presented.

Evaluation, uncertainty estimation and adjustment of capture cross sections for fission product nuclei, H. Gruppelaar, J. B. Dragt, A. J. Janssen, and J. W. M. Dekker, *SP425*, pp. 165-168 (Oct. 1975).

Key words: adjustment; evaluation; fission products; sensitivity analysis; σ_c; $^{101,102,104}Ru$; ^{127}I.

Part of the results of integral measurements, which have been performed in the STEK-facility for about 60 fission product nuclei, have been analysed and used for adjustment of capture cross sections needed for fast breeders. This paper gives an outline of the method used to obtain these adjusted cross sections as well as some conclusions for σ_c of $^{101,102,104}Ru$, ^{127}I.

Integral test of cross sections using neutron leakage spectra from spheres of iron, niobium, beryllium, and polyethylene, R. H. Johnson, J. J. Dorning, and B. W. Wehring, *SP425*, pp. 169-172 (Oct. 1975).

Key words: beryllium; carbon; integral cross section tests; iron; niobium.

Measurements of neutron leakage spectra in the energy range 1 to 15 MeV from homogeneous spherical assemblies have been made using an NE-213 spectrometry system. These benchmark-type measured spectra will be compared with detailed computed spectra as an integral test of evaluated nuclear data. Preliminary ANISN calculations using cross section sets based on ENDF/B-III are presented and compared with the measurements. Measurements on a 22 cm diam beryllium sphere, a 25-cm diam niobium sphere and a 46-cm diam polyethylene (CH_2) sphere, each with a ^{252}Cf source at the sphere center, have been made. The niobium calculation slightly underpredicts the leakage spectrum below 9 MeV. The beryllium and polyethylene calculations are in general agreement with the measurements

though discrepancies are seen for small energy ranges. Measurements have also been made for a 76-cm diam iron sphere with a 14-MeV source at the sphere center. The preliminary iron calculation (ENDF/B-III) greatly underpredicts the leakage spectrum from 1 to 8 MeV.

Uncertainties and correlations in evaluated data sets induced by use of standard cross sections. R. W. Peelle, *SP425*, pp. 173-176 (Oct. 1975).

Key words: correlation; covariance; ENDF/B; standard cross section; uncertainty file.

A file of cross-section uncertainty information for use in reactor performance uncertainty analysis should take into account the propagated effects of uncertainties in the standard cross sections used. This problem has been analyzed using first-order error theory in terms of the uncertainties in the standard cross sections and the energy-dependent weight given to each underlying experimental result in obtaining an evaluated cross section. Three cases occur depending on whether the energy dependence of the standard was utilized, and if so whether the absolute magnitude or only the shape of the standard cross section was used in an underlying experiment. The analysis yields the uncertainties in and correlations among the evaluated cross sections. The resulting uncertainty files need not refer explicitly to the uncertainties in standards and can use the same set of formats employed for other uncertainty data.

Shielding benchmark experiments and sensitivity studies in progress at some European laboratories. G. Hehn, M. Mattes, W. Matthes, R. Nicks, and H. Rief, *SP425*, pp. 177-183 (Oct. 1975).

Key words: benchmark; cross sections; graphite; neutron; sodium; water.

A 100 group standard library based on ENDF/B3 has been prepared by IKE and JRC. This library is used for the analysis of the current European and Japanese iron benchmark experiments. Further measurements are planned for checking the data sets for graphite, sodium, and water.

In a cooperation between the IKE and JRC groups coupled neutron-photon cross section sets will be produced.

Point data are processed at IKE by the modular program system RSYST (CDC 6600) for elaborating the ENDFB data, whereas the JRC group, apart from using standard codes such as SUPERTOG 3, GAMLEG, etc., has developed a series of auxiliary programs (IBM 360) for handling the DLC 2D and POPOP libraries and for producing the combined neutron-plus gamma library EL4 (119 groups). Sensitivity studies (in progress at IKE) make possible improvements in methods and optimization of calculation efforts for establishing group data. A tentative sensitivity study for a 3-dimensional MC approach is in progress at Ispra. As for nuclear data evaluation, the JRC group is calculating barium cross sections and their associated gamma spectra.

Assessment of neutron group constants for iron and stainless steel through measurements and analyses of energy and space distributions of neutrons in test assemblies. I. Kimura, K. Kobayashi, S. A. Hayashi, S. Yamamoto, H. Nishihara, M. Ando, S. Kanazawa, and M. Nakagawa, *SP425*, pp. 184-188 (Oct. 1975).

Key words: activation method; group constants; iron; neutron spectrum; one-dimensional transport calculation; stainless steel; time-of-flight.

In order to assess group constants (JAERI-FAST, ABBN, DLC-2D, etc.) for iron and stainless steel, neutron energy spectra from 1 keV to a few MeV in iron and stainless steel assemblies were measured by the linac-time-of-flight method. Neutron spatial distributions measured by the activation method ($^{58}Ni(n,p)^{58}Co$ and $^{197}Au(n,\gamma)^{198}Au$) showed a spherical symmetry around the photoneutron source, and enabled us to use one-dimensional transport codes (ANISN, DTF-IV, etc.). The measured neutron spectra agree with the predicted by ANISN code with DLC-2D for both materials. However, C/E agreement is poorer below the 25 keV resonance when JAERI-FAST constants for iron are used in calculation. This disagreement was considerably reduced by using a modified set of constants. General shape of fast-neutron spatial distributions agrees with the theoretically predicted for all cases.

ENDF/B dosimetry cross section file benchmark neutron flux-spectral uncertainties. W. N. McElroy, *SP425*, pp. 189-192 (Oct. 1975).

Key words: cross sections; flux; neutrons; reaction rates; spectra.

An ENDF/B file of evaluated energy dependent cross sections for dosimetry applications has been established. The fission and most reliable nonfission reaction cross sections on this file are used with current recommended sets of evaluated measured reaction rates for several benchmark spectra to establish multiple foil derived flux-spectra with Monte Carlo uncertainties for comparison with spectrometry and calculated spectra. It is concluded that integral data testing of cross sections on the ENDF/B-IV file is presently limited to the ± 5 to 10 percent (1σ) range because of uncertainties in the benchmark flux-spectra.

Fission-product gamma-ray and photoneutron spectra. M. G. Stamatelatos and T. R. England, *SP425*, pp. 193-198 (Oct. 1975).

Key words: fission products; gamma spectra; photoneutron spectra; reactors; ^{2}H; ^{9}Be.

Fission-product gamma-ray and photoneutron spectra from thermal and fast fission of ^{233}U, ^{235}U, ^{238}U, and ^{239}Pu have been calculated at 27 time intervals between 1 and 1000 hours following reactor shutdown. The gamma spectral calculations were made using CINDER, a depletion and fission-product code, which has been revised, extended, and variably dimensioned for applications to many problems involving irradiated materials. ENDF/B-IV yield and decay data for all fission products with half-lives ≥ 15 minutes and gamma energies above $^{9}Be(\gamma,n)^{8}Be$ threshold were used. An interesting general feature of the spectra is that they harden with time. The photoneutron spectra were calculated with PHONEX, a program general enough to operate on arbitrary gamma spectra incident on specific materials, e.g., ^{9}Be and ^{2}H. Time-dependent distributions of photons and photoneutrons/fission were calculated in 66 energy groups (50 keV grids). The constancy of these source strengths between ~ 10 and 200 hours following reactor shutdown indicates the possibility of sourceless start-ups.

Safeguards against theft or diversion of nuclear materials. T. B. Taylor, *SP425*, pp. 199-201 (Oct. 1975).

Key words: nuclear enterprises; nuclear materials; plutonium; safeguard; uranium.

An overview of the risks and safeguards relevant to the possible theft or national diversion of special nuclear materials from peaceful nuclear enterprises is presented.

Fission theory and actinide fission data. A. Michaudon, *SP425*, pp. 202-213 (Oct. 1975).

Key words: actinide; cross sections; fission.

The understanding of the fission process has made great progress recently, as a result of the calculation of fission barriers, using the Strutinsky prescription. Double-humped shapes were obtained for nuclei in the actinide region. Such shapes could explain, in a coherent manner, many different phenomena: fission isomers, structure in near-threshold fission cross sections, intermediate structure in subthreshold fission cross sections and anisotropy in the emission of the fission fragments. A brief review of fission barrier calculations and relevant experimental data is presented. Calculations of fission cross sections, using double-humped barrier shapes and fission channel properties, as obtained from the data discussed previously, are given for some U and Pu isotopes.

The fission channel theory of A. Bohr has greatly influenced the study of low-energy fission. However, recent investigation of the yields of prompt neutrons and γ-rays emitted in the resonances of ^{235}U and ^{239}Pu, together with the spin determination for many resonances of these two nuclei cannot be explained purely in terms of the Bohr theory. Variation in the prompt neutron and γ-ray yields from resonance to resonance does not seem to be due to such fission channels, as was thought previously, but to the effect of the (n,γ f) reaction.

The number of prompt fission neutrons and the kinetic energy of the fission fragments are affected by the energy balance and damping or viscosity effects in the last stage of the fission process, from saddle point to scission. These effects are discussed for some nuclei, especially for ^{240}Pu.

Nuclear data for actinide recycle, E. J. Hennelly, *SP425*, pp. 214-217 (Oct. 1975).

Key words: actinide burnup; cross section sets; neutron spectrum; transplutonium; waste management; yield.

Large quantities of heavy actinides will be byproducts of burning plutonium and uranium fuel in nuclear power reactors. Chemical recovery and subsequent recycle in reactors will be for the production of ^{238}Pu and ^{244}Cm as heat sources and ^{252}Cf as a unique source of neutrons or for the ultimate conversion of heavy actinides to shorter-lived fission products to reduce long-term waste storage problems. Test measurements and production yields have provided data for developing a consistent set of multigroup cross sections which give excellent predictions of actinide concentrations in a variety of reactor environments and exposures. These multigroup cross sections are compatible with advanced reactor theory calculational codes.

(n,f) cross sections for exotic actinides, J. B. Wilhelmy, H. C. Britt, A. Gavron, E. Konecny, and J. Weber, *SP425*, pp. 218-221 (Oct. 1975).

Key words: deduced σ_{nf}; nuclear reactions measured P_f $^{230-233}$Pa, ^{231,232}U, $^{233-239}$Np, ^{237,238}Pu, $^{239-243}$Am, $^{241-244}$Cm, ^{248,249}Bk using (^{3}He,df), (^{3}He,tf), E = threshold $-\sim$ 12 MeV.

Neutron induced fission cross sections have been obtained for 26 actinide nuclei using (^{3}He,df) and (^{3}He,tf) reactions to determine fission probabilities and then multiplying these values by calculated compound nuclear neutron reaction cross sections. Comparison with existing (n,f) data shows this to be a feasible approach for obtaining reliable estimates for (n,f) cross sections where direct measurements are not possible. Theoretical developments in interpreting fission probability measurements are discussed.

A study of the ^{233}U-^{232}Th reactor as a burner for actinide wastes, S. Raman, C. W. Nestor, Jr., and J. W. T. Dabbs, *SP425*, pp. 222-223 (Oct. 1975).

Key words: actinide fuel, fertile material, and wastes; recycle concept; transuranium element production; waste recycling in a ^{233}U-^{232}Th reactor.

A plausible method for reducing the storage problems and hazards now associated with long-lived actinide wastes might be to recycle and convert these to fission products. Several reactor types can be envisaged for this purpose. We note that in a ^{233}U-^{232}Th reactor, the production of ^{237}Np, Pu and transplutonium isotopes is greatly reduced compared to a ^{235}U-^{238}U reactor because several additional neutron captures are required to reach the same mass. Hence, the ^{233}U-^{232}Th reactor can be employed to effectively reduce Np, Pu, Am, and Cm wastes to fission-product wastes which entail shorter ($\approx$ 1000 yr) storage times.

A consistent set of transplutonium multigroup cross sections, R. W. Benjamin, V. D. Vandervelde, T. C. Gorrell, and F. J. McCrosson, *SP425*, pp. 224-228 (Oct. 1975).

Key words: heavy actinide burnup; multigroup cross sections; neutron reactions, heavy actinides; reactor production experiments.

A consistent set of multigroup neutron cross sections was developed for nuclides in the chain from ^{242}Pu to ^{253}Es. Evaluated multigroup cross section data were combined with experimental test measurements and production yields from long-term reactor irradiations in flux spectra of varying hardness. Thus 37- and 84-group data were derived in part from ENDF/B and existing Savannah River Laboratory evaluated libraries. Where differential data were lacking, resonance-region model calculations and integral cross section values were combined to form the multigroup data. The data were tested with the JOSHUA system to calculate the reactor environment as a function of time and to predict the concentration of actinide nuclides in the chain. Cross section data were modified within experimental uncertainties until predicted nuclide concentrations matched experimental results within reasonable limits over the range of neutron flux spectra.

Measurement of the neutron capture cross sections of the actinides, L. W. Weston and J. H. Todd, *SP425*, pp. 229-231 (Oct. 1975).

Key words: actinide management; neutron capture cross sections; Pu isotopes, ^{241}Am.

The capture cross sections of the isotopes heavier than ^{239}Pu are of great importance for the core physics, fuel recycle, and waste management for power reactors. Since total cross sections are not sufficient, a program for the measurement of these needed capture cross sections is being carried out at ORNL. Measurements have been almost completed on ^{240}Pu, ^{241}Pu, and ^{241}Am and have been planned for ^{242}Pu and possible ^{237}Np and ^{243}Am. The capture gamma-ray detector used is the "total energy detector" which is a modification of the Moxon-Rae detector. Fission, when present, is detected with fast neutron counters. Results obtained on ^{240}Pu, ^{241}Pu, and ^{241}Am will extend continuously from thermal neutron energies to 350 keV. The cross sections are normalized at thermal neutron energies and the neutron flux is measured relative to the ^{10}B(n,α) cross section up to 2 keV and ^{6}Li(n,α) at higher neutron energies. The accuracy of the techniques used varies with the sample but is about 8 percent. With such cross sections the long range management of the actinides produced in power reactors can be planned on a more systematic basis.

Measurements of the ^{6}Li and ^{10}B partial cross sections from 1 to 1500 keV, S. J. Friesenhahn, V. J. Orphan, A. D. Carlson,

M. P. Fricke, and W. M. Lopez, *SP425*, pp. 232-235 (Oct. 1975).

Key words: neutron cross section; standard; ^{10}B; ^{6}Li.

The $^{10}B(n,\alpha_0+\alpha_1)^7Li$, $^{10}B(n,\alpha_1)^7Li^*$ and $^{6}Li(n,\alpha)T$ cross sections have been measured between 1- and 1500-keV neutron energy. The neutron spectrum was measured using proton scattering as observed in a methane-filled proportional counter. Gamma rays from the $^{10}B(n,\alpha_1)^7Li^*$ reaction were observed with a high-resolution Ge(Li) spectrometer, and the reaction products from the $^{10}B(n,\alpha_0+\alpha_1)^7Li$ and $^{6}Li(n,\alpha)T$ reactions were observed in a large ion chamber. In an auxiliary measurement, the ratio of the $^{10}B(n,\alpha_0+\alpha_1)^7Li$ cross section to the hydrogen scattering cross section was obtained between 200 and 1000 keV by observation of interactions in a specially constructed $^{10}BF_3$ proportional counter containing a methane additive.

An absolute measurement of the $^{6}Li(n,\alpha)$ cross section at 964 keV, W. P. Stephany and G. F. Knoll, *SP425*, pp. 236-239 (Oct. 1975).

Key words: absolute cross section measurements; manganese bath; neutron cross sections; photoneutron sources; surface barrier detectors; $^{6}Li(n,\alpha)$.

A value of 356 mb ±12 percent was obtained for the $^{6}Li(n,\alpha)$ cross section at 964 keV. Neutrons were produced using a spherical Na-Be photoneutron source, calibrated relative to NBS-II using The University of Michigan manganese bath. Thin ^{6}LiF targets enriched to 95 atom percent ^{6}Li were vapor deposited onto the electrode surfaces of a 42 micron thick, fully depleted Si surface barrier detector. A summary of the data, corrections, and error analysis is presented.

Angular anisotropy in the $^{6}Li(n,\alpha)^3H$ reaction at 25 keV, I. G. Schroder, E. D. McGarry, G. de Leeuw-Gierts, and S. de Leeuw, *SP245*, pp. 240-243 (Oct. 1975).

Key words: cross sections; fast-neutron reactions; lithium; nuclear reactions; (n,α) cross sections.

The angular anisotropy in the $^{6}Li(n,\alpha)^3H$ reaction at 25 keV has been measured in two sets of experiments performed at an iron-filtered beam facility (99% of the flux at 25 keV) at the NBS Reactor. First, a surface-barrier detector coated with 80 $\mu g \cdot cm^{-2}$ of ^{6}LiF (front face) was used as a 2π detector. This detector was placed in four different angular positions with respect to the neutron beam: front face at 90 and 45° to the beam; back face at 90 and 45° to the beam. The pulse-height distributions of both the ^3H and ^4He were recorded for these four positions yielding a forward-to-backward asymmetry of 1.59 ± 0.11 in the center-of-mass system. A second detector was placed coaxially with the first (at 90° to the beam) and in such a way as to substend a 45° cone. Coincidence measurements, that simultaneously recorded the distributions in both detectors, yielded an asymmetry in the back-to-forward 45° cone of 1.80 ± 0.06 in the center-of-mass system. The existence of such a large anisotropy at this low energy and the possibility of similar behavior at still lower energies (i.e., 1 – 2 keV) should result from s-p wave interference. This would give rise to a constant anisotropy that is experimentally masked by the 1/v behavior of the isotropic s-s interference terms at lower energies.

Neutron total cross section of ^{6}Li from 10 eV to 10 MeV, J. A. Harvey and N. W. Hill, *SP425*, pp. 244-245 (Oct. 1975).

Key words: nuclear reactions; ^{6}Li, σ_{nT}, En = 10 eV to 10 MeV.

Transmission measurements have been made at ORELA upon two metal samples of ^{6}Li(98.72%) with inverse sample thicknesses of ^{6}Li of 11.99 and 2.987 b/atom. The measurements at low energies (from 10 eV to 300 keV) were made using a ^{6}Li glass scintillation detector at 17.878 m and 78.203 m and at high energies (from 50 keV to ~ 10 MeV) using an NE-110 scintillation detector at 78.203 m. The total cross section data from both samples and detectors are in good agreement and are believed to be accurate to 1 to 2 percent below 1 MeV. Total cross section data obtained from both samples at ~ 25 discrete energies up to 1 MeV using an iron-filtered beam are in good agreement with the continuous spectra data.

Observation and analysis of elastic neutron scattering from ^{12}C, R. J. Holt, A. B. Smith, and J. F. Whalen, *SP425*, pp. 246-249 (Oct. 1975).

Key words: measured $\sigma_t(E)$, E = 1.5-5.0 MeV, $\sigma(\theta,E)$, E = 1.8-4.0 MeV, θ_{lab} = 20 to 160°; nuclear reaction $^{12}C(n,n)^{12}C$; R-function analysis.

Angular distributions of neutrons elastically scattered from ^{12}C were measured from 1.8-4.0 MeV at intervals of ≥ 20 scattering angles distributed between 20-160 deg. Incident neutron energy resolutions were 20-50 keV. All differential cross sections were determined relative to those of the H(n,n) reaction. In addition, total neutron cross sections were deduced from monoenergetic (ΔE ≈ 2 keV) neutron transmissions in the energy range 1.5-5.0 MeV. The experimental results were interpreted in terms of a multilevel R-matrix analysis including considerations of previously reported cross sections and polarizations. The resulting R-matrix parameters are compared with the Yale values deduced from observed scattered neutron polarizations. The measured values and analysis suggest physically consistent standard carbon total and scattering cross sections readily referenced in measurement applications.

Fission spectrum neutrons for cross section validation and neutron flux transfer, J. A. Grundl and C. M. Eisenhauer, *SP425*, pp. 250-253 (Oct. 1975).

Key words: cross sections; dosimetry; evaluation; fission spectrum; neutron flux; neutrons.

A variety of measurement methods over more than two decades provides a base for proper evaluation of the fission spectrum shape. The evaluation presented recommends a Maxwellian reference description for ^{252}Cf (spontaneous fission) and ^{235}U (thermal-neutron-induced fission) with average energy parameters of 2.13 MeV and 1.97 MeV respectively over the energy range 0.25 to 8 MeV. A further multigroup summary of the experimental data presents the final evaluation as an empirical adjustment of Maxwellian segments and includes an estimate of credible departures from the true spectrum shape. The reference Maxwellian shapes differ from the final evaluated shape by < 2 percent over the above energy range. A few basic integral quantities, fission neutron age in water and the fission-spectrum-averaged fission cross section for ^{238}U, ^{235}U, and ^{237}Np, are reviewed briefly, based on the results of the evaluation. Two features of fission neutrons make them a useful reference for certain measurement problems in nuclear technology: the fission spectrum shape is preserved above ~ 1 MeV in important reactor-associated neutron environments, and small, intense sources of pure ^{252}Cf fission neutrons are now available. A restricted class of related applications using fission neutron sources is discussed.

Fundamental integral cross section ratio measurements in the thermal-neutron-induced uranium-235 fission neutron spec-

trum, A. Fabry, J. A. Grundl, and C. Eisenhauer, *SP425*, pp. 254-257 (Oct. 1975).

Key words: dosimetry; fission cross sections; neutron standards; uranium-235 cavity fission spectrum.

High-accuracy integral cross section ratio measurements have been performed in the thermal-neutron-induced uranium-235 fission neutron spectrum. This involves the basic fission reactions ^{235}U(n,f), ^{239}Pu(n,f), ^{238}U(n,f) and ^{237}Np(n,f); and the gold capture and ^{115}In(n,n')^{115m}In dosimetry reactions. The uranium-235 fission neutron spectrum is generated at the center of a one meter diameter spherical cavity within a graphite thermal column. Simple and variable geometrical arrangements were used and evaluated for neutron field purity. The fission rates were determined with the NBS double fission chamber as well as with others of different size and design. All fission detectors were validated within a parallel program of interlaboratory comparisons in the MOL-ΣΣ Standard Neutron Field. The activation rates have been measured with calibrated gamma-ray spectrometers. The resulting integral cross section ratios relative to the ^{238}U(n,f) reaction are, for ^{235}U(n,f): 3.94 ± 0.08; ^{239}Pu(n,f): 5.93 ± 0.13; ^{237}Np(n,f): 4.35 ± 0.13; ^{115}In(n,n')^{115m}In: 0.620 ± 0.019; and ^{197}Au(n,γ)^{198}Au: 0.287 ± 0.014.

Interlaboratory comparison of absolute fission rate and uranium-238 capture rate measurements in the Mol-ΣΣ secondary intermediate-energy standard neutron field, M. Pinter, W. Scholtyssek, P. Fehsenfeld, H. A. J. van der Kamp, W. H. J. Quaadvliet, A. Fabry, G. De Leeuw, S. De Leeuw, F. Cops, J. A. Grundl, D. Gilliam, and C. Eisenhauer, *SP425*, pp. 258-261 (Oct. 1975).

Key words: fast reactors; fission chambers; fission rates; mass assay; MOL-ΣΣ facility; uranium-238 capture rates.

Interlaboratory comparisons have been made during the past two years, of techniques that are currently applied for the measurement of fission rates and uranium-238 capture rates in a number of zero-power fast assemblies related to the LMFBR program. This effort has involved the exposure of absolute fission chambers and of activation foils, to the Mol-ΣΣ central neutron field. Long term flux level monitoring accuracy of better than ±0.5 percent in Mol-ΣΣ has been achieved. The perturbation of the neutron field by the access hole has been studied extensively. Uncertainties in measured reaction rates estimated by each laboratory relative to flux monitors are between ±1.5 percent and ±3.5 percent. Interlaboratory agreement for ^{235}U, ^{238}U, and ^{239}Pu fission rates is in the range ±0.5 to ±1.3 percent. Poor agreement is obtained for the ^{238}U capture rate measurements and further interlaboratory efforts are recommended including complementary experimental techniques. A set of ΣΣ preferred values of central fission rate ratios and uncertainties is presented.

Manganese bath systematic effects in measurements of nu-bar and eta, J. R. Smith, *SP425*, pp. 262-265 (Oct. 1975).

Key words: eta; fissile nuclei; manganese bath; nu-bar; ^{252}Cf.

Measurements using the manganese bath technique are central to the discrepancy that has existed between measured values of $\bar{\nu}$ for ^{252}Cf. Manganese bath measurements of $\bar{\nu}$ belong to the lower group of values, while the η measurements are consistent with the higher ν values. A three-part study was performed to see if the discrepancy could be explained by differences in manganese bath techniques: (1) A ^{252}Cf source previously calibrated by De Volpi was calibrated in the MTR manganese bath; (2) The recommendations made by De Volpi for altering the MTR eta values were carefully considered; and (3) The results of the Monte Carlo calculations of the MTR experiment, carried out at Bettis Atomic Power Laboratory, were examined in detail. The study produced insignificant changes in the η values.

Absolute ^{235}U fission cross section for ^{252}Cf spontaneous fission neutrons, H. T. Heaton II, J. A. Grundl, V. Spiegel, Jr., D. M. Gilliam, and C. Eisenhauer, *SP425*, pp. 266-269 (Oct. 1975).

Key words: fission spectrum; spectrum averaged cross section; ^{235}U(n,f); ^{252}Cf.

A measurement of the absolute ^{235}U fission cross section for ^{252}Cf spontaneous fission neutrons has been performed with two double fission chambers in compensated beam geometry. The fission chambers are mounted 10 cm apart on opposite sides of a small volume, single encapsulated ^{252}Cf source (4×10^9 n/sec, 0.34 cm^3 capsule vol; ~ 2 g steel and aluminum). In this geometry the effect of source position errors is small. The ^{252}Cf neutron source strength was determined with a Manganous Sulfate Bath relative to the internationally compared Ra-Be photoneutron standard neutron source, NBS-I, presently known to ±1.1 percent. Uncertainty in the Manganous Bath comparison of NBS-I and the Cf source was ±0.4 percent; the ^{235}U fissionable deposit masses have been ascertained to ±1.3 percent. Five scattering corrections were applied to the data: source capsule (0.6 ±0.8) percent, fission chamber (1.1 ±0.4) percent, support structure (0.6 ±0.5) percent, platinum deposit backing (1.3 ±0.8) percent and total room return (0.5 ±0.2) percent. The observed ^{235}U fission cross section is 1204 ± 29 mb. A computed value of 1245 mb is obtained using an evaluated ^{252}Cf fission neutron spectrum and ENDF/B-IV for the ^{235}U(n,f) cross section.

Fission cross section ratios in the ^{252}Cf neutron spectrum (^{235}U; ^{238}U; ^{239}Pu; ^{237}Np), D. M. Gilliam, C. Eisenhauer, H. T. Heaton II, and J. A. Grundl, *SP425*, pp. 270-272 (Oct. 1975).

Key words: fission cross section; fission spectrum; ^{252}Cf; ^{235}U; ^{238}U; ^{239}Pu; ^{237}Np.

In a ^{252}Cf neutron field, ratios of spectrum-averaged fission cross sections have been measured by back-to-back counting in a double fission ionization chamber with interchangeable deposits of ^{235}U, ^{238}U, ^{239}Pu, and ^{237}Np. These ratio measurements provide integral tests for evaluated cross section data. The dominant error in the ratio measurements was the ±1.4 percent to ±2.1 percent uncertainty in the fissionable deposit masses. Redundant mass assay methods were employed for all deposit nuclides. Corrections of up to (1.4 ± 7) percent were necessary for inelastic scattering effects on the neutron energy distribution in the cases of ^{238}U and ^{237}Np. For ^{235}U and ^{239}Pu fission rates, a correction of (0.45 ± 0.20) percent was made for the contribution of neutrons moderated and back-scattered by laboratory structures. The cross section ratios observed in the present measurements were as follows: 1.000: 0.266 ± 1.7 percent: 1.500 ± 1.6 percent: 1.105 ± 2.2 percent for ^{235}U: ^{238}U: ^{239}Pu: ^{237}Np, respectively. In comparison to the observed integral cross section ratios, the corresponding values derived from ENDF/B-IV data were 2.3 to 6.0 percent lower.

Measurement of cross sections for threshold reactions induced by californium-252 spontaneous fission neutrons, W. G. Alberts, J. Bortfeldt, E. Günther, K. Knauf, M. Matzke, G. Rassl, V. Siegel, and K. F. Walz, *SP425*, pp. 273-276 (Oct. 1975).

Key words: activity measurement; cross sections; fission

spectrum; neutron source; scattering corrections; threshold detectors.

An open-air experiment for measuring cross sections averaged over the californium-252 spontaneous fission neutron spectrum is described. In a low-scattering arrangement the ^{252}Cf source was enclosed by the sample materials for irradiation. From the source strength (3×10^{9} s^{-1} as of Jan. 1973) and the activities of the generated nuclides, average cross sections for the reactions $^{27}Al(n,\alpha)^{24}Na$, $^{54}Fe(n,p)^{54}Mn$, $^{56}Fe(n,p)^{56}Mn$, and $^{46}Ti(n,p)^{46}Sc$ were derived. The influence of neutron scattering in the source and samples has been taken into account by means of Monte Carlo calculations; in addition this influence in the samples was studied experimentally by activating samples of various thicknesses.

Absolute neutron flux determination in fast neutron spectra, . Schouky, S. Cierjacks, P. Brotz, D. Gröschel, and B. Leuers, *SP425*, pp. 277-280 (Oct. 1975).

Key words: gas scintillation transmission counters; neutron flux determination; $1 \leq E_n \leq 30$ MeV.

A flux detector system was developed in order to determine the fast neutron flux between 1-30 MeV obtained with the Karlsruhe isochronous cyclotron. The counter system represents a telescope-like proton recoil device using solid radiators and gas scintillation transmission counters. Flux determination is accomplished separately between about 1-6 MeV and ~ 5-30 MeV, with a small energy interval of overlap. Below 6 MeV, recoil protons are detected in a single gas scintillation chamber viewed by three photomultipliers requiring a fast coincidence. Above this range, high energy recoil protons are identified by coincidences in three adjacent chambers and by their specific energy losses. Since the transmission of the entire flux counter system is better than 99 percent, it can be used for simultaneous flux measurements in partial cross section determination. The accuracy for the determination of the neutron flux is about 5 percent.

Thermal parameters of the fissile isotopes, B. R. Leonard, Jr., *SP425*, pp. 281-285 (Oct. 1975).

Key words: evaluation; nuclear reactions ^{233}U, ^{235}U, ^{239}Pu, $^{241}Pu(n,F)$ (n,γ) (n,n) ν, E = 0-1 eV.

Evaluations have continued to better define the 2200 m/s nuclear data for the fissile isotopes. The author has been participating in such evaluations with both the International Atomic Energy Agency (IAEA) and the USAEC National Neutron Cross Section Center (NNCSC). Each study is faced with the same dilemma: the measured values of a given parameter form a set which is reasonably self-consistent, yet the average values of the interrelated parameters constitute a set which is significantly inconsistent. The obvious discrepancy is between the values of alpha deduced with high accuracy from irradiation experiments with the values which result from the ensemble of values of the other parameters which by themselves form a reasonably self-consistent set. However, the inconsistency could result from error assignments which are too small for two or more parameters, e.g., fission and eta. In order to expedite ENDF/B-IV, the NNCSC evaluation fixed certain input parameters including the thermal shapes which are in good agreement with differential data. As a result the least-squares-compromise adjusted absorption, fission, and nubar values by several tenths percent. In the IAEA evaluation, the primary adjustments of the LSQ fit were in nubar and g_γ values which implicitly infer significant systematic errors in the directly measured capture shapes. The Electric Power Research Institute has initiated studies to attempt to resolve this dilemma which is crucial to analyses of fission power reactors. These are: (1) A simultaneous LSQ fit to energy-dependent differential partial and total data; (2) A reevaluation of the accuracy assignment of absolute fission cross section values; and (3) A reexamination of irradiation alpha experiments with sophisticated analytical methods. Further experiments which would improve the knowledge of the thermal parameters include: (1) Confirmatory measurements of capture shapes extended to lower neutron energies; (2) Confirmatory measurements relative to the monoenergetic eta experiments; (3) Accurate coherent scattering amplitude measurements in the thermal region for all isotopes; (4) Measurement of the total cross section of ^{233}U from thermal to several tenths eV; (5) Improved thermal fission critical experiments and analysis for ^{239}Pu; and (6) Confirmatory high accuracy absolute fission cross-section experiments.

The third IAEA evaluation of the 2200 m/s and 20 °C Maxwellian neutron data for U-233, U-235, Pu-239, and Pu-241, H. D. Lemmel, *SP425*, pp. 286-292 (Oct. 1975).

Key words: Cf-252 spontaneous fission neutron yield; E = 0.0253 eV and 20 °C Maxwellian; fission-neutron yields; half-lives of U-233, U-234, Pu-239; mean energy of fission neutron spectrum; neutron cross-sections; neutron data evaluation; U-233, U-235, Pu-239, Pu-241; Westcott g-factors.

The paper presents a new consistent set of best values of 2200 m/s and 20 °C Maxwellian neutron cross-sections, fission-neutron yields, and Westcott g-factors for U-233, U-235, Pu-239, and Pu-241, and of related reference values such as the spontaneous fission-neutron yield of Cf-252, the mean fission-neutron spectrum energies of the five nuclides named, the α-decay half-lives of U-233, U-234, and Pu-239 and others.

This consistent set of values is derived from a multiparameter least-squares fit of all available experimental data, after reviewing and, where feasible, reassessing the authors' quoted values and errors usually after consultation with the authors.

The new best set of values is significantly different from that of the Second IAEA Review of 1969. The major changes are due to new lower experimental values of $\overline{\nu}$ (Cf-252) and of half-lives. Also discussed are some disturbing unresolved discrepancies among experimental data, which leave the accuracies of some parameters, for example the uranium fission cross-sections, still unsatisfactory.

Neutron cross section standards and flux determinations above thermal energies, A. D. Carlson, *SP425*, pp. 293-301 (Oct. 1975).

Key words: Au(n,γ); C(n,n); H(n,n); neutron flux determination; standard cross sections; $^{3}He(n,p)$; $^{6}Li(n,\alpha)$; $^{10}B(n,\alpha)$; $^{235}U(n,f)$; $^{237}Np(n,f)$.

The recent worldwide advances in nuclear technology, particularly fast fission and fusion reactors, have revealed the need for accurate neutron reaction cross sections for the design of these systems. The accuracies of these cross sections are generally limited by the standard cross sections relative to which they are measured. With the exception of the hydrogen scattering cross section, there have been serious problems with each of the standards in the energy region where it is being used as a standard. New measurements of many of these standards have been recently completed which will have a strong impact on the quality of these cross sections. A review will be presented of the status of the neutron cross section standards presently employed for

measurements of neutron cross sections. Light element, capture and fission standards will be included. Special emphasis will be placed on the techniques which have been used to obtain the neutron flux for measurements of neutron cross section standards.

R-matrix analysis of the light element standards, G. M. Hale, *SP425*, pp. 302-308 (Oct. 1975).

Key words: cross sections; light elements; R-matrix; standards; ^{6}Li; ^{10}B.

The application of multilevel, multichannel R-matrix theory to the analysis of reactions in light nuclear systems is outlined. The discussion then specializes to describe analyses of reactions in the ^{7}Li and ^{11}B systems, which contain (n,α) cross sections widely used as neutron standards. Comprehensive R-matrix analyses which were incorporated in Version IV of the Evaluated Nuclear Data File (ENDF/B-IV) for neutron reactions from ^{6}Li and ^{10}B are described, giving the reactions and data analyzed, the resulting parameters, and predicted cross sections. The effects of new experimental information on the ENDF/B-IV results are discussed for both lithium and boron. Particular attention is given to the perplexing question of determining the ^{6}Li(n,α) cross section in the region of the 240 keV resonance. Suggestions for further experimental work are given.

Computer-readable "Nuclear Data Sheets," W. B. Ewbank, *SP425*, pp. 309-312 (Oct. 1975).

Key words: computers; data; decay; ENSDF; evaluation; files; formats; levels; nuclear structure; radiations; reactions; tables; γ-rays.

The evaluated nuclear structure data contained in "Nuclear Data Sheets" are available in computer-readable form. Experimentally established properties of nuclear levels are included as well as radiations from nuclear reactions and radioactive decay. Portions of the data can be selected for distribution in several formats on magnetic tape or computer cards. A variety of different listing and drawing formats are also available.

Recent evaluation for the German nuclear data library KEDAK-3. B. Goel, H. Küsters, and F. Weller, *SP425*, pp. 313-316 (Oct. 1975).

Key words: evaluation; nuclear data; plutonium; uranium.

For the design and optimization of reactors a precise knowledge of the microscopic neutron data is needed. For this purpose new evaluations for a number of important fast reactor materials have been performed at this laboratory. In the paper we discuss reevaluations of U^{238} and Pu^{239}. To check the quality of the presently evaluated data in reactor physics calculations, their effect on k_{eff} for a large variety of critical assemblies is studied. Calculation shows that with the evaluated data for U^{235}, U^{238}, Pu^{239}, Pu^{240}, Pu^{241}, and Pu^{242} the value of k_{eff} for a large number of critical assemblies can be reasonably well reproduced without any adjustment of the data.

Description of the ENDF/B-IV silicon evaluation energy distributions of outgoing particles, D. Larson, *SP425*, pp. 317-319 (Oct. 1975).

Key words: cross sections; energy distributions; photon; tertiary; theoretical.

Calculations are presented for the energy distributions of secondary particles resulting from neutron-induced binary and tertiary reactions on ^{28}Si.

Evaluation of fission product nuclear data for 28 important nuclides, S. Igarasi, S. Iijima, M. Kawai, T. Nakagawa, Y. Kikuchi, K. Maki, and H. Matsunobu, *SP425*, pp.320-323 (Oct. 1975).

Key words: capture cross section; elastic and inelastic scattering cross sections; evaluation; fission product; optical model; resonance cross section; statistical model; total cross section.

Evaluation of 28 fission product nuclear data for fast reactors is performed for total, capture, elastic scattering and inelastic scattering cross sections up to 15.0 MeV. Resonance parameters as well as the data of resonance integrals are surveyed. The cross sections reproduced with these parameters are adjusted so as to fit the thermal values and are connected smoothly with the cross sections obtained by the statistical model calculations. For some nuclides whose resonance parameters are not experimentally obtained yet, the statistical model calculations are carried out down to fairly low energy point. The cross section values thus obtained are used as the expectation values of averaged cross sections in the resonance region. Numerical data obtained are stored on the magnetic tape in the ENDF/B format.

Evaluated decay-scheme data for the ILRR program, R. G. Helmer and R. C. Greenwood, *SP425*, pp. 324-327 (Oct. 1975).

Key words: evaluated half-lives; evaluated γ-ray intensities; ILRR program.

The half-lives and γ-ray intensities associated with radioactive decay have been evaluated for nuclides of interest to the Interlaboratory LMFBR Reaction Rate program. The results indicate that for most of the isotopes the decay parameters are known sufficiently well to meet the ILRR goals of 2 1/2 or 5 percent accuracy in reaction rate measurements.

Development of a two-step Hauser-Feshbach code with precompound decays and gamma-ray cascades—a theoretical tool for cross section evaluations, C. Y. Fu, *SP425*, pp. 328-331 (Oct. 1975).

Key words: fluorine; iron; photon; reaction; tertiary.

The code is used to calculate neutron-induced binary reaction, tertiary reaction and associated gamma-ray-production cross sections of ^{19}F, ^{40}Ca and ^{56}Fe. Comparisons with experimental data show much improved agreements over those previously possible.

Neutron cross sections and their uncertainties obtained from nuclear systematics, S. Pearlstein, *SP425*, pp. 332-334 (Oct. 1975).

Key words: cross section; neutrons; nuclear model.

Previously, neutron cross sections in the MeV range for nuclei ranging in Z from 21 through 41 were calculated using a hybrid empirical-statistical model code THRESH. The formalism includes level density, Coulomb barrier, and competing reaction effects and has been useful in the prediction of unmeasured cross sections or normalized to point measurements to generate complete excitation curves. Reaction data up to 20 MeV in the Z range 21 through 83 are used to refine the model and extend its range of validity. A least squares fitting technique optimizes the choice of parameters with the resulting matrix used to determine parameter uncertainties and correlations. Fitted cross sections and their calculated uncertainties are compared with measurements and quoted errors. A range of uncertainty is assigned to predicted cross sections.

Level density calculation for deformed nuclei, J. P. Felvinci, . Cacuci, and E. Melkonian, *SP425*, pp. 335-337 (Oct. 975).

Key words: level densities and positions of K-bands in rare earth and actinide nuclei.

Level densities for the rare earth and actinide nuclei have been calculated using a modified version of the Ericson formalism. The assumption was made, that K (the projection of J on the symmetry axis of the nucleus) is a good quantum number in the compound nucleus. Individual level densities for the different (K,J) values of the compound nucleus formed by low energy neutron interactions were calculated. The results show good agreement with the interpretation of recent results obtained on U-235 in this laboratory. Using the above calculations it is also possible to infer from the measured level densities the locations of the band heads of different K bands in the compound nucleus. The results also indicate that the K bands responsible for the level densities exclude the ground state rotational band. Levels built on the higher lying β and γ vibrational bands and their composites are sufficient in number to explain the observed level densities.

Odd-even fluctuations in neutron strength functions, G. J. rouac, *SP425*, pp. 338-341 (Oct. 1975).

Key words: doorway states, optical model; neutron strength function.

Systematic fluctuations are reported for the s-wave neutron strength functions of adjacent mass target nuclei with odd and even neutron number. Within the 3S and 4S single-particle resonances, the fluctuations appear to be related to odd-even variations in the doorway state density which are correlated with the excitation energy. A simple model calculation successfully reproduces the strength function fluctuations in the first peak of the split 4S resonance ($143 \leq A \leq 160$). An examination of all available even-Z strength function data suggests a general trend; S-odd > S-even near single-particle resonances and S-even > S-odd between resonances. This result is discussed in terms of the optical model spreading width W and other fundamental nuclear properties.

Statistical estimation of physical quantities in thermal- and t-neutron-induced fission, T. Yamamoto and K. Sugiyama, *425*, pp. 342-345 (Oct. 1975).

Key words: actinide nuclide; fast-neutron-induced fission; ission; fission fragment; fission product; kinetic energy; mass yield; prompt neutron; scission point; statistical heory.

Making use of a model based on the statistical theory in which the scission-point distance is treated as an adjustable parameter, calculations were performed to obtain the mass yields of fission products, the kinetic energies of fission fragments and the numbers of prompt neutrons from neutron-induced fission of ^{232}Th, ^{231}Pa, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu, and ^{241}Pu for incident-neutron energies ranging from thermal o 14.7 MeV. Calculated results reproduced experimental values well. The proposed method could be used in the estimation of unknown physical quantities in fission.

Theoretical estimates of (n,γ) cross sections for 6-15 MeV utrons, G. Longo and F. Saporetti, *SP425*, pp. 346-349 ct. 1975).

Key words: calculations; complex interaction; semi-direct nodel; volume form; (n,γ) cross sections.

The knowledge of the correct values of (n,γ) cross sections for high energy neutrons is of great interest for studies into nuclear reaction mechanism as well as for reactor shielding purposes and in particular fusion-reactor design. The use of theoretical estimates is therefore required to fill the gaps in the available experimental data. For this purpose the semi-direct capture model has been refined (a) by replacing the previous surface form factors of the interaction by volume form factors, (b) by including quadrupole terms in addition to the dipole ones. Calculations, based on the refined model, agree satisfactorily with experimental data.

Reaction mechanism in the high energy tail of the 14 MeV ^{56}Fe(n,n′)-process, H. Jahn, C. H. M. Broeders, and I. Broeders, *SP425*, pp. 350-353 (Oct. 1975).

Key words: angular distribution; inelastic scattering; proton emission; scattered neutron.

Measured cross-sections of 14 MeV-neutrons scattered inelastically on ^{56}Fe are analyzed to carry out investigations about the reaction mechanism. It is shown that a considerable part of direct inelastic scattering has to be added to the evaporation and pre-equilibrium processes in order to reproduce the data, especially the angular distribution, for energies of the scattered neutron above 7 MeV.

Calculations of (n,α) rates for iron-group materials, F. M. Mann and Z. E. Switkowski, *SP425*, pp. 354-356 (Oct. 1975).

Key words: calculated σ(E), (α,n), (n,α), Hauser-Feshbach; nuclear reactions Fe group.

The Hauser-Feshbach statistical model is used to calculate (α,n) and (n,α) cross sections for Fe-group elements to provide information on helium production within fusion reactors. A parametrization of the cross sections is discussed.

Parametric fit of the total cross section of ^{45}Sc, B. A. Magurno and S. F. Mughabghab, *SP425*, pp. 357-359 (Oct. 1975).

Key words: bound level parameters; spin assignments; thermal cross sections.

A parametric fit to the total cross section of Sc-45 based on the Breit-Wigner multilevel formalism was carried out. To reproduce the minimum in the total cross section at 2.0 keV and to get an acceptable fit for the low energy resonances, the spins of the bound level, the 3.24, and 4.27 keV resonances are 4,3,4 respectively. At higher energies the spins adopted for the resonances at 6.5, 7.9, 8.9, and 11.7 keV were 3,4,3,4. The parameters of the bound level are $E_o = -270$ eV, $\Gamma_n^o = 2.05$ eV (J=4) and $\Gamma_\gamma = 0.38$ eV.

Neutron capture mechanism in light and closed shell nuclides, B. J. Allen, J. W. Boldeman, M. J. Kenny, A. R. deL. Musgrove, H. Pe, and R. L. Macklin, *SP425*, pp. 360-362 (Oct. 1975).

Key words: nuclear reactions: Al, Si, ^{40}Ca, ^{52}Cr, ^{90}Zr, ^{138}Ba(n,γ), $E_n > 2.5$ keV, measured σ(n,γ), ^{6}Li monitor, enriched targets, deduced resonance parameters, correlation coefficient, valence component.

High resolution neutron capture cross section measurements have been made at the Oak Ridge Electron Linear Accelerator on Al, Si, ^{40}Ca, ^{52}Cr, ^{90}Zr, and ^{138}Ba for the energy range above 2.5 keV. These data have been analysed at Lucas Heights where capture measurements with Ge(Li) and Moxon-Rae detectors have provided complementary information. While valence model calculations are important for these nuclides in explaining the shape of the γ-ray spectra and the observed correlation between reduced neutron and radiative widths, the valence component cannot adequately account for the observed radiative widths and a

substantial single particle component, uncorrelated with neutron widths, is required.

Radiation Shielding Information Center data activities, R. W. Roussin, B. F. Maskewitz, and D. K. Trubey, *SP425*, pp. 363-366 (Oct. 1975).

Key words: analysis; cross sections; evaluation; information; processing; radiation; shielding.

Activities developed at the Radiation Shielding Information Center (RSIC) play an important role in the utilization of nuclear cross sections in various radiation transport applications and help improve the general utility of the national ENDF/B effort. The activities involving processed and evaluated data libraries on behalf of RSIC's various sponsoring agencies are described.

Evaluation of the resonance parameters and capture cross section for chromium up to 600 keV, D. Abramson, J. C. Bluet, and P. Fardeau, *SP425*, pp. 367-370 (Oct. 1975).

Key words: capture; chromium; cross section; evaluation; neutron; resonance.

Experimental results are examined. An extensive comparison of recent sets of results allows a point-wise evaluation of the capture cross section versus energy. Moreover a set of resonance parameters has been chosen. The curve calculated with these parameters and a smoothly varying background agrees pretty well with the point-wise evaluation.

Representation of the neutron cross sections in the unresolved resonance region, G. de Saussure and R. B. Perez, *SP425*, pp. 371-379 (Oct. 1975).

Key words: cross sections; ENDF/B; neutrons; reactors; resonances; unresolved.

We discuss some limitations of the statistical approach to the representation of cross sections in the unresolved region and suggest that the actual Doppler-broadened cross sections should be used instead.

Helium production in reactor materials, E. P. Lippincott, W. N. McElroy, and H. Farrar, *SP425*, pp. 375-377 (Oct. 1975).

Key words: benchmark; cross sections; helium; neutron.

Comparisons of integral helium production measurements with predictions based on ENDF/B Version IV cross sections have been made. It is concluded that an ENDF/B helium production cross section file should be established in order to ensure a complete and consistent cross section evaluation to meet accuracies required for LMFBR, CTR, and LWR applications.

Fast reactor fission yields for ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, and recommendations for the determination of burnup on FBR mixed oxide fuels, W. J. Maeck, *SP425*, pp. 378-384 (Oct. 1975).

Key words: burnup monitors; capture-to-fission; dilution mass spectrometry; fast fission yields; yields vs. energy; ^{233}U, ^{235}U, ^{238}U, ^{239}Pu.

Absolute fast reactor fission yields are presented for over 40 stable and long-lived isotopes of Kr, Rb, Sr, Zr, Mo, Ru, Sb, Xe, Cs, Ba, La, Ce, Nd, and Sm for ^{233}U, ^{235}U, ^{238}U, and ^{239}Pu irradiated in EBR-II. A method for ordering fission yields as a function of neutron energy is given. Recommendations for the determination of burnup on mixed-oxide fuels irradiated in a fast reactor are given.

Effects of nuclear data uncertainties upon LMFBR fuel cycle characteristics, R. D. McKnight, L. G. LeSage, and J. M Christenson, *SP425*, pp. 385-388 (Oct. 1975).

Key words: breeding ratio; cross section uncertainties equilibrium cycle; fuel cycle; reactivity swing; sensitivit study.

Fuel cycle sensitivity calculations have been performe to determine the effect which nuclear data uncertaintie have upon the long term properties of a typical LMFBF These effects are assessed by direct comparison of a serie of fuel cycle calculations which evaluate the approach t equilibrium conditions. The effects of uniform cross sectio adjustments (for the fission and capture cross sections fo ^{238}U, ^{238}Pu, ^{240}Pu, and ^{241}Pu) upon the fuel cycle chara teristics, including breeding ratio, doubling time, power di tribution, fissile loading, fissile mass discharge rates, contr requirements and reactivity swing are presented for the in tial burn cycle and the equilibrium cycle. ENDF/B-3 da are used for a data reference. Several of the cross sectio modifications produced significant uncertainties in LMFB design parameters. The effects of these changes upon th fuel cycle characteristics propagate from cycle to cycle bu in general, do not increase with time. The most significa effects were produced by uncertainties in σ_f for ^{239}Pu ar ^{241}Pu, and σ_c for ^{238}U. Uncertainties in these cross sectio produce large changes in control requirements, breedi potential, and reactivity swing.

The sensitivity of k_{eff} of metallic assemblies to the parametr representation of the fission and the inelastic scattering spectr H. Nissimov and J. J. Wagschal, *SP425*, pp. 389-391 (Oc 1975).

Key words: critical assemblies; ENDF/B-IV; fission spe trum; inelastic scattering; sensitivity; ^{239}Pu.

The fission spectrum and the inelastic scattering spectru of ENDF/B-IV ^{239}Pu data were modified. The variations k_{eff} and of the leakage spectrum induced by these modific tions were calculated for a bare ^{239}Pu critical sphere, as typical metallic assembly. In certain cases these modific tions lead to substantial variations in k_{eff}. Guides f reasonable changes in the representation of the spectra we obtained. The variations in k_{eff} and in the leakage spectru caused by these reasonable changes were found to be with their experimental errors.

Comparison of Doppler broadening methods, D. E. Culle C. R. Weisbin, R. Q. Wright, and J. E. White, *SP425*, pp. 39 397 (Oct. 1975).

Key words: calculation; comparison; Doppler broadenin line shape.

Burnup calculations for the KWO reactor, D. C. Lut *SP425*, pp. 398-400 (Oct. 1975).

Key words: burnup calculation; burnup model; critic boron concentration; fission products; KWO; RSYST.

An effort was made to reproduce the measured shape the critical boron concentration for the KWO react (PWR) during the first cycle starting from basic nuclear da (ENDF/BII). The overall results are quite satisfactory b there are some local differences up to 80 ppm.

Fission product nuclear data obtained by use of on-line ma spectrometer, P. L. Reeder, J. F. Wright, and R. A. Ande *SP425*, pp. 401-404 (Oct. 1975).

Key words: cumulative yields; delayed-neutrons; fissi products; half-lives; independent yields; mass spectrometr

A Spectrometer for On-Line Analysis of Radionuclid

(SOLAR) has been installed at a 1 MW TRIGA reactor at Washington State University. Fission product ions from a combination target/ion source located within the thermal column are brought out to a 60° magnetic sector mass spectrometer. Surface ionization provides copious beams of Rb^+ and Cs^+ ions and less intense beams of Br^- and I^- ions with negligible contamination by other elements. About 40 fission product nuclides can thus be chemically and physically separated in times of less than 1 second. Past results on independent and cumulative fission yields along with measurements of half-lives of some very neutron-rich nuclides will be presented. Current work on delayed-neutron emission probabilities and energy spectra of delayed neutrons from individual nuclides will be described.

Differential cross sections and integral data: The ENDF/B-4 ɔrary and "clean" criticals, J. J. Wagschal, A. Ya'ari, and Y. eivin, *SP425*, pp. 405-408 (Oct. 1975).

Key words: adjustment; critical assemblies; cross sections; evaluation; integral data; sensitivities; uncertainties.

The ENDF/B-4 cross sections of the principal isotopes of U and Pu are adjusted by critical-mass data on 15 metallic assemblies. Only very minor cross-section modifications are needed in order for neutronic calculations to reproduce the integral data well within their experimental errors. The nature of the adjustments and the quality of the input integral data are discussed.

Neutron attenuation in normal and ilmenite concretes, R. J. dams and K. H. Lokan, *SP425*, pp. 409-414 (Oct. 1975).

Key words: ilmenite concrete; Monte Carlo; neutron attenuation; time of flight.

Energy distributions of neutrons transmitted through slabs of normal (density = 147 lb/ft³) and ilmenite loaded (240 lb/ft³) concretes have been obtained using time of flight methods, for concrete thicknesses increasing in 3 inch steps from 0 to 18 inches. The incident spectrum was a photoneutron continuum from aluminium irradiated with 35 MeV bremsstrahling, and was generally similar to a fission neutron spectrum.

The measured distributions are compared with the results of a Monte Carlo calculation, and agree well within the experimental errors. Results from the calculations are used to extrapolate to greater thicknesses and other ilmenite concrete densities.

Analysis of the BNL ThO_2-^{233}U exponential experiments, D. ibby, *SP425*, pp. 415-418 (Oct. 1975).

Key words: cross sections; ThO_2 resonance integral; ^{232}Th; ^{233}U.

The BNL ThO_2-3 w/o ^{233}U light-water-moderated exponential experiments were analyzed to evaluate (1) cross section library sets for ^{233}U and ^{232}Th, and (2) correlations with measured ThO_2 resonance integral data. A total of six cross section library sets were evaluated, including ENDF/B-2 and ENDF/B-3 libraries for ^{232}Th, ENDF/B-2 library for ^{233}U, and ThO_2 resonance integral correlations based on data by Weitman and Pettus, Hardy and Palowitch, and corrections to the latter data by Steen. A modified version of the LEOPARD code was used throughout this analysis. The principal results of this work are as follows: (1) The library set containing ENDF/B-2 data for ^{233}U and ENDF/B-3 data for ^{232}Th, together with ThO_2 resonance integral correlation based on Steen's corrections to the Hardy and Palowitch data, yields the best agreement with measurements, giving an average k_{eff} of 0.9975 with a standard deviation of 0.0067 for the 21 analyzed configurations. (2) With respect to this "best" set, the ENDF/B-2 ^{232}Th data is less reactive than the corresponding ENDF/B-3 data by $\sim 0.1\%\Delta k$. (3) The ThO_2 resonance integral correlation based on data by Weitman and Pettus yields resonance integrals that are consistently higher than those produced by the correlation with Steen's values, even though the latter is normalized to an infinitely dilute resonance integral of 85.9 barns (0.5 eV cutoff), while the former is normalized to a corresponding value of 80 barns. Thus, with respect to the "best" set, the ThO_2 resonance integral correlation based on the Weitman and Pettus data is less reactive by $\sim 0.75\%\Delta k$.

Tabular cross section file generation and utilization techniques, D. E. Cullen, O. Ozer, and C. R. Weisbin, *SP425*, pp. 419-421 (Oct. 1975).

Key words: cross sections; linearization; paging; preprocessing; relative error; thinning.

Criteria of importance to the generation of linear cross section tabulations are presented. Algorithms for reducing or thinning such tables within a desired accuracy criterion and the implementation of paging techniques for efficient utilization of large data tables are reviewed.

Neutron energy spectrum controlled blanket for fast breeder reactor, L. H. Tang, *SP425*, pp. 422-425 (Oct. 1975).

Key words: high plutonium productivity; moderation-jacket in blanket; thermal boosts.

It is shown that the productivity of a blanket can be substantially improved by introducing a "moderation-jacket" around the inner blanket facing the fast core. The operational procedure and the expected significance of the jacket are investigated. For a flux level similar to that of EBR-II, it is shown that one can shorten the plutonium production time by 34.5 percent for 0.7 percent plutonium density buildup and 15.4 percent for 1.5 percent plutonium density buildup. The overall time saving is about 100 days per recycling from density buildup of 0.7 to 2.0 percent.

Use of Monte Carlo method in the estimation of fast neutrons leaked through a concrete-paraffin shielding, L. S. Chuang and K. C. Wong, *SP425*, pp. 426-430 (Oct. 1975).

Key words: application of nuclear cross section; Monte Carlo method; 14 MeV neutron shielding.

A neutron generator shielding house, in which a 14 MeV neutron generator with a 4π yield of 1×10^{11} neutron per second is installed, was built with labyrinth geometry and made of ordinary concrete and paraffin block. Rough estimation for fast neutron flux in a location directly above the neutron generator target, but outside the shielding layers, is 7.7×10^{-3} n/cm²-s which was resulted from the approximation that for 14 MeV neutron, the flux is reduced by a factor of 10 for each 15 inches of solid concrete, or for each 8.2 inches of paraffin wax, disregarding the effect of scattering from the surrounding shielding materials. In order to take the geometrical effect of the shielding into consideration, a computer program, FORTRAN IV, was devised for calculating the neutron flux at the same location, using the Monte Carlo technique in a simplified 1-dimensional diffusion of neutron through the shielding layers. The result of this calculation was about 10^{-1} n/cm²-s; in good agreement with the result of measurement using a BF_3 counter.

A comparison of air-over-ground transport calculations using different cross sections, J. C. Saccenti and W. A. Woolson, *SP425*, pp. 431-435 (Oct. 1975).

Key words: cross section sensitivity; gamma ray; neutron; transport calculations.

Time dependent neutron and secondary gamma-ray transport calculations for 14 MeV and fission sources were performed in air-over-ground geometry utilizing cross sections from the DNA working cross section library. These calculations were compared with earlier calculations which have been widely used in weapon effects studies. Several significant differences were found attributed to the different cross sections used in the calculations.

The sensitivity of neutron air transport to nitrogen cross section uncertainties, A. Niiler, W. B. Beverly, and N. E. Banks, *SP425*, pp. 436-439 (Oct. 1975).

Key words: air transport; cross sections; neutrons; nitrogen; sensitivity calculation.

The sensitivity of the transport of 14-MeV neutrons in sea level air to uncertainties in the ENDF/B-III values of the various nitrogen cross sections has been calculated using the correlated sampling Monte Carlo neutron transport code SAMCEP. The source consisted of a 14.0- to 14.9-MeV band of isotropic neutrons and the fluences (0.5-15.0 MeV) were calculated at radii from 50 to 1500 metres. The maximum perturbations, assigned to the ENDF/B-III or base cross section set in the 6.0- to 14.5-MeV energy range were; (1) 2 percent to the total, (2) 10 percent to the total elastic, (3) 40 percent to the inelastic and absorption and (4) 20 percent to the first Legendre coefficient and 10 percent to the second Legendre coefficient of the elastic angular distributions. Transport calculations were carried out using various physically realistic sets of perturbed cross sections, bounded by evaluator-assigned uncertainties, as well as the base set. Results show that in some energy intervals at 1500 metres, the differential fluence level with a perturbed set differed by almost a factor of two from the differential fluence level with the base set.

Monte Carlo studies of the effect of cross section characteristics on fast neutron penetration in iron, L. P. Ku and H. Goldstein, *SP425*, pp. 440-443 (Oct. 1975).

Key words: cross section; fission neutrons; inelastic scattering; iron; minima; Monte Carlo.

Using Monte Carlo Method, we are able to study the mechanisms of neutron transport in natural iron and their relations to the cross section properties. Fission neutrons in 15 MeV to 10 keV range are discussed. It is concluded that the low energy spectrum exiting from a small bare sphere is particularly sensitive to inelastic cross sections near the threshold. For larger, and for reflected spheres, inelastic scattering plays a much less important role. At distances of practical significance ($\gtrsim$ 1 meter) it is found that transport in the regions of cross section minima, while significant, does not provide dominant channels in determining the penetrating neutron spectra.

Neutron-coupled gamma-ray cross-section requirements for gas-cooled fast breeder reactors, M. Nagel and R. J. Cerbone, *SP425*, pp. 444-446 (Oct. 1975).

Key words: gas-cooled fast breeder reactor; neutron-coupled gamma-ray cross sections.

The generation, application, and testing of neutron-coupled gamma-ray cross sections required for Gas-Cooled Fast Breeder Reactor shield analysis are described.

Cross section preparation for the continuous-energy Monte Carlo code VIM, R. E. Prael, *SP425*, pp. 447-450 (Oct. 1975).

Key words: cross section; interpolation; Monte Carl probability; resonance; thinning; unresolved.

Improvements in the methods used to represent cross se tions in the data library for the Monte Carlo code VIM a discussed. The degree to which observed difficulties ha been eliminated and the reliability of the current VIM lib ry based on ENDF/B Version 3 data are illustrated by co parison of broad-group cross section calculations made VIM and by ETOE-2/MC^2-2.

A comparison of VIM and MC^2-2—Two detailed solutions the neutron slowing-down problem, R. E. Prael and H. He ryson II, *SP425*, pp. 451-454 (Oct. 1975).

Key words: benchmark; cross section; eigenvalue; Mor Carlo; multigroup; reactor; resonance; slowing-dow stochastic; transport.

A comparison of solutions by the Monte Carlo code VI and by ETOE-2/MC^2-2 of a zero-dimensional slowing-do problem in the homogeneous ZPR-6 Assembly 7 core co position demonstrates the ability of either code to provid reliable computational benchmark capability for such cal lations.

Decay heat analysis for an LMFBR fuel assembly usi ENDF/B-IV data, G. W. Morrison, C. R. Weisbin, and C. Kee, *SP425*, pp. 455-458 (Oct. 1975).

Key words: CRBR; decay heat; ENDF/B-IV fissi product; LMFBR; ORIGEN.

Recently evaluated ENDF/B-IV fission product da have been used in decay heat calculations for typi LMFBR fuel assemblies exposed to 100,000 MWd/M burnup. The decay heat and radioactivity of the fuel asse blies have been calculated as a function of time fr discharge. Important contributors to the decay have be identified.

A two dimensional cross section sensitivity analysis of iron a concrete shield, T. E. Albert and G. L. Simmons, *SP425*, 459-463 (Oct. 1975).

Key words: cross section; sensitivity; shield; two dim sional.

A cross section sensitivity analysis of iron in a family concrete shields is performed to illustrate the dependence the cross section sensitivity to the spatial distributio reinforcing steel. The results of this study demonstrate t one dimensional sensitivity methods can be inadequate multidimensional problems.

GCFR benchmarks: Experiments and analysis, S. Seth, Heer, M. Jermann, C. McCombie, E. Ottewitte, R. Richmo and P. Wydler, *SP425*, pp. 464-468 (Oct. 1975).

Key words: benchmarks; data testing; GCFR; integral m surements.

Measurements of reaction rate ratios and neutron spec in GCFR benchmark lattices are described. An import feature of the lattices is that rod fuel elements are us Several data sets have been tested against the experime and deficiencies indicated.

Biomedical application of shortlived positron emitt isotopes, P. Meyer, E. Behrin, R. Frank, R. Holub, and C. McJilton, *SP425*, pp. 469-471 (Oct. 1975).

Key words: Anger positron camera, lung function; radio tive tracers.

Radioactive nitrogen, oxygen and ozone have been u

for dynamic lung-function studies on live dogs with an Anger positron camera. In particular an attempt was made to determine the feasibility of this method to study early functional changes caused by ozone.

Energy-dependent pion mean free path length for star formation, C. Werntz and C. W. Lucas, Jr., *SP425*, pp. 472-475 (Oct. 1975).

Key words: cross sections; pion; star formation.

Through the use of a simple model in which true absorption of a pion in flight by a nucleus is treated analogously to collisional broadening in optics, the energy dependent mean free path for star formation in water is calculated. Besides the absorption cross section, the cross sections for elastic and inelastic scattering are presented.

Spectrum and shielding measurements and calculations of neutrons produced by 800 MeV protons, L. R. Veeser, G. J. Russell, E. D. Arthur, P. A. Seeger, W. F. Sommer, D. M. Drake, R. G. Fluharty, and R. F. Bentley, *SP425*, pp. 476-479 (Oct. 1975).

Key words: analysis by Monte Carlo; angular dependence; deep penetration of neutrons in Fe + H shield; measured neutron spectra; shielding, $^{238}U(p,xn)$, $E_p = 800$ MeV.

Measurements were made to check: (a) calculation of the neutron flux produced by 800-MeV protons on a cylinder of depleted uranium, and (b) computations of the energy-dependent neutron flux as a function of thickness for a rectangular shield surrounding the target. A proton recoil spectrometer was used to measure neutron fluxes from the shield between 300 keV and 7 MeV. Agreement has been obtained between the proton recoil data and Monte Carlo calculations for shields composed of steel and gypsum for thicknesses between 0.48 and 1.37 m. Agreement is good at most angles for energies above 1 MeV.

Nuclear data for assessment of activation of scintillator materials during spaceflight, C. S. Dyer, J. I. Trombka, and S. M. Seltzer, *SP425*, pp. 480-483 (Oct. 1975).

Key words: activation; Apollo; background; computation, decay-schemes; cross-sections; scintillators; spacecraft, gamma-rays; spallation.

A calculation is outlined which predicts energy-loss spectra observed in detector materials due to the decay of radioactive nuclides which are produced by particle irradiation in spaceflight. The input decay schemes and cross-section requirements are described. Examples are given from the Apollo gamma-ray spectrometer experiments.

Proton scattering for analysis of atmospheric particulate matter, K. R. Akselsson, J. W. Nelson, and J. W. Winchester, *SP425*, pp. 484-487 (Oct. 1975).

Key words: air particulate matter; proton scattering; quantitative analysis.

Proton scattering has been applied to the problem of elemental quantitative analysis of air particulate matter. Elements up through chlorine may be resolved using 16 MeV protons incident upon targets up to about 1 mg/cm² in thickness. Using the FSU Super FN Tandem Accelerator and a large area solid state proton detector, an analysis can be performed in several minutes. Combination of this technique with proton induced x-ray emission analysis provides a means of quantitative analysis for all elements. These accelerator based methods are being applied to studies of the composition of air particulate matter in diverse locations such as St. Louis, Mo.; Los Angeles, Ca.; several cities in Florida; and Bermuda.

Use of elastic scattering cross section anomalies for depth profiling helium and hydrogen isotopes in solids, R. S. Blewer, *SP425*, pp. 488-491 (Oct. 1975).

Key words: depth; deuterium; diffusion; elastic; helium; migration; oxide; proton; range; scattering.

A proton elastic scattering technique is described which makes possible direct accurate depth profile measurements of light element isotopes (deuterium, tritium, helium, etc.) in metal or insulator hosts. Several examples of the application of this technique to current problems are given in the fields of energy research and neutron generator target evaluation.

Spallation cross sections and the LAMPF medical radioisotope program, B. R. Erdal, P. M. Grant, V. R. Casella, A. E. Ogard, and H. A. O'Brien, Jr., *SP425*, pp. 492-495 (Oct. 1975).

Key words: E = 800 MeV; isotope production; La,Mo,V(p,spallation); measured σ; nuclear medicine; nuclear reactions.

The intense beam of medium-energy protons (600 to 800 MeV) from the LAMPF accelerator will be used to prepare multi-curie quantities of radioisotopes of value in diagnostic and therapeutic nuclear medicine. Thin-target cross section measurements of spallation-induced reactions represent a significant segment of the LASL Medical Radioisotope Research Program, as these data provide a basis for calculating specific radioisotope yields in thick targets, evaluating potential isotopic interferences, and monitoring hot-cell operations. Recent measurements include the cross sections (cumulative yields) of ^{123}I, ^{127}Xe, ^{82}Sr, and ^{43}K formed in the interaction of 800-MeV protons with La, Mo, and V targets; they are reported to be 51 ± 3 mb, 51 ± 7 mb, 24.5 ± 0.8 mb, and 5.4 ± 0.3 mb, respectively. Comparison with previous results at 590 MeV are made, and quantity and product quality estimates are presented for biomedical isotopes under the irradiation conditions expected to prevail at LAMPF.

Feasibility of neutron-gamma techniques for field analysis of fresh concrete, M. C. Taylor, J. R. Rhodes, and D. L. Bernard, *SP425*, pp. 496-499 (Oct. 1975).

Key words: analysis; application; concrete; feasibility; gamma rays; neutrons.

A technique has been developed which employs two neutron sources (^{252}Cf and ^{238}Pu-Be) and three NaI(Tl) detectors to determine the H, Ca, Si and C content of calcareous aggregate concrete in its plastic state. These elements are indicative of the water, cement, fine aggregate and coarse aggregate components which along with air entrainment are key factors in strength determination. Results are presented which demonstrate the feasibility of the technique for analysis of typical samples in a total time of the order of 10 minutes.

Cross section requirements for industrial gauging applications, B. Y. Cho and T. P. Sheahen, *SP425*, pp. 500-503 (Oct. 1975).

Key words: industrial gauging; isotopes; Monte Carlo calculations; multiple scattering.

We use nuclear isotopes for gauging and control of industrial products. The use of recycled materials have made paper, steel, plastic, etc., into ever-changing composite media, forcing us to update calibrations empirically. This paper lists those areas of research that would benefit our work. Specifically, we need: differential cross sections for electrons scattered from most common elements, as a func-

tion of energy below 3.6 MeV; Monte Carlo calculations that simulate isotopic sources (Kr-85, Sr-90/Y-90) interacting with common materials; phenomenological models or empirical expressions that coalesce scattering formulas and Monte Carlo results into forms usable for gauge design.

Li, Be and B production in proton-induced reactions: Implications for astrophysics and space radiation effects, C. T. Roche, R. G. Clark, G. J. Methews, and V. E. Viola, Jr., *SP425*, pp. 504-508 (Oct. 1975).

Key words: astrophysical production of Li, Be and B; E = 45 – 100 MeV; L = Li, Be, B; measured $\sigma(E)$ for A = 6, 7, 9, 10, 11; nuclear reactions $^{12}C(p,L)$.

Cross sections for the production of mass 6 to 11 isobars from proton spallation of carbon targets have been measured at bombarding energies of 45, 55, 60, 65, 75 and 100 MeV. The results of these measurements and similar studies by other groups are used to test theories of Li, Be and B nucleosynthesis. The measured abundance ratios for $^7Li/^6Li$, $^{11}B/^{10}B$, Li/Be and B/Li can be reproduced using measured cross sections and models which propose interstellar proton fluxes $\phi(E)$ of the form $(m_pC^2+E)^{-2.6}$, $E^{-\gamma}$ ($\gamma \approx 1.5 - 2.0$) or E^{-3} for $E > 30$ MeV, if a substantial amount of ^7Li is synthesized via some other source. The cross sections for formation of Li, Be and B are also of importance because of possible high LET effects in biological material exposed to cosmic radiation. Our measurements are compared with calculated cross sections that have been used to estimate LET effects.

Long lived isotope production cross sections from proton bombardment of rhenium, A. J. Armini and S. N. Bunker, *SP425*, pp. 509-511 (Oct. 1975).

Key words: cross sections; excitation function; proton; rhenium.

The production cross reaction of long lived isotopes produced by proton bombardment of rhenium has been measured between 15 and 160 MeV. A set of stacked graphite disks impregnated with rhenium was used as a target. The data have been used to calibrate a high temperature graphite thickness gauge.

A need for (p,n) cross sections for selected targets at lower energies, H. S. Ahluwalia, *SP425*, pp. 512-515 (Oct. 1975).

Key words: acceleration mechanisms; neutrons; nuclear reactions; protons; solar flares.

We have argued elsewhere that protons of energy $\lesssim 10$ MeV are probably accelerated, in the active regions on the sun, for several days, following a solar flare. These protons must undergo nuclear interactions with the constituents of the solar atmosphere producing, among other things, neutrons. Being electrically neutral the neutrons are not affected by the solar or interplanetary magnetic fields. So they should be observable when the active regions lie on the earth-sun line. No solar neutrons have been detected so far. We think that the reason for this null-result is that the energy response of most of the detectors used, peaks at too high an energy (~ 100 MeV). Recent discovery of solar deuterons indicates that the solar neutrons probably have lower energies. They are probably produced in (p,n) reactions involving C,N,O,Ne,Mg,Si,S,Ca,Fe, etc. The available cross sections, in the energy range 3.4 MeV to 30 MeV, certainly bear out this expectation for Fe. The cross sections for some other elements are as yet unknown. Our conclusions are presented and the urgent need for the determination of the (p,n) cross sections for other elements is discussed.

The measurement of thermal neutron constants of the soil; application to the calibration of neutron moisture gauges and to the pedological study of soil, P. Couchat, C. Carre, J. Marcesse and J. Le Ho, *SP425*, pp. 516-519 (Oct. 1975).

Key words: calibration; neutron moisture gauge; pedology; soil; thermal neutron constants.

The neutronic method for measuring the water content of soils is more and more used by agronomists, hydrogeologists and pedologists. On the other hand the studies on the phenomena of slowing down and diffusion process have shown a narrow relation between the thermal absorption (Σ_a) and diffusion (Σ_d) constants and the thermal flux developed in the soil around a fast neutron source like Am-Be. Then, the authors present two original applications of the direct measurement of Σ_a and Σ_d.

The method described consists in the measurement, in a cube of graphite with an Am-Be source in the middle, on one side of the perturbation of the thermal flux, obtained by the introduction of 300 g of soil, and on the other side of the transmitted thermal flux measured through the same sample of soil, on a side of the cube.

After calibrating the device, these two parameters give Σ_a and Σ_d which are easily introduced in the calibration equation of neutron moisture gauge. Also these two values are useful for the pedologists because Σ_d is connected to clay content in the soil and Σ_a is connected to the type of clay by the way of rare earth contents.

Medical uses of nuclear data, R. S. Tilbury, R. E. Bigler, L. Zeitz, and J. S. Laughlin, *SP425*, pp. 520-526 (Oct. 1975).

Key words: activation cross-section; bone mineral; *in vivo* neutron-activation analysis; therapy.

Nuclear data is used in modern medicine in a myriad of ways. Activation cross sections are used in the calculation of radioisotope production rates for both neutron and charged particle activation. The radioisotopes so produced are used in diagnostic nuclear medicine for the early detection of disease and for therapy either by external radiation or by internal radiation. The calculation of radiation dose from internally administered radioisotopes involves a knowledge of the decay scheme, mode and energy of decay, internal conversion coefficients, x-ray fluorescent and Auger electron yields. The decay scheme of radioisotopes including parent-daughter equilibria is essential knowledge for their accurate assay and for the understanding of radioisotope generators. Range-energy relationships for neutrons of various energies, charged particles, gamma-rays and electrons are also necessary for therapy and dose considerations. Applications to *in vivo* neutron activation analysis and photon absorptiometry for bone mineral measurement are also considered. An attempt is made to briefly describe these applications and to point out where more basic nuclear data measurements would be helpful.

Medical use of fast neutrons in radiotherapy and radiograph D. K. Bewley, *SP425*, pp. 527-532 (Oct. 1975).

Key words: dosemeter; radiography; radiotherapy; tissue.

Over 400 patients have been treated with fast neutrons from a cyclotron at Hammersmith Hospital, London, using 16 MeV deuterons on beryllium. A large variety of malignant disease is included in this trial. A randomized trial of fast neutron therapy for cancer of the mouth and throat is in progress and preliminary results will be given. Fast neutron radiographs are often taken to check the position of the fields used on the patients. These show no contrast from bone, but demonstrate only the presence of gas-filled

cavities. As a diagnostic method, fast neutron radiography suffers from a number of disadvantages, the main ones being lack of sensitivity of the image-forming system and the hazard to the patient due to a large Quality Factor. Estimation of the absorbed dose given to different types of tissue is an important factor in the medical use of fast neutrons. More data are needed on the processes whereby fast neutrons impart energy to matter, particularly for neutrons above 15 MeV.

Biomedical radiation transport calculations as an application f nuclear data, R. G. Alsmiller, Jr., *SP425*, pp. 533-539 (Oct. 975).

Key words: absorbed dose; cell survival; heavy particles; OER; radiotherapy.

The extent to which transport calculations of biomedical interest for negatively charged pions, neutrons, protons, alpha particles, and heavier ions can presently be performed is reviewed.

Geochemical mapping of the moon by orbital gamma-ray pectroscopy, R. C. Reedy, *SP425*, pp. 540-545 (Oct. 1975).

Key words: cosmic-ray reactions; lunar chemistry; lunar γ-rays; neutron capture; nonelastic scattering.

Chemical compositions of the surfaces of the moon and certain planetary bodies can be determined by orbital γ-ray spectroscopy. The major sources of γ-ray lines (and of radionuclides) in the moon are the decay of the primordial radioelements (U, Th, and ^{40}K) and nuclear reactions induced by the bombardment of the moon by cosmic-ray particles. The major cosmogenic γ-ray lines are produced by neutron nonelastic scattering and neutron capture reactions. The fluxes of γ-ray lines expected from the moon for each major source have been calculated. Gamma-rays from the moon were measured by γ-ray spectrometers during the Apollo 15 and 16 missions. The preliminary analysis of the data show that O and Si vary little over the moon's surface, that Mg, Fe, and Ti have higher concentrations in the maria than in the lunar highlands, and that the radioelements are significantly more abundant in and near the western near-side maria than in the rest of the moon.

A measurement of the fission cross section of ^{235}U from 1 keV 1 MeV, J. B. Czirr and G. S. Sidhu, *SP425*, pp. 546-548 Oct. 1975).

Key words: fission; measurement; ratio; ^{235}U.

We have measured the ratio of the ^{235}U fission cross section to the ^{6}Li (n,α) reaction for neutron energies from thermal to 1 MeV. This experiment is the third in a series which is designed to measure the relative fission cross section of ^{235}U from thermal to 20 MeV. The first two experiments covered the energy range from 0.8- to 20-MeV, and used the n,p scattering reaction to measure the energy dependence of incident flux.

The average number of prompt neutrons, $\bar{\nu}_p$, from neutron induced fission of ^{235}U between 0.2 and 1.4 MeV, F. Käppeler and . E. Bandl, *SP425*, pp. 549-552 (Oct. 1975).

Key words: $E_n = 0.2$-1.4 MeV; fast time-of-flight technique; number of prompt fission neutrons; ^{235}U.

For the clarification of existing discrepancies in the energy dependence of $\bar{\nu}_p$ for ^{235}U an experiment was performed which was based on a method independent of current techniques. A considerable reduction of background and correction problems was achieved by renouncing on an absolute measurement. Thus the resulting systematic uncertainty was 0.6 percent. In the energy range between 0.2 and 1.4 MeV the shape of $\bar{\nu}_p$ was measured at 22 points in steps of 50 keV with an average energy resolution of 3.3 percent. Repetition of several runs with modified experimental conditions ensured the consistent reproduction of the results. It was found that $\bar{\nu}_p$ of ^{235}U shows distinct deviations of up to 2 percent from a linear energy dependence.

Monte Carlo analysis of direct measurements of the thermal eta (0.025 eV) for U^{233} and U^{235}, J. J. Ullo and M. Goldsmith, *SP425*, pp. 553-556 (Oct. 1975).

Key words: E = 0.25 eV; eta; fission neutrons per absorption; nuclear reactions; U^{233}; U^{235}.

In support of the LWBR program, the manganese bath measurements of eta of U^{233} and U^{235} at 0.025 eV were analyzed using Monte Carlo methods. The calculated values of eta, including statistical, cross section, and experimental uncertainties, are $\eta^{233} = 2.2993 \pm 0.0082$ and $\eta^{235} = 2.0777 \pm 0.0064$. The systematic corrections to the experiments were also studied in detail.

Monte Carlo analysis of manganese bath measurement of eta of ^{233}U and ^{235}U using thermalized neutrons, M. Goldsmith and J. J. Ullo, *SP425*, pp. 557-559 (Oct. 1975).

Key words: E = 0.0253 eV; eta; fission neutrons per absorption; nuclear reactions; ^{233}U; ^{235}U.

Monte Carlo analysis of the ORNL manganese bath measurements of eta of ^{233}U and ^{235}U at 2200 m/sec yields: $\eta_{2200}{}^{233} = 2.3019 \pm 0.0086$, and $\eta_{2200}{}^{235} = 2.0746 \pm 0.0078$. The analysis was confirmed by calculating measured quantities used by the experimentalists in their determinations of η_{2200}.

Parameters of the subthreshold fission structure in ^{240}Pu, G. F. Auchampaugh and L. W. Weston, *SP425*, pp. 560-563 (Oct. 1975).

Key words: $\Gamma_{f\lambda^c}$, $\Gamma_{f\lambda^{c,II}}$, $\langle H_{\lambda^c\lambda^{c2}} \rangle$; ^{240}Pu(n,f); 500 to 10 000 eV.

The neutron subthreshold fission cross section of ^{240}Pu has been measured from 500 eV to 10 000 eV using the Oak Ridge Electron Linear Accelerator neutron facility. A total of 82 fission widths were obtained from area and shape analysis of those resonances which define the class II states at $\cong$ 782 eV, $\cong$ 1406 eV, $\cong$ 1936 eV, and $\cong$ 2700 eV. The average square of the coupling matrix element for the first three class II states is 4.08 ± 1.63 eV^2. The average class II fission width is 2.47 ± 0.96 eV. Approximately 22 clusters of class I resonances were observed below 10 keV, which results in a value of 450 ± 50 eV for the average class II level spacing. Assuming parabolic inner and outer barriers, the following barrier parameters were obtained: $V_A - B_{II}/\hbar\omega_A = 0.59 \pm 0.06$ and $V_B - B_{II}/\hbar\omega_B = 0.54 \pm 0.006$.

Measurement of the ^{239}Pu fission cross-section and its ratio to the ^{235}U fission cross-section in the energy range from 1 keV to 1 MeV, D. B. Gayther, *SP425*, pp. 564-567 (Oct. 1975).

Key words: cross-sections; fission; measured; neutrons; 1 keV – 1 MeV; ^{239}Pu; ^{235}U.

The cross-section for the ^{239}Pu(n,f) reaction has been measured on the Harwell 45 MeV linac using the time-of-flight method. Fission events were recorded by detecting the prompt neutrons and the incident neutron flux spectrum was measured with a detector which was calibrated against two standard detectors. The cross-section was normalized in the 10 to 30 keV energy interval to agree with the recent evaluation of Sowerby et al. Comparison with this evaluation shows agreement to within 5 percent at energies above a few

keV. The agreement with the ENDF/B-IV evaluation is generally within 4 percent throughout the complete energy range. A similar comparison is made for the ratio of the ^{239}Pu and ^{235}U fission cross-sections, obtained from the present measurement, and a previously published measurement of the $^{235}U(n,f)$ cross-section made with the same equipment.

A measurement of the $^{238}U/^{235}U$ fission cross-section ratio, M. S. Coates, D. B. Gayther, and N. J. Pattenden, *SP425*, pp. 568-571 (Oct. 1975).

Key words: cross-sections; fission; measured; neutrons; ratio; ^{238}U; ^{235}U; 600 keV-22 MeV.

The ratio of the neutron induced fission cross-sections of ^{238}U and ^{235}U have been measured in the energy range from 600 keV to 22 MeV using the time-of-flight method on the Harwell synchrocyclotron, at a nominal resolution of 0.5 ns/m. Fission fragments were detected in a gas scintillation chamber containing foils of each material mounted back-to-back and perpendicular to the incident beam. The measured cross-section ratio was normalized at 14 MeV to the ratio evaluated by Sowerby et al. The estimated standard deviation error in the ratio measurements is ± 2 1/2 percent. Comparison with other recent data shows reasonable agreement throughout most of the energy range.

Precision measurement of prompt fission neutron spectra of ^{235}U, ^{238}U and ^{239}Pu, P. I. Johansson, B. Holmqvist, T. Wiedling, and L. Jéki, *SP425*, pp. 572-575 (Oct. 1975).

Key words: fast fission neutron spectra; TOF-technique; ^{235}U; ^{238}U; ^{239}Pu.

Prompt neutron spectra from fission of ^{235}U, and ^{239}Pu have been measured at incident neutron energies of 0.10, 0.18, 0.53 and 2.07 MeV. A major effort was made to obtain an accurate experimental determination of the efficiency and energy response function of the time-of-flight neutron detector in the energy range 0.15 to 15 MeV. The spectra have been analytically described by the so called Watt distribution, as well as with a Maxwell distribution. It is shown that the Watt relation gives a somewhat better description of the spectra than the Maxwell formula. The angular correlation between incident-neutrons and fission-neutrons was measured for ^{235}U and ^{238}U at an incident neutron energy of 2.07 MeV. The data indicate some slight anisotropies, being rather small or even negligible for ^{235}U and somewhat more pronounced for ^{238}U. The results show that the shape of the neutron energy distribution is independent of the angle of observation.

Spin determination of resonances in ^{235}U, G. A. Keyworth, C. E. Olsen, J. D. Moses, J. W. T. Dabbs, and N. W. Hill, *SP425*, pp. 576-579 (Oct. 1975).

Key words: fission channels; J; multilevel fits; polarized neutrons; polarized target; $^{235}U(n,f)$.

A polarized beam of neutrons and a polarized ^{235}U target have been used to determine the spins of resonances below 150 eV. Most spins are assigned by inspection of the data; others by comparison with multilevel or single-level fits. Previously published data on fission fragment angular distributions, in conjunction with our spin assignments, indicate that two or more fission channels are available to each spin state. The ratio of symmetric to asymmetric fission appears to be uncorrelated with the resonance spin.

Quantum numbers of low lying neutron resonances in U-235, J. P. Felvinci, E. Melkonian, and W. W. Havens, Jr., *SP425*, pp. 580-583 (Oct. 1975).

Key words: spins of ^{235}U resonances.

Experiments were performed at ORELA to measure t low energy fission cross section of U-235. Times of flight the neutrons causing fission and the fission fragment ener detected by a solid state detector were recorded event-b event. Analysis of the data showed marked pulse heig variation among resonances. Several of the large resonanc were shown to be composites and the level density obtain is much higher than previously determined. The results we interpreted by the hypothesis that K is a good quantu number in the compound nucleus. This assumption and t systematic variation of the fission fragment energies amo resonances enabled us to assign J and K quantum numbe to many levels. Three families of fission resonances we seen, $J=4^-$; $K=2$, $J=4^-$; $K=1$, and $J=3^-$; $K=1$. O results have implications as to the accuracy of fission cro section measurements and to the calculation of cross se tions in the unresolved energy region.

keV capture cross section of ^{242}Pu, R. W. Hockenbury, A. Sanislo, and N. N. Kaushal, *SP425*, pp. 584-586 (Oct. 197

Key words: capture; normalization; strength functions.

The neutron capture cross section of ^{242}Pu has been me sured from 5 to 70 keV. The high-low bias method was us to distinguish between capture and fission events. Transm sion experiments were also made in the resonance region. normalization method was developed using the absorpti and transmission data from six resonances. Using average s-wave radiation width of 22 MeV, an s-wa strength function of 1.16×10^{-4} and our measured captu cross section, we have determined p-wave contributio to the ^{242}Pu capture cross section below 70 keV.

Spontaneous fission decay constant of plutonium-238, R. G and R. Sher, *SP425*, pp. 587-590 (Oct. 1975).

Key words: coincidence counting; decay constant; pluto um-238; safeguards data; spontaneous fission; track rec ders.

The spontaneous fission decay constant of plutonium-2 was measured by two methods: fission-track counting mica and coincidence counting of the fission fragments solid-state detectors. The efficiency of the mica track dete tor was determined by thermal column irradiation of the pl tonium source-mica detector assembly and subseque counting of tracks arising from plutonium-239 fission. T coincidence counting result was combined with a determir tion of the Pu^{238} alpha emission rate of the sample to obta the spontaneous fission decay constant. The results of t two methods were $\lambda_{sf} = (4.75 \pm 0.12) \times 10^{-19}$ sec^{-1} and (4 $\pm 0.4) \times 10^{-19}$ sec^{-1}, respectively.

Neutron-induced fission cross sections of ^{233}U, ^{234}U, ^{236}U, a ^{238}U with respect to ^{235}U, J. W. Behrens, G. W. Carlson, and W. Bauer, *SP425*, pp. 591-596 (Oct. 1975).

Key words: fission cross section ratios; linear accelerat time-of-flight technique; uranium isotopes—^{233}U, ^{234}U, ^{235} ^{236}U, ^{238}U; 0.001 to 30 MeV.

Ratios of the neutron-induced fission cross sections ^{233}U, ^{234}U, ^{236}U, and ^{238}U relative to ^{235}U and of ^{238}U relati to ^{233}U were measured with fission ionization chambers the LLL 100-MeV electron linear accelerator. The time-f flight technique was used to measure the cross section rati as a function of neutron energy from 0.1 to 30 MeV, exce for the ^{233}U:^{235}U and ^{238}U:^{233}U ratios, which were measur from 0.001 to 30 MeV, and 1 to 30 MeV, respectively. T continuous energy spectrum of the neutron source allow us to cover the entire energy range of each ratio in one me surement. The threshold cross section method was used

normalize the ratios independent of other cross section measurements. Typical energy resolutions of the data are 5 percent at 20 MeV and 1.5 percent at 1 MeV. Most of the data have counting uncertainties smaller than 4 percent. Systematic errors are discussed, and current results are compared with previous measurements.

On sub-barrier fission in ^{238}U, J. A. Wartena, H. Weigmann, and E. Migneco, *SP425*, pp. 597-598 (Oct. 1975).

Sub-barrier fission in ^{238}U has first been observed by R. Block et al., using ionization chambers for fission fragment detection. In the present measurements a liquid scintillator was used to detect prompt fission neutrons. Thereby, with a sample of 250 g of ^{238}U, neutron time-of-flight measurements could be performed at a 30 m flightpath with a nominal resolution of 1.3 nsec/m. The result of the present investigation is a full confirmation of the findings of Block et al. This includes a confirmation, by high resolution data, of the fact that the resonance at 721.0 eV and 1210.7 eV contribute most strongly to the observed fission in the two sub-barrier structures at low neutron energies. Their fission widths are found to be (0.85 ± 0.13) MeV and (0.25 ± 0.05) MeV, respectively (assuming $\Gamma_\gamma = 23$ MeV). For most of the other resonances in these two structures only upper limits for the fission widths are obtained.

Capture-to-fission ratio of ^{235}U from the measurement of low-energy γ-rays, F. Corvi and P. Giacobbe, *SP425*, pp. 599-602 (Oct. 1975).

Key words: E = 86 eV – 31.6 keV; enriched target; measured capture-to-fission ratio; nuclear reactions ^{235}U(n,f) and ^{235}U(n,γ).

A new technique of α-determination is presented, consisting of measuring with a Ge(Li)-detector low-energy γ-ray spectra following neutron absorption in ^{235}U, as a function of neutron energy. A relative value of α can then be deduced assuming that the intensity of a given capture (fission) γ-ray is proportional to the average capture (fission) cross-section. Such an assumption is thoroughly discussed in the text. More specifically, α was taken proportional to the ratio between the intensity of the 642 keV capture transition and those of the fission γ-rays at 352 keV and 1280 keV. Average α-values with statistical errors less or equal to ± 5 percent were determined for 20 intervals in the range 86 eV – 31.6 keV.

Intermediate structure in the keV fission cross section of ^{235}U, E. Migneco, P. Bonsignore, G. Lanzanò, J. A. Wartena, and H. Weigmann, *SP425*, pp. 607-610 (Oct. 1975).

The relative fission cross section of ^{235}U has been measured up to 200 keV with a nominal resolution of 1.0 ns/m, using a thin foil plastic scintillator detector. The data have been analyzed in order to detect nonstatistical effects due to intermediate structure. Statistical tests which have been applied to this fission and similar total cross section data include calculations of the auto-correlation function and Wald-Wolfowitz tests on the cross-section and on the autocorrelograms. The comparison of the results indicates the presence of intermediate structure effects in fission cross-section which may be interpreted on the basis of the double-humped deformation potential.

The ^{241}Pu neutron induced fission cross section from 0.01 eV to 50 eV and its normalization, C. Wagemans and A. J. Deruytter, *SP425*, pp. 603-606 (Oct. 1975).

Key words: normalization; Westcott g_f-factor; ^{241}Pu fission cross-section.

The neutron induced fission cross-section of ^{241}Pu has been measured at an 8 m flightpath of the CBNM Linac (from 50 eV to below thermal energy) with respect to the ^{10}B(n,α)^{7}Li cross-section. Several fission integrals were calculated as well as the 20.44 °C Westcott factor $g_f = 1.046 \pm 0.006$. Special attention is given to normalization problems.

Energy spectrum of delayed neutrons from photo-fission of ^{238}U, S. Iwasaki, K. Yana, S. Sato, K. Sano, M. Hagiwara, and K. Sugiyama, *SP425*, pp. 611-614 (Oct. 1975).

Key words: delayed neutron; energy spectrum, β – n time-of-flight; fission; group 2; ^{238}U(γ,f).

Energy spectrum of the second group delayed neutrons ($T_{1/2} = 22$ sec.) from photo-fissions of ^{238}U has been obtained using a time-of-flight technique between beta-particles and neutrons. Experimental results show a fine structure in the spectrum. The six prominent peaks of energies; 200-, 240-, 280-, 380-, 540- and 750-keV are observed.

^{235}U fission cross section measurements relative to neutron-proton scattering, G. S. Sidhu and J. B. Czirr, *SP425*, pp. 615-619 (Oct. 1975).

Key words: linac source; neutron energy 0.8 to 20 MeV; relative to n-p scattering; U235 fission cross section.

Energy dependence of the fission cross section of ^{235}U with respect to the n-p scattering reaction was measured for neutron energies from 0.8 to 20 MeV. The LLL linac target was used as the pulsed neutron source; neutron energies were measured by time-of-flight technique. A ^{235}U ion chamber was designed and operated to make the fission detection efficiency independent of the angular distribution of fission fragments. The neutron flux monitor consisted of an annular polyethylene radiator with a shielded proton recoil detector. Data in the energy range from 3 to 20 MeV were obtained with a 3.3 mg/cm^2 radiator; a 0.31 mg/cm^2 radiator was used for the range from 0.8 to 4 MeV. Both sets of data were normalized to yield the average fission cross section value of 1.198 b in the overlapping region from 3 to 4 MeV. Total error in the relative ^{235}U(n,f) cross section is ± 1 percent below 7 MeV, ± 2 percent at 14 MeV, and ± 6 percent at 20 MeV.

Measurement of the ^{238}U capture cross section shape in the neutron energy region 20 to 550 keV, R. R. Spencer and F. Käppeler, *SP425*, pp. 620-622 (Oct. 1975).

Key words: E_n = 20-550 keV; $\sigma_\gamma(^{238}U)$ shape.

The Karlsruhe 800 l liquid scintillator detector and 3 MV pulsed Van de Graaff were used to measure the shape vs. neutron energy of the ^{238}U capture yield relative to a gold capture sample and relative to ^{235}U fission. The resulting cross section shape computed from the gold capture cross section is consistent with that computed from a recent evaluation of the ^{235}U fission cross section. Below 100 keV a significant intermediate structure is observed which corresponds to that in recent ORNL data.

Intermediate structure in the ^{238}U neutron capture cross section, R. B. Perez and G. de Saussure, *SP425*, pp. 623-626 (Oct. 1975).

Key words: doorway states; intermediate structure; ^{238}U capture cross section.

Recent measurements of the ^{238}U neutron capture cross section show large fluctuations in the unresolved resonance region. To test whether or not the observed long-range fluctuations of the neutron capture represent departures from the compound nuclear model, the Wald-Wolfowitz runs and correlation tests were applied to the ^{238}U neutron capture

data obtained at ORELA. The Wald-Wolfowitz runs test deals with the statistic, R, which is the number of unbroken sequences of data points above or below a given reference line. This statistic is to be compared with the expected value of runs $E(R) \pm \sigma(R)$ arising from randomly distributed data. In the correlation test we have computed the first serial correlation coefficient of the data as well as its expected value and variance for a set of random data. In both tests one computes the probability, P, for the given statistical entity to depart from its expected value by more than ϵ standard deviations. Both tests confirm the presence of intermediate structure between 5 and 100 keV. The range of the structure far exceeds the width of the experimental resolution and level widths.

A direct comparison of different experimental techniques for measuring neutron capture and fission cross sections for ^{239}Pu, R. Gwin, L. W. Weston, J. H. Todd, R. W. Ingle, and H. Weaver, *SP425*, pp. 627-630 (Oct. 1975).

Key words: comparison; cross sections; fission, absorption; measurement; ^{239}Pu.

A comparison of the results of two different experimental methods of measuring the neutron absorption and fission cross sections for ^{239}Pu is made. These measurements were normalized at thermal energy and extend to 200 keV. The ratio of the neutron capture to fission cross section for ^{239}Pu derived in these two experiments is shown to be in good agreement.

Fast neutron fission spectrum measurement of ^{235}U at 0.52 MeV incident neutron energy, P. I. Johansson and J. M. Adams, *SP425*, pp. 631-634 (Oct. 1975).

Key words: fast neutron fission; prompt fission neutron spectrum; T-O-F technique; U-235.

There exists a large number of measurements of the prompt fission neutron spectrum of ^{235}U. The discrepancies in the results, however, indicate systematic errors which might be attributable to the different experimental equipment and facilities used at the various laboratories. This measurement is a collaboration between the Harwell Nuclear Physics Division and the Neutron Physics Laboratory in Studsvik. The purpose was to repeat measurements on ^{235}U at Studsvik and Harwell. The experiments were performed on 1BIS, the Harwell neutron time-of-flight facility and the experimental parameters of importance were chosen to be identical, viz the same incident neutron energy, detector angle, sample size and composition etc., and also the highly critical parameters, viz the neutron detector response function and the energy calibration of the neutron time-of-flight spectrometer, were obtained by using the same experimental technique and nuclear reactions.

The fission cross section of ^{235}U for Na-Be photoneutrons, D. M. Gilliam and G. F. Knoll, *SP425*, pp. 635-636 (Oct. 1975).

Key words: fission cross section; manganese bath; NBS-II; track-etch detector; ^{235}U; ^{24}Na; ^{9}Be(γ,n).

The fission cross section of ^{235}U for Na-Be photoneutrons has been measured with absolute flux determination. The neutron flux was determined absolutely (i.e., without significant dependence on other cross section data) by using a manganese bath to compare the photoneutron source with the standard source NBS-II. Fission counts were accumulated with the source positioned symmetrically between two identical detectors, all suspended in a low-albedo laboratory. Fission fragments passing through limited solid angle apertures were recorded on polyester track-etch films. Use of a projection microscope counting system allowed rapid measurement of track diameters, so that the smallest track could be distinguished reliably from background pits th were not much smaller in diameter. The masses of the U_3O deposits (7 mg each) were determined by microbalanc weighings. After making a small correction for the calc lated energy distribution of the source neutrons, a value f the fission cross section at 964 keV of 1.21 barns $\pm$ 2.1 pe cent (1.8% systematic and 1.0% random) is derived from th present measurement.

The total cross section and the fission cross section of ^{241}Am the resonance region, resonance parameters, H. Derrien and L Lucas, *SP425*, pp. 637-641 (Oct. 1975).

Key words: neutron; resonance parameters; total cross se tion; ^{241}Am.

The ^{241}Am total and fission cross sections have been me sured in the resonance region, using the 60 MeV Sacl linac as a pulsed neutron source. The resonance paramete obtained by a single level shape analysis of the transmissi data are given for 189 levels up to 150 eV neutron energ The mean level spacing, corrected for 18 percent of miss resonances in the 0 to 50 eV energy range, is $(0.55 \pm 0.0$ eV. The s-wave neutron strength function value, in the 0 150 eV energy range, is equal to $(0.94 \pm 0.09)10^{-4}$. Th average radiation width obtained from 43 resonances (43.77 ± 0.72) meV. Only preliminary results of the fissi experiment are available now; 38 fission widths are given u to 32 eV neutron energy, with the average value $\langle \Gamma_f \rangle \approx 0.2$ meV; the statistical distribution of these fission widths co responds to a X^2 law with 4 degrees of freedom. An ar analysis of the Los Alamos fission data has also been don from which we obtain 36 Γ_f values in the 20 to 50 eV energ range; the corresponding average value is: $\langle \Gamma_f \rangle$ 0.52 me the statistical distribution obeys to a X^2 law with 15 degre of freedom, in disagreement with the Saclay results.

Structures in ^{232}Th(n,f) and ^{238}U(n,f) cross sections, J. Blon C. Mazur, and D. Paya, *SP425*, pp. 642-645 (Oct. 1975).

Key words: cross sections; structures; ^{232}Th(n,f); ^{238}U(n,f

The ^{232}Th(n,f) and ^{238}U(n,f) cross sections have been me sured relative to that of ^{235}U up to 6 MeV. The best energ resolution was 3 keV at 1.6 MeV. Below the fissi threshold of ^{238}U, intermediate structures are observed. I the ^{232}Th(n,f) cross section, the broad vibrational resonanc located above 1 MeV are resolved into sharp structur which are interpreted as rotational states. The angul anisotropy of fission fragments has been also measured i the same energy range. Thereby, values of K and J hav been determined for each structure. The moment of inerti of ^{233}Th in shape isomeric deformation has been deduced.

Nuclear data needs for fusion reactor design, D. Steine *SP425*, pp. 646-650 (Oct. 1975).

Key words: fusion reactor design; nuclear data for fusion.

The nuclear data needs associated with the developme of fusion as an energy source will be discussed in terms seven areas of design application including: fusion fuel c cles, tritium breeding performance (for concepts based o the D-T fuel cycle), nuclear heating, radiation damage e fects, induced activity, radiation shielding, and hybrid co cepts. Dosimetry applications will also be considered. Th areas of application described above will be related t specific types of nuclear data and to the programmati requirements of the Controlled Thermonuclear Research e fort. The paper concludes with a summary of recent activ ties relevant to CTR nuclear data needs.

Model calculations as one means of satisfying the neutron cross section requirements of the CTR program, D. G. Gardner, *SP425*, pp. 651-658 (Oct. 1975).

Key words: applications to CTR; cross-section calculations; fast neutron reactions; gamma-ray production; isomers; radiation widths; statistical model codes.

A large amount of cross-section and spectral information for neutron-induced reactions will be required for the CTR design program. To undertake to provide the required data through a purely experimental measurement program alone may not be the most efficient way of attacking the problem. It is suggested that a preliminary theoretical calculation be made of all relevant reactions on the dozen or so elements that now seem to comprise the inventory of possible construction materials to find out which are actually important, and over what energy ranges they are important. A number of computer codes for calculating cross sections for neutron induced reactions have been evaluated and extended. These will be described and examples will be given of various types of calculations of interest to the CTR program.

Energy from charged particle reactions among light nuclei, T. A. Tombrello, *SP425*, pp. 659-663 (Oct. 1975).

Key words: CTR energy production; nuclear reactions.

The copious production of neutrons in the "standard" CTR fuels has led to a renewed interest in proposals that various "exotic" fusion fuels be investigated. These fuels invariably involve reactions on lithium, beryllium, or boron isotopes in which most of the energy is liberated in the form of charged particles. Obtaining reaction cross sections at the appropriate energies or extrapolating the yield into inaccessible energy regions is, however, not always a straightforward procedure; and each reaction may require the development of new techniques. By means of selections from among such "exotic" fuel reactions, I shall show examples of experimental techniques for charged particle cross-section measurements at low energies and some techniques for extrapolation to still lower energies.

A survey of fast-neutron induced reaction cross-section data, M. Qaim, *SP425*, pp. 664-673 (Oct. 1975).

Key words: cross-section data and systematics; cross-section measurement; excitation functions; fast neutrons; nonelastic interactions; nuclear reactions; sources and spectra.

Sources of fast-neutrons and their spectra are discussed briefly. A critical survey of experimental techniques employed in studies of nuclear reactions (excluding fission) at $E_n \geq 14$ MeV is presented. The recent experimental cross-section data are described concisely. Special attention is paid to the case of low-yield reactions, such as processes with trinucleon emission. A review of recently discussed cross-section systematics together with an outline of some of the theoretical implications is given.

A quantitative assessment of CTR cross section needs, S. A. W. Gerstl, D. J. Dudziak, and D. W. Muir, *SP425*, pp. 674-679 (Oct. 1975).

Key words: cross sections; fusion reactors; perturbation; sensitivity; uncertainties.

A computational method to quantitatively determine cross section requirements is described and applied to a particular CTR design project. In order to provide a rational basis for the priorities assigned to new cross section measurements or evaluations, this method includes a quantitative assessment of the uncertainty of currently available data, the sensitivity of important nuclear design parameters to selected cross sections, and the accuracy desired in predicting nuclear design parameters. Perturbation theory is used to combine estimated cross section uncertainties with calculated sensitivities to determine the variance of any nuclear design parameter of interest. Selected computational results are presented for a model of the Tokamak Fusion Test Reactor.

A sensitivity study of data deficiencies weighting functions, and 14 MeV neutron source spectrum effects in a ^{238}U fueled fusion-fission hybrid blanket, B. R. Leonard, Jr., U. P. Jenquin, D. L. Lessor, D. F. Newman, and K. B. Stewart, *SP425*, pp. 680-682 (Oct. 1975).

Key words: fusion blanket neutronics; nuclear reactions; ^{238}U.

Neutronic calculations have been made for a hybrid DT fusion reactor blanket in which the initial region is fueled with depleted uranium followed by lithium and graphite. The important parameters of the blanket are the tritium production, fissions, ^{238}U captures, and thermal flux in the graphite. The sensitivity of these integral parameters was studied as a function of ^{238}U region thickness and the ^{238}U microscopic data used. In particular the effect of modifying some improbable secondary neutron energy distributions of ^{238}U on both versions III and IV of ENDF/B was calculated. Calculations were made for multigroup data obtained by collapsing over constant and E^{-1} weighting functions below the fusion peak. Results were also obtained for a narrow DT fusion neutron peak and for neutron source distribution resulting from an essentially exact calculation of a mirror plasma driven by 100 keV neutral ^{2}H and ^{3}H.

Advanced fuels for nuclear fusion reactors, J. R. McNally, Jr., *SP425*, pp. 683-687 (Oct. 1975).

Key words: advanced-fuels; DD; D^{6}Li; fusion-dynamics; 1-layer; reactivity-coefficients.

Should magnetic confinement of hot plasma prove satisfactory at high beta ($\Sigma 8\pi nkT/B^2 > 0.2$), nuclear fusion fuels other than DT will be important in future fusion reactors. The prospect of the advanced fusion fuels DD and ^{6}LiD in such fusion reactors appears very promising provided the system is large, well reflected and has a sufficiently high density and temperature (high beta). Steady state burning of DD can ensue in a 60 kG field, 5m radius reactor for $\beta \gtrsim 0.1$ and wall reflectivity $R_\mu = 0.9$. The first generation thermonuclear reactions between D and D or ^{6}Li produce the very active, energy-rich fuels t and ^{3}He which exhibit a high burnup probability in very hot plasmas. Steady state burning of ^{6}LiD has also been demonstrated theoretically for low concentrations of ^{6}Li; however, important features of the ^{6}Lid system still need to be incorporated in the calculation. In particular, there is a need for new and improved nuclear cross section data on over 80 reaction possibilities.

A study of the ^{6}Li(n,α)t reaction between 2-10 MeV, C. M. Bartle, *SP425*, pp. 688-691 (Oct. 1975).

Key words: angular distribution; 2-10 MeV; ^{6}Li(n,α)t.

Absolute ^{6}Li(n,α)t cross section measurements are reported between 2.16 and 9.66 MeV. The results agree with the Pendlebury evaluation. The possibility of unfolding angular distributions from the pulse-height distributions in ^{6}LiI(Eu) is investigated.

Absolute cross sections for neutrons from ^{6}Li + d reactions at energies between 0.2 and 0.9 MeV, A. J. Elwyn, R. E. Holland,

F. J. Lynch, J. E. Monahan, and F. P. Mooring, *SP425*, pp. 692-696 (Oct. 1975).

Key words: $E_d = 0.2$-0.9 MeV; measured $(d^2\sigma)/(dE_d d\Omega)$ $(\theta; E_d)$, $\sigma_t(E_d)$ for ^{7}Be breakup reaction; measured $\sigma(\theta; E_d)$, $\sigma_t(E_d)$ for ^{6}Li(d,n)^{7}Be reactions.

Absolute differential and total cross sections in reactions of deuterons with ^{6}Li have been measured for neutrons corresponding to the formation of ^{7}Be in both its ground and its first excited state, and for the continuum neutrons involved in the breakup of ^{7}Be at deuteron energies between 0.2 and 0.9 MeV. Discussion of the experimental procedure is presented. The results indicate that the breakup neutrons are a substantial portion of the total neutron production cross section in this reaction. The reaction rates of the various neutron production reactions are presented.

Cross section measurements for charged particle induced reactions on ^{6}Li, C. R. Gould, J. M. Joyce, and J. R. Boyce, *SP425*, pp. 697-700 (Oct. 1975).

Key words: deduced σ $\alpha\nu\delta$ $\langle\sigma v\rangle$; measured $\sigma(\theta)$; nuclear reactions; ^{6}Li(p,p); ^{6}Li(p,^{3}He); ^{6}Li(^{3}He,p); ^{6}Li(d,p); ^{6}Li(d,α).

Investigations of proton, deuteron and helium induced reactions on ^{6}Li are of importance in connection with the advantages of fusion reactor cycles involving only charged particles. The cross section data for many of these reactions are incomplete and poorly known. We report measurements of the absolute cross sections of the reactions ^{6}Li(p,p), ^{6}Li(p,^{3}He) at $E_p = 3$-12 MeV, ^{6}Li(d,p), ^{6}Li(d,α) at $E_d = 2.25$-6 MeV and ^{6}Li(^{3}He,p) at $E = 3$-6 MeV. Our data are combined with available information in the literature to determine reaction rate parameters as a function of the temperature of the reacting nuclei.

Phase shift analysis of nD, nT, DD, DT, TT, αD and αT cross sections, C. Abulaffio and A. Peres, *SP425*, pp. 701-703 (Oct. 1975).

Key words: alpha particles; cross sections; deuterons; neutrons; phase shifts; tritons.

Explicit formulas are given for the elastic and inelastic cross sections of neutrons, deuterons, tritons and alpha particles. These formulas, obtained by a phase shift analysis, are the best fit to currently available experimental data, for all angles and energies up to 14 MeV.

^{238}U pulsed sphere measurements and CTR fusion-fission blanket calculations, C. Wong, J. D. Anderson, R. C. Haight, L. F. Hansen, and T. Komoto, *SP425*, pp. 704-707 (Oct. 1975).

Key words: implications for fusion-fission blanket calculations; spectra from 10 keV to 15 MeV compared with calculations; ^{238}U pulsed sphere measurements.

The neutron emission spectra from ^{238}U spheres pulsed with 14-MeV neutrons have been measured from the source energy down to 10 keV and have been compared with calculations employing ENDF/B-IV and ENDL cross sections. The low energy spectra (10 keV to 1 MeV) are best described using ENDF/B-IV cross sections while the high energy spectra (2 MeV to 15 MeV) are best described using ENDL cross sections. It is concluded that use of ENDL cross sections should yield the best estimate of tritium breeding and ENDF/B-IV that of Pu breeding in a CTR fusion-fission blanket.

The ^{94}Nb(n,γ)^{95}Nb, ^{95m}Nb reaction for the CTR reactor technology program, P. J. Persiani, E. M. Pennington, Y. D. Harker, and R. L. Heath, *SP425*, pp. 708-711 (Oct. 1975).

Key words: afterheat; blanket; cross-section; experimen fusion; radioactivity; resonance-levels.

Depending on the assumptions made of the neutron cro section behavior in the high-energy region, the captures ^{94}Nb have been found to be the major components influen ing the afterheat and radioactivity in fusion reactor desi problems. Preliminary blanket designs indicate that abo 60 percent of the capture rates in ^{94}Nb occur above 1 ke and 90 percent occur above 100 eV. Therefore an importa and timely cross section need is an estimate and measu ment of the ^{94}Nb(n,γ)^{95}Nb, ^{95m}Nb reaction in the keV-Me energy region. Nuclear level systematic studies using t two known positive energy resonances, the thermal cro section, the resonance integral and the apparent high-den ty of the low-lying levels in niobium, have suggested post lating the existence of negative energy levels or level. The considerations involved the postulated negative ener resonances, and assumptions about positive ener resonances above 50 eV and average unresolved paramete based on nuclear systematics. The experimental techniq to obtain a measured integrated cross-section in the fast f sion spectrum of the Coupled Fast Reactivity Measu ments Facility (CFRMF) and the Argonne Fast Sour Reactor (AFSR) is investigated with foils of ^{93}Nb containi 4.1 percent ^{94}Nb utilizing Ge(Li) spectrometry.

Production cross sections of some micro and milliseco isomers with 14.8 MeV neutrons, G. N. Salaita and P. Eapen, *SP425*, pp. 712-715 (Oct. 1975).

Key words: cylic activation; formation cross sections me surements; isomeric states.

The formation cross sections for the isomeric states Mg, Al, Y, In, Hf, Tl, Pb, and Bi by the (n,p), (n,α), a (n,2n) reactions have been measured using the cyclic activ tion technique and a Ge(Li) detector. The half-lives of t induced isomeric activities were determined using a wi range time-to-pulse height converter and a multichan analyzer.

Reactivities for two-component fusion calculations, G. Miley and H. H. Towner, *SP425*, pp. 716-721 (Oct. 1975).

Key words: advanced fusion fuels; Doppler effect; fusi cross sections; fusion energy multiplication; fusion reacti ties; Two-Component Torus (TCT).

Tables and graphs of fusion reactivities ($\langle\sigma v\rangle$) are read available for fusion in thermalized (Maxwellian) plasr using common fuels. However, plans to construct the Tw Component Torus (TCT) have created a need for reacti ties to characterize fusion via high-energy beams interacti with low-temperature target plasmas. Such reactivities a derived in the present paper for a variety of fuels includi $D \rightarrow T$, $D \rightarrow {}^3He$, $D \rightarrow D$, $T \rightarrow T$, $T \rightarrow {}^3He$, and $p \rightarrow {}^{11}$ Some examples of the use of these reactivities in two-co ponent calculations are also described.

Application of Bondarenko formalism to fusion reactors, D. Soran and D. J. Dudziak, *SP425*, pp. 722-728 (Oct. 197

Key words: Bondarenko; f-factors; fusion reactors; nio um; Reference Theta-Pinch Reactor; tritium breeding.

The Bondarenko formalism used to account for resonan self-shielding effects (temperature and composition) in Reference Theta-Pinch Reactor is reviewed. A material interest in the RTPR blanket is ^{93}Nb, which exhibits a lar number of capture resonances in the energy region bel 800 keV. Although Nb constitutes a small volume fracti of the blanket, its presence significantly affects t

nucleonic properties of the RTPR blanket. The effects of self-shielding in ^{93}Nb on blanket parameters such as breeding ratio, total afterheat, radioactivity magnet-coil heating and total energy depositions have been studied. Resonance selfshielding of 93Nb, as compared to unshielded cross sections, will increase tritium breeding by ~ 7 percent in the RTPR blanket, and will decrease blanket radioactivity, total recoverable energy, and magnet-coil heating. Temperature effects change these parameters by less than 2 percent. The method is not restricted to the RTPR, as a single set of Bondarenko f-factors is suitable for application to a variety of fusion reactor designs.

Neutron cross-section measurements on ^{236}U, L. Mewissen, . Poortmans, G. Rohr, J. Theobald, H. Weigmann, and G. anpraet, *SP425*, pp. 729-732 (Oct. 1975).

Key words: enriched target; measured $\sigma_{n,T}$, $\sigma_{n,\gamma}$, $\sigma_{n,n'}$; nuclear reactions ^{236}U(n,n), ^{236}U(n,γ), E = 30-1800 eV; ^{237}U resonances deduced Γ_n, Γ_γ.

Capture, scattering and total cross-section measurements have been performed on ^{236}U, over an energy range from 30 eV up to 1.8 keV. The neutron width Γ_n could be determined for 97 levels and the capture width Γ_γ for 57 among them. The average radiative width is: $\Gamma_\gamma = [23.0 \pm 0.3$ (stat.) ± 1.5(syst.)] meV. For the s-wave strength function we find: $S_n = (1.05 \pm 0.14)10^{-4}$.

p-wave assignment of ^{238}U neutron resonances, F. Corvi, G. ohr, and H. Weigmann, *SP425*, pp. 733-737 (Oct. 1975).

Key words: enriched targets; measured σ(E, Eγ) and $\sigma_{n\gamma}$ ^{238}U deduced resonances, π, gΓ_n; nuclear reactions ^{238}U(n, γ), E = 10-1600 eV.

A method of p-wave assignment of ^{238}U resonances is presented, consisting of measuring the fraction of capture γ-rays above 4.3 MeV for neutron resonances in the range 10-1600 eV. In this way, 57 resonances showing an enhancement of the high energy γ-ray yield, were identified as p-waves. In addition, a capture cross-section measurement was performed on a $6.32 \cdot 10^{-3}$ at/barn thick sample in order to obtain the gΓ_γ values of such small resonances. The derived final estimates of the p-wave strength functions S_1 and of the s-wave level spacing D_o are: $S_1 = (2.3^{+0.5}_{-0.4}) \cdot 10^{-4}$; $D_o = (22.4 \pm 1.0)$eV.

Neutron resonance parameters of ^{238}U, Y. Nakajima, A. sami, M. Mizumoto, T. Fuketa, and H. Takekoshi, *SP425*, . 738-741 (Oct. 1975).

Key words: background; JAERI linac; natural U; resonance parameters Γ_n^o up to 5 keV; three thicknesses; transmission measurements; 190-m flight path.

Neutron transmission measurements on natural U samples were performed in the energy region from 20 eV up to 30 keV on a 190-m flight path of the JAERI 120-MeV linac neutron time-of-flight spectrometer. Samples were all metallic slabs with three thicknesses of 0.00725, 0.0144 and 0.0236 atoms/barn, respectively. One of them was cooled down to 77 K to reduce Doppler broadening. The best nominal resolution of the measurements was 0.3 nsec/m. A special attention has been paid to determine the background, because the shape of the background was found to depend on the thickness of the sample in the beam. Resonance parameters Γ_n^o are obtained in the energy region up to about 5 keV with the Atta-Harvey area-analysis program. Results are compared with currently available experimental data.

Evidence for structure in the sequence of s-wave levels in ^{238}U, E. Melkonian, J. P. Felvinci, and W. W. Havens, Jr., *SP425*, pp. 742-743 (Oct. 1975).

Key words: collective motion; correlations; level densities; resonance levels; ^{238}U; Γ_n^o; Γ_γ^o.

The levels in ^{238}U show unusual clusterings of large and small levels as evidenced by runs statistics and sequential correlation of values of Γ_n^o. Also, Γ_n^o is found to show significant correlation with Γ_γ. These effects are interpreted in terms of a model which assumes that excitation states are built upon persistent states of collective vibration and that an entering neutron seeks to form those states involving minimum change of particle motion.

Total neutron cross section measurements on gross fission products, H. G. Priesmeyer and U. Harz, *SP425*, pp. 744-747 (Oct. 1975).

Key words: gross fission products; neutron cross section; time-of-flight; 1-240 eV.

Fast-chopper time-of-flight transmission measurements have been made using gross fission product samples of different irradiation and cooling histories, in order to find isotopic identifications and parameters of fission product resonances. The covered energy range was from 1 eV to 240 eV with resolutions of 47 ns/m and 94 ns/m. Some prominent fission product resonances have been found and can partly be identified. From the transmission analysis the U 235 content and burnup can be calculated within ≤ 5 percent.

High resolution total neutron cross-section in ^{54}Fe and ^{56}Fe, M. S. Pandey, J. B. Garg, J. A. Harvey, and W. M. Good, *SP425*, pp. 748-753 (Oct. 1975).

Key words: high resolution; total neutron cross section; ^{54}Fe; ^{56}Fe.

High resolution neutron total cross-section measurements on ^{54}Fe and ^{56}Fe have been made using the ORELA facility and resonance parameters are reported up to an energy of 500 keV. The total cross-section data were analyzed by R-matrix multi-level code for broad, interfering s-wave resonances. For narrow and noninterfering s-wave resonances and $l > 0$-wave resonances transmission data were analyzed using Harvey-Atta code of area analysis. From these values of resonance parameters, the values of level density $\langle D \rangle$ and strength function for s- and p-wave neutron scattering have been determined. Statistical distributions of spacing and reduced neutron widths are presented. A large number of p-wave resonances are observed which have not been reported before.

Thick sample transmission measurement and resonance analysis of the total neutron cross section of iron, S. Cierjacks, G. Schmalz, R. Töpke, R. R. Spencer, and F. Voss, *SP425*, pp. 754-757 (Oct. 1975).

Key words: Fe(n), $E_n = 0.5$-30 MeV; measured σ_{nT}(E); multilevel R-matrix resonance analysis.

New transmission measurements on natural iron samples were performed at the 190 m flight path of the Karlsruhe fast neutron time-of-flight spectrometer, allowing for an improved resolution of 0.015 ns/m. The measurements were carried out in the energy range from 0.5-30 MeV using two largely different sample thicknesses. The thick sample results indicate, that the deep s-wave minima are now fully explored in the energy range below the inelastic scattering threshold at about 850 keV. From the highly resolved transmission data resonance parameters were determined by multilevel R-matrix analysis. The results of the thick sample

measurements between 0.5-30 MeV and the resonance parameters determined in the range between 500-800 keV are presented.

Gamma-ray production measurements due to interactions of neutrons with elements required for nuclear power applications and design, G. T. Chapman, J. K. Dickens, T. A. Love, G. L. Morgan, and E. Newman, *SP425*, pp. 758-761 (Oct. 1975).

Key words: cross sections; (n,xγ); photon energy.

For the past three years neutron-induced gamma-ray production cross sections have been made for a variety of elements at the Oak Ridge Electron Linear Accelerator. A large, well shielded, NaI spectrometer was used as the gamma-ray detector and ORELA as the neutron source. The facility provides a consistent data set for neutron energies from 0.7 to 20 MeV and photon energies from 0.3 to 10.5 MeV. Typically the samples are flat plates of the element of ≈ 0.02 atoms/barn thickness, although several elements studied required samples in compound form. The data are accumulated in a two-parameter array, gamma-ray pulse height versus neutron time-of-flight. Data reduction was accomplished by binning in desired neutron-energy groups and in fixed photon-energy groups. For each neutron-energy group the data were unfolded using FERD unfolding routine, and the results are in the form of absolute differential cross sections, $d^2\sigma/d\omega dE$, for each photon-energy bin. So far data have been obtained for 20 elements (Li, C, N, O, F, Mg, Al, Si, Ca, Fe, Ni, Cu, Zn, Nb, Ag, Sn, Ta, W, Au, and Pb).

Cross sections for the production of low energy photons by neutron interactions with fluorine and tantalum, J. K. Dickens, G. L. Morgan, and F. G. Perey, *SP425*, pp. 762-765 (Oct. 1975).

Key words: cross sections; fluorine; neutron-induced low-energy photons; tantalum.

Differential cross sections for the production of low energy photons (< 240 keV) by neutron interactions in fluorine and tantalum have been measured for neutron energies between 0.1 and 20 MeV. Photons were detected at 92° using an intrinsic germanium detector. Incident neutron energies were determined by time-of-flight techniques for a white source spectrum.

Spectral gamma-ray production cross-section measurements from threshold to 20 MeV, V. C. Rogers, V. J. Orphan, C. G. Hoot, V. V. Verbinski, D. G. Costello, and S. J. Friesenhahn, *SP425*, pp. 766-769 (Oct. 1975).

Key words: E_n to 21 MeV; E_γ to 10 MeV; σ(n,xγ) measurements.

The gamma-ray production cross-section measurement program at IRT is described. Neutrons from epithermal energies to 21 MeV were produced with the IRT Linac, and gamma rays resulting from neutron interactions were detected with a Ge(Li) spectrometer system. Representative results are presented for C, N, Al, Si, and Fe.

Fourteen-MeV, neutron-induced gamma-ray production cross sections for several elements, E. D. Arthur, D. M. Drake, M. G. Silbert, and P. G. Young, *SP425*, pp. 770-773 (Oct. 1975).

Key words: $E_n = 14.2$ MeV; measured $d^2\sigma/d\Omega dE$; nuclear reaction (n,n′γ).

A pulsed 14.2 MeV neutron source and a NaI(Tl) gamma-ray spectrometer were used to measure gamma-ray production cross sections for several elements in the range A = 12 to 239. Angular distributions for some of the more prominent gamma ray groups were obtained. Complete gamma-ray production cross sections were measured for all the sample materials, including those in which no clearly separable gamma ray groups appeared.

The low energy total cross section of ^{36}Ar, S. F. Mughabghab and B. A. Magurno, *SP425*, pp. 774-775 (Oct. 1975).

Key words: parameters of bound level of Ar-36.

To compare the predictions of the valence model with measured partial radiative widths of Ar-36 an accurate knowledge of the bound-level parameters is required. This is achieved by carrying out a Breti-Wigner parameter fit to the total cross section of Ar-36 measured by Chrien et al. and renormalized to the recommended values of the thermal capture and scattering cross sections. The result is as follows:

$$E_n = -10 \text{ keV}, \Gamma_n^o = 92.3 \text{ eV}, \Gamma_\gamma = 1.26 \text{ eV}.$$

Neutron cross sections of Ni-59, G. J. Kirouac and H. M. Eiland, *SP425*, pp. 776-779 (Oct. 1975).

Key words: nickel-59; resonance integral; resonance parameters; thermal cross section.

The thermal cross section and resonance integral for Ni-59 have been measured in integral measurements using the pile oscillator technique. The results are σ_n (2200 m/sec) = 92 ± 4 barns and RI = 125 ± 8 barns. Separate differential measurements of the neutron total cross section from 0.5 eV to above 2 keV were performed at the RPI linear accelerator. A resonance was observed at 203 eV and analyzed by shape and area methods. Parameters for the resonance have been determined. The integral and differential results were compared and found to be in reasonable agreement.

Neutron resonance spectroscopy at Nevis laboratories, G. Hacken, H. I. Liou, J. Rainwater, and U. N. Singh, *SP425*, pp. 780-783 (Oct. 1975).

Key words: measured $\sigma_t(E)$; (n,n), (n,γ), E = 1 eV-few keV; nuclear reactions; summary of deduced E_n, $g\Gamma_n$, Γ_γ, S_o, $\langle D_o \rangle$; various statistical tests.

A review of the results of high resolution, high intensity neutron time of flight spectroscopy with the Columbia University Nevis Synchrocyclotron is presented. The review includes a brief description of the experimental facilities and a summary of resonance parameter results.

Threshold photoneutron spectroscopy of nuclei near A = 140, R. J. Holt and H. E. Jackson, *SP425*, pp. 784-787 (Oct. 1975).

Key words: deduced $\Sigma\Gamma_{\gamma 0}$ (M1) and $\Sigma\Gamma_{\gamma 0}$ (E1); $E_x \approx 9$ MeV; measured $\sigma(E_n,\theta)$; nuclear reactions ^{138}Ba(γ,n), ^{140}Ce(γ,n).

The E1 and M1 radiative strength functions have been measured for nuclei with atomic mass number near A = 140 and at an excitation energy of approximately 9 MeV using the threshold photoneutron technique. A method was developed for extracting the dipole strength even though the first excited state of the daughter nucleus is near the ground state. The photoneutron spectra were measured at laboratory angles of 90° and 135° and with high resolution (0.5 ns/m) using the time-of-flight spectrometer associated with the Argonne high-current linac. In particular the dipole strengths found in ^{138}Ba and ^{140}Ce are discussed. These results are compared with theoretical estimates and with the radiative strengths of nuclei in the mass range 50 < A < 250.

Analyzing powers of the ^{6}Li($\vec{n}$, t)^{4}He reaction, M. Karim and J. C. Overley, *SP425*, pp. 788-791 (Oct. 1975).

Key words: deduced analyzing powers A(0); measured yield asymmetries; nuclear reactions: ^{6}Li($\vec{n}$, t)^{4}He, E = 0.2-1.4 MeV.

We have measured analyzing powers for the ^{6}Li($\vec{n}$, t)^{4}He reaction for neutron energies between 0.2 and 1.4 MeV. An energy continuum of neutrons was produced by bombarding a thick lithium metal target with a 3.5-MeV, nanosecond-pulsed proton beam. The partially polarized neutrons emitted at 50° were incident on an evaporated ^{6}Li metal target. A silicon surface barrier detector was used to measure triton and α-particle yields as a function of particle energy. Tritons were distinguished from α particles with time-of-flight techniques. Yield asymmetries were determined at laboratory angles of 35, 60 and 80° with angular resolutions of ±5°. The α-particle yield asymmetries were converted to backward angle triton asymmetries, providing data at six angles. Analyzing powers as a function of angle were deduced. Although results are tentative, analyzing powers near 90° and 250 keV are negative (~ −0.3) while above 700 keV they are large and positive (~ −+0.9) and vary slowly with neutron energy.

Neutron-absorption cross section of sodium-22, R. Rundberg, M. F. Elgart, H. L. Finston, E. T. Williams, and A. H. Bond, Jr., *SP425*, pp. 792-794 (Oct. 1975).

Key words: cross section; neutron; resonance; sodium-22; thermal; Westcott.

We describe a simple method for determining the neutron-absorption cross sections for radionuclides produced and consumed in a reactor-neutron flux. Data were obtained for ^{22}Na which through application of Westcott's procedure, yielded the following: σ_{n} = 51.1 ± 3.1 Kbarns, s_{n} = 2.3 ± 0.1, and Σ' = 100 ± 10 Kbarns.

Evidence for valence neutron capture in s-wave neutron capture in ^{36}Ar and ^{54}Fe, S. F. Mughabghab, *SP425*, pp. 795-798 (Oct. 1975).

Key words: thermal capture spectra; valence capture in ^{36}Ar and ^{54}Fe.

The valence and channel neutron model of Lane and Lynn remarkably account for partial radiative widths of neutron resonances in the 3p-giant resonance. In this investigation, evidence is presented for valence neutron capture at and in the neighborhood of the 3s- giant resonance in target nuclei Ar-36 and Fe-54. In addition, the variation of the correlation coefficient $\rho(\Gamma_{\gamma ij}\, E_{\gamma}^{-n}, (2J+1)\, S_{nlp})$ with the reduction power factor n of the γ ray energy is studied.

Neutron resonance spectroscopy. ^{209}Bi, U. N. Singh, J. Rainwater, H. I. Liou, G. Hacken, and J. B. Garg, *SP425*, pp. 799-801 (Oct. 1975).

Key words: deduced E_{n}, l, J, $g\Gamma_{n}$, S_{n}, S_{l}; measured $\sigma_{t}(E)$; nuclear reactions ^{209}Bi (n,n), (n,γ), E = 500 eV-75 keV.

Neutron time of flight transmission measurements were made on several samples of ^{209}Bi using the Nevis Synchrocyclotron of Columbia University. The resonance parameters are given for 29 levels to 75 keV. Out of the 29 observed levels 10 were l = 0 and 19 were l = 1 levels. The implied s and p-strength functions are $10^{4}S_{n} = (0.60\ ^{+0.39}_{-0.21})$ and $10^{4}S_{1} = (0.19^{+0.08}_{-0.05})$.

Measurement of neutron capture cross section near 24 keV, . Yamamuro, T. Doi, T. Hayase, Y. Fujita, K. Kobayashi, id R. C. Block, *SP425*, pp. 802-805 (Oct. 1975).

Key words: $C_{6}F_{6}$ detector; Fe-filtered beam; neutron capture cross section; pulse-height weighting; time-of-flight method; ^{93}Nb, Ag, ^{127}I, ^{165}Ho, ^{197}Au and ^{238}U.

Neutron capture cross sections of ^{93}Nb, Ag, ^{127}I, ^{165}Ho, ^{197}Au and ^{238}U were measured near 24 keV using the Fe-filtered-beam method. A 15-cm thick Fe filter was placed in the neutron time-of-flight beam produced by the KUR 46-MeV electron Linac. Capture γ-rays were detected by two $C_{6}F_{6}$ total energy detectors located on a 12-m flight path. Pulse-height weighting was used to determine the relative capture efficiency. The neutron flux was determined with the detector via the ^{10}B (n;$\alpha_{1}\gamma$) reaction and saturated resonance capture in Ag at 5.2 eV. Multiple scattering corrections were applied to the data, resulting in 24 keV capture cross sections of 0.33, 1.10, 0.76, 1.26, 0.68 and 0.50 barns for ^{93}Nb, Ag, ^{127}I, ^{165}Ho, ^{197}Au and ^{238}U, respectively. Total errors are 5 to 7 percent, with an estimated systematic error of 4 percent.

Fluctuations in the neutron strength function, C. M. Newstead, *SP425*, pp. 806-809 (Oct. 1975).

Key words: fluctuations; neutron strength functions; optical potential; quasi-particles.

Strength function fluctuations are interpreted in terms of variation of the quasi-particle state density. The anomalous behaviour of the neodymium isotopes is described and an account of the fluctuations of S_{n} in the 3S and 4S size resonances is given. Fluctuations of the local strength fluctuations with energy are discussed.

Measurements of thermal neutron cross sections for helium production in ^{59}Ni, J. McDonald and N. G. Sjöstrand, *SP425*, pp. 810-812 (Oct. 1975).

Key words: alpha particles; cross section; helium; nickel; neutron; spectrum.

The cross section for the reaction ^{59}Ni (n,α)^{56}Fe was measured at three neutron energies from 0.029 to 0.042 eV. The alpha particles were recorded using a Si surface barrier detector. The measurements were made relative to Li-6. Within experimental errors the cross section ratio remained constant for the three energies. Assuming that the 1/v law applies the ^{59}Ni (n,α) cross section at 0.0253 eV is found to be 22.2 ± 1.7 barn.

Differential cross sections for the 0.847-MeV gamma ray from iron for incident neutrons of 8.5, 10.0, 12.2, and 14.2 MeV, D. M. Drake, L. R. Veeser, M. Drosg, and G. Jensen, *SP425*, pp. 813-815 (Oct. 1975).

Key words: E_{n} = 8.5, 10.0, 12.2, 14.2 MeV; Fe(n,xγ); measured $\sigma(\theta)$ for E_{γ} = 0.847 MeV; nuclear reactions; θ = 90°, 75°, 55°, 35°.

Neutron-induced differential gamma-ray production cross sections for the 0.847-MeV gamma ray from iron have been measured using a pulsed ^{3}H(p,n)^{3}He neutron source and a NaI spectrometer. Background caused by break-up neutrons and Compton-scattered gamma rays was suppressed by placing the sample about one meter from the neutron source and using time-of-flight to select only pulses caused by the monoenergetic ^{3}H(p,n)^{3}He neutrons.

High energy γ-ray transitions of ^{56}Fe resonances in the energy range 7-70 keV, H. Beer, R. R. Spencer, and F. Käppeler, *SP425*, pp. 816-818 (Oct. 1975).

Key words: E_{n} = 7-70 keV; natural iron target; nuclear reaction ^{56}Fe (n,γ); relative partial radiation widths; γ-transitions in ^{57}Fe of ^{56}Fe resonances.

High energy γ-ray transitions to low lying states in ^{57}Fe following neutron capture in ^{56}Fe were investigated for individual resonances in the energy region 7-70 keV at the Karlsruhe 3 MV pulsed Van-de-Graaff-accelerator by means of a 50 cc Ge(Li)-detector. As a result relative partial radiation widths for 5 transitions of 4 resonances were determined.

Excitation functions of the (n,2n) reactions on ^{12}C and ^{238}U, A. Ackermann, B. Anders, M. Bormann, and W. Scobel, *SP425*, pp. 819-822 (Oct. 1975).

Key words: measured σ(E); nuclear reactions $^{12}C(n,2n)$, E= 23-34 MeV; statistical model calculations; $^{238}U(n,2n)$, E= 13-18 MeV.

The excitation functions of the reaction $^{12}C(n,2n)^{11}C$ for incident neutron energies from 23 to 34 MeV and of $^{238}U(n,2n)^{237}U$ from 13 to 18 MeV have been measured with activation techniques. The results are compared with existing data and interpreted with the statistical model approach. The calculations performed for ^{238}U include fission competition and preequilibrium contributions to account for an enhanced (n,2n) yield at projectile energies above 15 MeV.

Incoherent neutron scattering cross-sections as determined by diffuse neutron scattering techniques, W. Schmatz, G. Bauer, and M. Löwenhaupt, *SP425*, pp. 823-824 (Oct. 1975).

Key words: diffuse neutron scattering; incoherent neutron scattering; point defects.

A discussion is given of the way in which small incoherent scattering cross-sections can be obtained as a by-product of point defect scattering studies. A table with σ_{inc}-values for ten elements is given.

Cross section and method uncertainties: The application of sensitivity analysis to study their relationship in calculational benchmark problems, C. R. Weisbin, E. M. Oblow, J. Ching, J. E. White, R. Q. Wright, and J. Drischler, *SP425*, pp. 825-833 (Oct. 1975).

Key words: air transport; benchmark; profiles; sensitivity; uncertainties.

Sensitivity analysis is applied to the study of an air transport benchmark calculation to quantify and distinguish between cross-section and method uncertainties. The boundary detector response was converged with respect to spatial and angular mesh size, P_l expansion of the scattering kernel, and the number and location of energy grid boundaries. The uncertainty in the detector response due to uncertainties in nuclear data is 17.0 percent (one standard deviation, not including uncertainties in energy and angular distribution) based upon the ENDF/B-IV "error files" including correlations in energy and reaction type. Differences of approximately 6 percent can be attributed exclusively to differences in processing multigroup transfer matrices.

Benchmark experiments for nuclear data, E. M. Bohn, R. J. LaBauve, R. E. Maerker, B. A. Magurno, F. J. McCrosson, and R. E. Schenter, *SP425*, pp. 834-841 (Oct. 1975).

Key words: benchmark experiments; dosimetry; fast reader testing; fission products; shielding; thermal reactor testing.

Benchmark experiments offer the most direct method for validation of nuclear data. Benchmark experiments for several areas of application of nuclear data have been specified by CSEWG. These experiments are surveyed and tests of recent versions of ENDF/B are presented.

Estimated uncertainties in nuclear data—An approach, F. G. Perey, *SP425*, pp. 842-847 (Oct. 1975).

Key words: correlations; covariances; data adequacy; estimated uncertainties; evaluations; neutron transport.

The need to communicate estimated uncertainties in evaluated nuclear data to be used in the assessment of their adequacy in applications has been recognized in the ENDF/B system. Starting with ENDF/B-IV, the data files contain formatted data describing the estimated covariances of some of the microscopic cross sections in such a form that they can be processed by computer codes to generate covariance matrices of quantities used in solving neutron transport problems such as group cross sections. The basic concepts behind the representation of such quantities will be described and the work done so far in the representation and manipulation of such quantities will be discussed. Problem areas not yet addressed in ENDF/B-IV but under study will be discussed.

A survey of computer codes which produce multigroup data from ENDF/B-IV, N. M. Greene, *SP425*, pp. 848-854 (Oct. 1975).

Key words: computer codes; multi-group data; survey.

The features of three code systems that produce multigroup neutron data are contrasted. This includes the ETOE-2/MC²-2/SDX, MINX/SPHINX and AMPX code packages. These systems all contain a fairly extensive set of processing capabilities with the current evaluated nuclear data files—ENDF/B. They were designed with different goals and applications in mind. This paper discusses some of their differences and the implications for particular situations.

Measurement of (n,2n) and (n,3n) cross-sections for incident energies between 6 and 15 MeV, J. Fréhaut and G. Mosinski, *SP425*, pp. 855-858 (Oct. 1975).

Key words: E_n = 8-15 MeV; measured σ(En); nuclear reactions ^{56}Fe, ^{59}Co, $^{76,78,80,82}Se$, ^{89}Y, ^{93}Nb, ^{103}Rh, ^{169}Tm, ^{175}Lu, ^{181}Ta, W, Pt, ^{197}Au, ^{209}Bi, $^{238}U(n,2n)$; $^{238}U(n,3n)$.

Cross sections for the (n,2n) and (n,3n) reactions have been measured for several nuclides between 6 and 15 MeV using a large liquid scintillator to count the neutrons directly. Measurements were made relative to fission cross section of ^{238}U for ^{56}Fe, ^{59}Co, ^{76}Se, ^{78}Se, ^{80}Se, ^{82}Se, ^{89}Y, ^{93}Nb, ^{103}Rh, ^{169}Tm, ^{175}Lu, ^{181}Ta, ^{197}Au, ^{209}Bi, ^{238}U, and for the natural elements Pt and W. The relative accuracy was generally in the range 5 to 10 percent. The present results are compared with previous measurements.

Excitation curve for the production of $^{115}In^m$ by neutron inelastic scattering, D. C. Santry and J. P. Butler, *SP425*, pp. 859-861 (Oct. 1975).

Key words: excitation curve; neutron elastic scattering; $^{115}In^m$; 0.335-14.7 MeV.

Cross sections for the reaction $^{115}In(n,n')^{115}In^m$ have been measured by the activation method from a threshold energy of 0.335 MeV to 14.74 MeV. Cross sections at energies below 5.3 MeV were based on neutron flux measurements determined with a calibrated neutron long counter, while at higher energies measurements were made relative to the known cross section for the $^{32}S(n,p)^{32}P$ reaction. An effective cross section for a ^{235}U fission neutron spectrum calculated from the measured excitation curve is 173 ± 9 mb.

Inelastic neutron excitation of the ground state rotational band of ^{238}U, P. Guenther and A. Smith, *SP425*, pp. 862-865 (Oct. 1975).

Key words: E=0.3-3.0 MeV; nuclear reaction ^{238}U(n,n) and ^{238}U(n,n'); $\sigma(\Theta,E)$; Θ_{lab}=20 to 160°.

Cross sections for the neutron excitation of the 2+(45 keV), 4+(148 keV) and 6+(308 keV) states in ^{238}U were measured to incident energies of ≈3.0 MeV. The experimental resolution was sufficient to resolve these components throughout the measured energy range. Particular attention was given to energies near threshold and in the few MeV range where direct reaction contributions were appreciable. The experimental results were compared with theoretical estimates based upon statistical and coupled-channel models deduced from comprehensive studies of neutron scattering from heavy-rotational-deformed nuclei. An evaluated inelastic scattering data set was derived from the present experimental and calculational results and previously reported experimental values and compared with respective values from the ENDF-IV file.

Differential elastic and inelastic scattering of 9-15 MeV neutrons from carbon, F. O. Purser, D. W. Glasgow, H. H. Hogue, J. C. Clement, G. Mack, K. Stelzer, J. R. Boyce, D. H. Epperson, S. G. Buccino, P. W. Lisowski, S. G. Glendinning, E. G. Bilpuch, H. W. Newson, and C. R. Gould, *SP425*, pp. 866-870 (Oct. 1975).

Key words: measured $\sigma(E)_{n},\theta)$; nuclear reactions C(n,n), C(n,n'), E=9-15 MeV.

Measurements have been made of the differential elastic and inelastic scattering cross sections, at 28 angles each, for 9, 9.21, 9.6, 10, 10.25, 10.74, 11, 11.22, 11.79, 12, 13, 14, 14.5, and 15 MeV neutrons incident upon natural carbon. The measurements were made with the TUNL FN tandem accelerator and a high-precision goniometer time-of-flight spectrometer. Monte Carlo simulation has been used to correct the differential cross sections for multiple scattering. Absolute uncertainties are typically 5 percent. These data partially fill the 9-15 MeV gap in the C elastic and inelastic scattering data set required for the CTR program.

Neutron inelastic scattering cross sections in the energy range 2 to 4.5 MeV, M. A. Etemad, *SP425*, pp. 871-874 (Oct. 1975).

Key words: Hauser-Feshbach; inelastic-scattering; measurements; MeV range 2 to 4.5; neutrons; time-of-flight.

Fast neutron inelastic scattering cross sections have been measured for the elements Al, Ti, V, Mn, Fe, Ni, Nb, Pb and Bi by the time-of-flight technique. The measurements were made in the energy range of 2 to 4.5 MeV in steps of 0.25 MeV and at a scattering angle of 125°. The experimental results are compared to the excitation functions calculated on the basis of the Hauser-Feshbach formalism and corrected for the effects of the level width fluctuations.

The absolute polarization of fast neutrons elastically scattered from light nuclei, F. W. K. Firk, J. E. Bond, G. T. Hickey, R. J. Holt, R. Nath, and H. L. Schultz, *SP425*, pp. 875-878 (Oct. 1975).

Key words: E=2 to 5 MeV; measured $\vec{p}(E,\theta)$ absolutely for ^{12}C(n,$\vec{n}$) reaction then determined $\vec{A}(E,\theta)$ for other reactions; nuclear reactions ^{4}He($\vec{n}$,n); ^{6}Li($\vec{n}$,n); ^{9}Be($\vec{n}$,n); ^{12}C($\vec{n}$,n) and ^{16}O($\vec{n}$,n); R-function and phase-shift analyses; θ_{lab}=20 to 150°.

Photoneutrons from the target of the Yale LINAC were polarized by elastic scattering from a cylinder of graphite. The polarized neutrons were observed at angles of 50 and 130° and their energies determined with a time-of-flight resolution of 0.75 ns·m^{-1}. The *absolute* polarization of the neutrons was measured in a true double-scattering experiment; this polarized source then was used to measure the analyzing powers of the reactions $\vec{n}$-^{4}He, $\vec{n}$-^{6}Li, $\vec{n}$-^{9}Be, and $\vec{n}$-^{16}O over wide ranges of energy and angle. These reactions are of interest from three viewpoints i) the design of fission and fusion power reactors ii) absolute neutron standards and iii) fundamental theory. General, multi-level R-function analyses and phase-shift analyses of the observed analyzing powers were made in all cases. Differential and total cross sections were predicted and compared with currently available measurements.

Inelastic scattering of fast neutrons from ^{103}Rh, D. Reitmann, E. Barnard, D. T. L. Jones, and J. G. Malan, *SP425*, pp. 879-882 (Oct. 1975).

Key words: fast neutrons; inelastic scattering; isomeric state; level scheme; optical model; rhodium-103.

Cross sections for elastic and inelastic scattering of fast neutrons from ^{103}Rh were measured at energies up to 1500 keV. Additional information about the level scheme followed from (n,n'γ) measurements. The effective cross section for excitation of the isomeric state at 40 keV was derived from these results and compared with activation measurements and theoretical results.

ORNL neutron scattering cross section measurements from 4 to 8.5 MeV: A summary, W. E. Kinney and F. G. Perey, *SP425*, pp. 883-885 (Oct. 1975).

Key words: cross section; differential; elastic; inelastic; neutron; scattering.

The ORNL program to measure neutron elastic and inelastic scattering cross sections for 26 nuclides from C to ^{238}U in the 4-8.5 MeV energy range is summarized. Data acquisition and reduction techniques are reviewed and typical results given. The nuclides investigated are tabulated.

Differential elastic scattering cross sections of sulphur for 14.8 MeV neutrons by surface of revolution technique, A. M. Ghose, A. Chatterjee, and S. Nath, *SP425*, pp. 886-888 (Oct. 1975).

Key words: differential elastic scattering cross section; fast neutrons; scattering geometry; uniform sensitivity neutron counter.

A new technique has been developed for the absolute measurements of differential elastic scattering cross sections of nuclei for fast neutrons. The method is based on constant angle scatterers shaped in the form of a surface of revolution around the source to detector line as axis. Inelastically scattered neutrons have been discriminated by the multiple bias technique applied to recoil proton plastic detectors. The results obtained for sulphur for 14.8 MeV neutrons will be presented.

Differential cross sections for carbon neutron elastic and inelastic scattering from 8.0 to 14.5 MeV, G. Haouat, J. Lachkar, Y. Patin, J. Sigaud, and F. Coçu, *SP425*, pp. 889-892 (Oct. 1975).

Key words: angular distributions; carbon-neutron elastic and inelastic scattering; E_{n}=8.0-14.5 MeV; excitation functions.

Differential elastic and inelastic cross sections for fast neutrons scattered by carbon have been measured between 8.0 and 14.5 MeV. No other results on ^{12}C seem to have been reported, at this time, between 9 and 14 MeV. A

complete and consistent set of data for carbon, including total, elastic and inelastic, (n,α) and (n,n'3α) cross sections, is now available for energies below 14.5 MeV.

Level and decay schemes of even-A Se and Ge isotopes from (n,n'γ) reaction studies, J. Sigaud, Y. Patin, M. T. McEllistrem, G. Haouat, and J. Lachkar, *SP425*, pp. 893-896 (Oct. 1975).

Key words: E_γ; $E_n = 2.0$-4.1 MeV; level schemes; (n,n'γ) reaction; $\sigma(E_\gamma,\Theta)$; ^{76,78,80,82}Se, ^{76}Ge.

The energy levels and the decay schemes of ^{76}Se, ^{78}Se, ^{80}Se and ^{76}Ge have been studied through the measurements of (n,n'γ) differential cross sections. Gamma-ray excitation functions have been measured between 2.0- and 4.1-MeV incident neutron energy, and angular distributions have been observed for all of these isotopes.

Symmetry effects in neutron scattering from isotopically enriched Se isotopes, J. Lachkar, G. Haouat, M. T. McEllistrem, Y. Patin, J. Sigaud, F. Coçu, *SP425*, pp. 897-900 (Oct. 1975).

Key words: deduced optical-model parameters; enriched targets; measured $\sigma(\theta)$; nuclear reactions ^{76,78,80,82}Se(n,n), (n,n'), E = 6-10 MeV.

Differential cross sections for neutron elastic and inelastic scattering from ^{76}Se, ^{78}Se, ^{80}Se and ^{82}Se, have been measured at 8-MeV incident neutron energy and from ^{76}Se and ^{82}Se at 6- and 10-MeV incident energies. The differences observed in the elastic scattering cross sections are interpretable as the effects of isospin term in the scattering potentials. A full analysis of the elastic scattering data are presented.

Fast neutron capture and activation cross sections, W. P. Poenitz, *SP425*, pp. 901-904 (Oct. 1975).

Key words: fast neutron capture; Co, Ni, Cu, Zn, Nb, Ho, Ta, Au, ^{238}U; theory and experiment.

Fast neutron capture cross sections were measured in the energy interval from 0.02 to 0.7 MeV using white source neutron time-of-flight techniques and from 0.3 to 3.0 MeV using monoenergetic neutrons. Target materials were Co, Ni, Zn, Cu, Nb, Ho, Ta, Au and ^{238}U. A 1300 l liquid scintillator was used as a capture γ-ray detector. Flat efficiency neutron detectors and/or the standard capture cross section of Au were used for the neutron flux determination. Fast neutron capture and activation cross sections were calculated in terms of the statistical model. The Hauser-Feshbach formalism and a gamma cascade model previously described were used.

Fission product capture cross sections in the keV region, R. W. Hockenbury, H. R. Knox, and N. N. Kaushal, *SP425*, pp. 905-907 (Oct. 1975).

Key words: average Γ_γ, D, S^0 and S^1; capture cross sections.

Capture cross section measurements have been made on ^{105}Pd, ^{151,153}Eu and ^{103}Rh from 20 eV to 200 keV. Capture data in the resolved resonance region are combined with our own transmission data to obtain a consistent capture normalization. For these experiments, the statistical uncertainty of the normalization is ± 4 percent for ^{151}Eu, ^{153}Eu and ^{105}Pd, and ± 8 percent for ^{103}Rh. The statistical uncertainty of the keV capture cross section point data is about ± 4 percent. The information derived from these measurements is the measured keV capture cross section and the average s and p wave parameters $\bar{\Gamma}_\gamma$, S^0 and S^1.

Integral capture cross-section measurements in the CFRMF for LMFBR control materials, R. A. Anderl, Y. D. Harker, E. H. Turk, R. G. Nisle, and J. R. Berreth, *SP425*, pp. 908-911 (Oct. 1975).

Key words: boron carbides; capture cross sections; CFRMF reactor; control materials; europium oxides; fast reactors; neutron reactions; tantalum.

Integral capture-cross sections for separated isotopes of Eu and Ta are reported for measurements in the Coupled Fast Reactivity Measurements Facility (CFRMF). These cross sections along with that measured in the CFRMF for ^{10}B(n,α) provide an absolute standard for evaluating the relative reactivity worth of Eu_2O_3, B_4C and Ta in neutron fields typical of an LMFBR core. Based on these measurements and for neutron fields characterized by the ^{235}U:^{238}U reaction rate spectral index ranging from 23 to 50, the infinitely dilute relative worth of Eu_2O_3 has been estimated to be 25 to 40 percent higher than that for B_4C and 80 to 100 percent higher than that for Ta.

Radiative capture of neutrons in the keV region, R. C. Greenwood, R. E. Chrien, and K. Rimawi, *SP425*, pp. 912-915 (Oct. 1975).

Key words: iron filter; Mn(n,γ); neutron capture gamma-rays; ^{6}Li filter; ^{154}Gd(n,γ); ^{156}Gd(n,γ).

Essentially monoenergetic neutrons with keV energies can be obtained from a reactor by using suitable filters. To date, prompt γ-ray spectra have been measured using 24-, 2-, and 1-keV neutrons, obtained through Fe + Al + S, Sc + Ti and ^{6}Li filters, respectively. Two features of these data are of note to reactor shielding. First, the radiative capture spectra from higher Z nuclei usually result from an average over many resonance states. Hence statistical fluctuations in the primary γ-ray intensities, to which the corresponding thermal neutron capture spectra are subject, are averaged out. Second, such data provide information on the dependence of radiative capture spectra on neutron energy. The data shows that at 24 keV there is a significant p-wave contribution to these spectra, even for those mass regions where the ratio of the p-to-s wave strength function is close to a minima. This occurs because the smallness of the relative penetrability at 24 keV, $0.04 < (kR)^2 < 0.08$ for $100 < A < 240$, is compensated for by the branching ratio Γ_γ/Γ which is now much larger for p-wave than for s-wave resonances.

Measurement of the γ-ray production cross sections from inelastic neutron scattering in some chromium and nickel isotopes between 0.5 and 10 MeV, F. Voss, S. Cierjacks, D. Erbe, and G. Schmalz, *SP425*, pp. 916-919 (Oct. 1975).

Key words: $E_n = 0.5$-10 MeV; ^{52}Cr, ^{58}Ni, ^{60}Ni (n,n',γ) experimental results of γ-ray production cross sections.

At the Karlsruhe fast neutron time-of-flight spectrometer the investigation of γ-ray production cross sections of technologically important materials has been continued with the elements Cr and Ni. The excitation functions for the γ-ray production cross sections in inelastic neutron scattering have been measured at 125° from threshold to 10 MeV. The Karlsruhe cyclotron was used to produce a pulsed beam of neutrons having a continuous energy spectrum between ~ 0.5 and 30 MeV. The incident neutron energy was determined by the time of flight technique. The energy resolution ranged from 2.2 keV at 1 MeV to 70 keV at 10 MeV. Neutron flux determination was accomplished by use of a calibrated proton recoil detector. Preliminary results are shown for the γ-ray energies 1434 keV in ^{52}Cr, 1454 keV in ^{58}Ni and 1333 keV in ^{60}Ni and compared with the results of other authors.

Measurement of 24.3 keV activation cross sections with the

iron filter technique, K. Rimawi and R. E. Chrien, *SP425*, pp. 920-922 (Oct. 1975).

Key words: relative ^{10}B standard; 24.3 keV neutron activation cross sections.

Using high-resolution detection techniques, intensities of specific activation lines from $^{197}Au(n,\gamma)^{238}U(n,\gamma)$,$^{127}I(n,\gamma)$, and $^{115}In(n,\gamma)$ {54 min + 2.2 sec} were recorded, using the BNL HFBR iron-filtered neutron beam. From a comparison with the reaction $^{10}B(n,\alpha\gamma)$, cross sections at 24.3 keV were determined.

Radiative capture gamma rays from the reaction $^{208}Pb(n,\gamma)^{209}Pb$ for 11-MeV incident neutrons, D. M. Drake, E. D. Arthur, I. Bergqvist, D. K. McDaniels, and P. Varghese, *SP425*, pp. 923-925 (Oct. 1975).

Key words: measured capture gamma rays resolution approximately 80 keV; nuclear reactions $^{208}Pb(n,\gamma)^{209}Pb$ $E_n = 11.2$ MeV.

The spectrum of gamma rays emitted by ^{209}Pb from 11-MeV neutron capture has been measured with a Ge(Li) detector. Although the statistical quality of the data is poor it seems apparent that two-particle, one-hole states, as well as single-particle states, play a prominent role in fast neutron capture in ^{208}Pb.

γ-ray spectra from $l = 1$ neutron capture near 24 keV, K. Rimawi and R. E. Chrien, *SP425*, pp. 926-928 (Oct. 1975).

Key words: $E_n = 24.3$ keV; neutron capture γ-rays; width correlations.

The characteristics of neutron capture γ-ray spectra near $E_n = 24.3$ keV are discussed. The E-1 transitions following the capture of p-wave neutrons show a marked preference for populating low-lying states with and s or d single-particle character. This preference introduces a significant correlation between partial (n,γ) cross sections and the neutron reduced widths for final states as measured in the (d,p) reaction.

Shape analysis and width correlation studies based on neutron capture data for ^{56}Fe, ^{58}Ni, ^{60}Ni and ^{61}Ni, F. H. Fröhner, *SP425*, pp. 929-933 (Oct. 1975).

Key words: nuclear reactions ^{56}Fe, $^{58,60,61}Ni(n,\gamma)$, E = 6-150 keV, deduced Γ_γ, width correlations; shape analysis.

Previously reported neutron capture data were analyzed up to 150 keV for ^{56}Fe, ^{58}Ni and ^{60}Ni, and up to 30 keV for ^{61}Ni with a newly developed multilevel shape analysis code with the aim to improve and extend older area analysis results, to check whether the reported correlations between neutron and radiation widths are not produced e.g. by neglect of multilevel effects in the older self-shielding and multiple-scattering calculations and to search for channel effects such as asymmetric peak shapes.

γ-ray production cross sections for neutron inelastic scattering from Cr, Ni, ^{92}Zr, and ^{94}Zr from 3 to 6 MeV, G. Tessler and S. S. Glickstein, *SP425*, pp. 934-937 (Oct. 1975).

Key words: Cr, Ni, Zr; $E_n = 3$-6 MeV; $(n,n'\gamma)$; nuclear reactions; γ-production.

Cross sections for γ-ray production by neutron inelastic scattering from Cr, Ni, ^{92}Zr, and ^{94}Zr have been measured for incident neutrons in the energy range 3-6 MeV. The γ rays were detected with a 55 cm^3 coaxial Ge(Li) anti-Compton spectrometer located at 55° to the incident neutron direction. Background associated with neutrons scattering from the samples into the Ge(Li) detector was suppressed by the pulsed beam time-of-flight technique. Assignment of γ rays to transitions from specific energy levels of the isotopes of Cr, Ni, and Zr has been made using γ-ray energies determined from this work and energies and level schemes reported in the literature. Many of the observed γ rays could not be assigned to known levels.

Scattering of neutrons by nitrogen and oxygen from 5.0 to 9.3 MeV, D. L. Bernard and M. C. Taylor, *SP425*, pp. 938-941 (Oct. 1975).

Key words: angular distributions; differential cross sections; neutron cross sections; neutron time-of-flight spectroscopy.

Angular distributions of neutrons scattered elastically and inelastically from nitrogen-14 and oxygen-16 have been measured at neutron energies of 5.04, 6.25 and 9.29 MeV. Neutron flux attenuation and multiple scattering corrections were made using a modified version of an existing computer code. Special consideration was given in the modification of the code to developing an angular resolution function to treat the effects on multiple scattering corrections due to the solid angle subtended by the scattering sample at the neutron producing target. Graphs and tabulated results are presented as center of mass differential scattering cross sections versus the cosine of the center of mass scattering angle.

Deformation effects in neutron scattering from the Sm isotopes, M. T. McEllistrem, J. Lachkar, G. Haouat, C. Lagrange, Y. Patin, R. E. Shamu, J. Sigaud, and F. Coçu, *SP425*, pp. 942-945 (Oct. 1975).

Key words: calculated $\sigma(\theta)$; measured $\sigma(\theta)$; nuclear reactions $^{146}Nd(n,n)$, (n,n'), $^{148,150}Sm(n,n)$, (n,n'), $^{152,154}Sm(n,n+n')$, E = 7.0 MeV.

Deformation effects in neutron scattering from isotopically enriched Sm_2O_3 samples have been studied at an incident neutron energy of 7 MeV where a maximum of the deformation effects was observed in total cross section measurements on the same isotopes.

Differential cross sections for elastic scattering and inelastic scattering (first 2^+ state) were measured for ^{148}Sm and ^{150}Sm and for ^{146}Nd, which was included in this study to aid in separating isospin effects from deformation effects. Cross sections for the sum of elastic and inelastic scattering (first 2^+ state) were determined for ^{152}Sm and ^{154}Sm.

Experimental cross sections are compared to the results of nonspherical optical-potential coupled-channel calculations.

Small-angle scattering of fast neutrons, W. Bucher, C. E. Hollandsworth, and J. E. Youngblood, *SP425*, pp. 946-949 (Oct. 1975).

Key words: fast neutrons; Pb; scattering; small angles; U.

By the application of a new technique, absolute cross sections for the small-angle elastic scattering of neutrons by U have been accurately determined at various energies in the range 7-14-MeV. The data show less strong forward-peaking at small angles than previously reported results. In addition, measurements of the small-angle scattering by Pb were also carried out over the same energy range; and the results, while in conflict with some previous reported measurements, are, apart from normalization, in excellent agreement with optical model calculations based on the energy independent, nonlocal potential of Perey and Buck.

Elastic and inelastic differential neutron scattering cross sections for ^{238}U from 0.9-2.7 MeV, J. J. Egan, G. H. R. Kegel, G.

P. Couchell, A. Mittler, B. K. Barnes, W. A. Schier, D. J. Pullen, P. Harihar, T. V. Marcella, N. B. Sullivan, E. Sheldon, and A. Prince, *SP425*, pp. 950-952 (Oct. 1975).

Key words: compared with calculated excitation functions; measured $\sigma(E_n, 90°)$ for ground, 45, 148 keV states; nuclear reactions $^{238}U(n,n)$, (n,n'), E = 0.9-2.7 MeV; time-of-flight.

Differential cross sections have been measured via the time-of-flight method for neutrons scattered at 90° from the ground and first two excited states, at 45 and 148 keV, of ^{238}U in the bombarding energy range 0.9 to 2.7 MeV. The $^{7}Li(p,n)^{7}Be$ reaction was the neutron source. The LTI 5.5 MeV Van de Graaff accelerator in conjunction with a Mobley bunching system generated proton pulses with durations as short as 320 picoseconds (fwhm). The excellent timing characteristics of this system enabled the three states in ^{238}U to be resolved up to 2.7 MeV. Above 1.5 MeV the present results for the 2^+ state at 45 keV are 2 to 2.5 times larger than the ENDF/IV cross sections. However, the present results are in good agreement with theoretical calculations which incorporate both direct interaction and compound nucleus contributions to the cross sections.

Absolute measurements of neutron radiative capture cross sections for Na^{23}, Cr, Mn^{55}, Fe, Ni, Rh^{103}, Ta, U^{238} in the keV energy range, C. Le Rigoleur, A. Arnaud, and J. Taste, *SP425*, pp. 953-956 (Oct. 1975).

Key words: absolute radiative capture cross sections; keV energy range – Na^{23}, Cr, Mn^{55}, Fe, Ni, Rh^{103}, Ta, U^{238}.

The absolute measurements of several neutron radiative capture cross sections in the keV energy range are presented. The total energy weighting technique was used. Absolute neutron flux were done. Special care was given to the correction arising from the neutron sensitivity of the gamma detector.

Capture cross section of ^{197}Au between 10 keV and 500 keV, E. Fort and C. Le Rigoleur, *SP425*, pp. 957-960 (Oct. 1975).

Key words: absolute values; fluctuations; Monte Carlo calculations for corrections; total energy weighting technique; $4\pi\beta\gamma$ detector.

This reference capture cross-section has been measured by two different absolute methods; prompts γ measurements, activation method. The results obtained are in good agreement between themselves and with Poenitz's recommendation.

Self shielding factor measurements for natural iron and Na^{23} between 24 keV and 160 keV at 300 K, A. Arnaud, C. Le Rigoleur, and J. P. Marquette, *SP425*, pp. 961-963 (Oct. 1975).

Key words: Fe; multigroup capture cross section; Na^{23}; self shielding factor; 24 keV; 160 keV.

We present experimental values of the multigroup capture cross section and self shielding factor for natural iron and Na^{23} between 24 keV and 160 keV. The capture rate is measured with a shielded neutron flux $\phi = \phi_n \exp(-n\sigma_t X)$ after transmission through a sample of iron or Na^{23}, at room temperature. The self shielding factors at the non zero dilution are obtained by analytical calculation.

SP426. **Bibliography of low energy electron and photon cross section data (through December 1974)**, L. J. Kieffer, *Nat. Bur. Stand. (U.S.), Spec. Publ. 426*, 219 pages (Mar. 1976) SD Catalog No. C13.10:426.

Key words: atom; collision cross section; detachment; dissociation; elastic scattering; electron; excitation; fluorescence; ion; ionization; molecule; photon; positron.

A bibliography of original reports of measurements or calculations of electron, positron and photon cross sections and their ions is presented. A detailed index to the bibliography allows retrieval of cross section data for specific processes and atomic or molecular species. A comprehensive author index is included. The bibliography covers the period 1921 through calendar year 1974 but some references late in 1974 may not have been found and included. No references were found prior to 1921.

SP427. **Secondary ion mass spectrometry.** Proceedings of a Workshop on Secondary Ion Mass Spectrometry and Ion Microprobe Mass Analysis, held at the National Bureau of Standards, Gaithersburg, Md., September 16-18, 1974, K. F. J. Heinrich and D. E. Newbury, Eds., Nat. Bur. Stand. (U.S.),

Key words: Auger electron spectroscopy; elemental depth profiling; ion microprobe mass analysis; ion optics; local thermal equilibrium (LTE); mineral analysis; secondary ion mass spectrometry (SIMS); surface analysis.

This book is the formal report of the Workshop on Secondary Ion Mass Spectrometry (SIMS) and Ion Microprobe Mass Analysis held at the National Bureau of Standards in September 1974. Invited and contributed papers cover a range of topics in the SIMS field: design of SIMS instrumentation; factors affecting secondary ion collection; techniques of reducing secondary ion mass spectra to yield quantitative compositional information; comparisons of SIMS with Auger electron spectroscopy (AES); techniques of obtaining elemental depth profiles and the instrumental and physical factors affecting such profiles; and applications of SIMS to the study of geological samples. The papers include both tutorial reviews and detailed reports on current research in SIMS. The volume should be of interest to all workers in the SIMS and surface analysis fields. *These proceedings include the following papers (indented):*

The ion microprobe—Instrumentation and techniques, H. Liebl, *SP427*, pp. 1-31 (Oct. 1975).

Looking at the collection efficiency problem through the ion microscope optics, G. Slodzian, *SP427*, pp. 33-61 (Oct. 1975).

High mass resolution secondary ion mass spectrometry, P. Williams and C. A. Evans, Jr., *SP427*, pp. 63-68 (Oct. 1975).

A comparison of mass spectra from three ion probes, J. G. Bradley, D. Y. Jerome, and C. A. Evans, Jr., *SP427*, pp. 69-77 (Oct. 1975).

A critical discussion of the local thermal equilibrium model for the quantitative correction of sputtered ion intensities, C. A. Andersen, *SP427*, pp. 79-119 (Oct. 1975).

An outline of secondary ion emission models, J. M. Schroeer, *SP427*, pp. 121-127 (Oct. 1975).

Empirical quantitation procedures in SIMS, J. A. McHugh, *SP427*, pp. 129-134 (Oct. 1975).

Application of SIMS microanalysis techniques to trace element and isotopic studies in geochemistry and cosmochemistry, J. F. Lovering, *SP427*, pp. 135-178 (Oct. 1975).

Factors that influence an elemental depth concentration profile, J. A. McHugh, *SP427*, pp. 179-189 (Oct. 1975).

A comparison of Auger electron spectroscopy (AES) and secondary ion mass spectrometry (SIMS), J. M. Morabito, *SP427*, pp. 191-224 (Oct. 1975).

SP428. Parts 1, 2, and 3. **Bibliography of infrared spectroscopy through 1960,** C. N. R. Rao, S. K. Dikshit, S. A. Kudchadker, D. S. Gupta, V. A. Narayan, and J. J. Comeford, *Nat. Bur. Stand. (U.S.), Spec. Publ. 428/1-3,* 2399 pages (Jan. 1976) SD Catalog No. C13.10:428/1-3.

Key words: bibliography; data; infrared; inorganic; minerals; ores; organic; polymers; spectroscopy.

This bibliography is based on a systematic search of the literature on infrared spectroscopy up to the end of 1960. It covers, directly or through abstract journals, 121 periodicals. As a general rule, any paper of interest in the field of infrared spectroscopy is included. Substance coverage is provided in four sections: organic compounds, inorganic compounds, polymeric compounds, and minerals and ores. Information provided includes: empirical formula, compound name, range of wavelengths reported, state of material, type of data presented in paper, and literature reference. Issued in three parts.

SP429. **Proceedings of the 7th Annual Conference of the National Conference of States on Building Codes and Standards,** S. A. Berry, Ed., Nat. Bur. Stand. (U.S.), Spec. Publ. 429, 129 pages (Sept. 1975) SD Catalog No. C13.10:429.

Key words: ASHRAE 90-P; building codes; mobile homes; NCSBCS.

The National Conference of States on Building Codes and Standards had its formal beginning in Wisconsin in 1967. Its formation represented a response by the States to recommendations for intergovernmental reforms in the area of building codes, prepared by the Advisory Commission on Intergovernmental Relations. The formative meeting held in Wisconsin was a direct outgrowth of an earlier exploratory meeting, involving several States, called by the National Bureau of Standards. At this meeting, the States represented discussed the idea of a national organization of the States similar to the National Conference of Weights and Measures, assisted by the National Bureau of Standards, leading to a cooperative solution regarding the multiple problems in the entire building regulatory system.

The Governor of Wisconsin issued an invitation to the States to gather in Wisconsin to address the problem, to develop an organization which could effectively respond to this national need, and to consider the offer of assistance of the National Bureau of Standards. Sixteen States attended this meeting and unanimously agreed to the formation of the NCSBCS and to accept the secretariat role of the National Bureau of Standards.

The Conference is structured to develop many technical and general recommendations in the field of comprehensive building code administration and its programs explore the entire system of this important segment of governmental regulatory service.

The secretariat of the National Conference of States on Building Codes and Standards located in the Office of Building Standards and Codes Services, Center for Building Technology, National Bureau of Standards, Washington, D.C. 20234.

SP430. **Household weights and measures,** Nat. Bur. Stand. (U.S.), Spec. Publ. 430, 2 pages (Sept. 1975) SD Catalog No. C13.10:430.

Key words: consumer metric information; International System of Units; kitchen measurement units; metric system; weights and measures.

This card presents weights and measures tables most useful for household (kitchen) purposes. It also introduces metric information for consumer use.

SP431. **Fourth international congress for stereology.** Proceedings of the Fourth International Congress for Stereology held at the National Bureau of Standards, Gaithersburg, MD, Sept. 4-9, 1975, E. E. Underwood, R. de Wit, and G. A. Moore, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 431,* 547 pages (Jan. 1976) SD Catalog No. C13.10:431.

Key words: stereology; stereometry; stereoscopy; stochastic models; structures; three-dimensional reconstruction.

These proceedings contain most of the papers presented at the technical sessions and workshops of the Fourth International Congress for Stereology, held at the National Bureau of Standards, Gaithersburg, Maryland, from 4-9 September 1975. Of the 113 papers recorded here, 10 are invited lectures, 66 are submitted papers, and 37 come from the six workshops. Three of these workshops containing 17 papers were integrated into the technical sections for these proceedings. Topics covered in the Technical Sections are Principles and Mathematical Developments, Pattern Recognition, Instrumentation, Three-dimensional Reconstruction, and Stereological Applications in Materials and Biology. Additional topics covered in the Workshops are Mathematical Foundations of Stereology, Particle Science, and Size Distributions. *These proceedings include the following papers (indented):*

On estimating aggregate and overall characteristics from thick sections by transmission microscopy, R. E. Miles, *SP431,* pp. 3-12 (Jan. 1976).

Computational methods in stereology, R. S. Anderssen and A. J. Jakeman, *SP431,* pp. 13-18 (Jan. 1976).

Estimation of linear functionals by maximum likelihood, W. L. Nicholson, *SP431,* pp. 19-24 (Jan. 1976).

The geometry and stereology of "Cubo-Spherical" particles, R. Warren, *SP431,* pp. 25-28 (Jan. 1976).

Quantitative microscopy of lineal features in three dimensions, R. T. DeHoff and S. M. Gehl, *SP431,* pp. 29-40 (Jan. 1976).

Connectivity of "Dispersed" particles: A probabilistic computation, G. A. Moore, *SP431,* pp. 41-44 (Jan. 1976).

Analytic results for the connectivity of dispersed particles, R. de Wit, *SP431,* pp. 45-48 (Jan. 1976).

Topological analysis of dendritic trees, M. Berry, *SP431,* pp. 49-54 (Jan. 1976).

Theoretical and experimental studies of the stereological properties of porosity, specific surface, and connectivity, R. B. Martin, *SP431,* pp. 55-58 (Jan. 1976).

Assessment of sampling errors in stereological analysis, J. E. Hilliard, *SP431,* pp. 59-67 (Jan. 1976).

On optimal forms for stereological data, A. J. Jakeman and R. S. Anderssen, *SP431,* pp. 69-74 (Jan. 1976).

Multivariate data analysis to describe intra- and intergranular relations in thin sections, W. Good, *SP431,* pp. 75-78 (Jan. 1976).

Correction of stereological parameters from biased samples on nucleated particle phases, L. M. Cruz-Orive, *SP431,* pp. 79-82 (Jan. 1976).

Stochastic models in stereology: Strength and weaknesses, J. P. Serra, *SP431,* pp. 83-86 (Jan. 1976).

A stereological view of data analysis, G. A. Moore and G. T. Eden, *SP431,* pp. 87-90 (Jan. 1976).

Three-dimensional shape parameters from planar sections, E. E. Underwood, *SP431,* pp. 91-92 (Jan. 1976).

Interpretation of some of the basic features of field-ion image projections from a hemispherical to a planar surface using Moire patterns, P. D. Ownby, R. M. Doerr, and W. Bollmann, *SP431,* pp. 93-98 (Jan. 1976).

Network simulation of connectivity and aggregate size in two-phase mixtures, W. D. Leahy and J. H. Steele, Jr., *SP431,* pp. 99-105 (Jan. 1976).

What can pattern recognition do for stereology?, G. C. Cheng, *SP431,* pp. 107-112 (Jan. 1976).

Theory and applications of imagery pattern recognition, C. H. Chen, *SP431,* pp. 113-116 (Jan. 1976).

A new, fast and storage-saving image analysis procedure for investigating individuals by a digital computer, M. Rink, *SP431,* pp. 117-120 (Jan. 1976).

System for computer input and processing of two-dimensional pictures, I. Krekule and M. Indra, *SP431,* pp. 121-122 (Jan. 1976).

Pattern recognition on the quantimet 720 image analyzing computer, K. E. Lawson, *SP431,* pp. 123-126 (Jan. 1976).

Recognition and classification of structure by means of stereological methods in neurobiology, G. Bernroider, *SP431,* pp. 127-132 (Jan. 1976).

Projectors in pattern recognition categories, M. Pavel, *SP431,* pp. 133-139 (Jan. 1976).

Automatic image analyzing instruments today, H. P. Hougardy, *SP431,* pp. 141-148 (Jan. 1976).

Texture analysis of stereological specimens, W. Hunn, *SP431,* pp. 149-154 (Jan. 1976).

A computerized image process for isolating individuals in an originally netted pattern, M. Rink, *SP431,* pp. 155-158 (Jan. 1976).

An image analysis system based on feature descriptors, R. R. A. Morton, *SP431,* pp. 159-162 (Jan. 1976).

Implications of recent advances in image analysis for stereological theory, H. Schmeisser, *SP431,* pp. 163-166 (Jan. 1976).

Experiences with optomanual automated evaluation-systems in biological research, especially in neuromorphology, H. Haug, *SP431,* pp. 167-172 (Jan. 1976).

A user-oriented automatic scanning optical microscope, J. E. Hilliard, *SP431,* pp. 173-176 (Jan. 1976).

The determination of particle shape and size distributions using automatic image analysis techniques, J. Slater and B. Ralph, *SP431,* pp. 177-180 (Jan. 1976).

Some shape functions for use in automatic image analysers for the classification of particulate materials, A. C. Terrell and R. J. Willes, *SP431,* pp. 181-184 (Jan. 1976).

Determination of particle size and shape distribution by automatic feature analysis, J. R. Schopper, *SP431,* pp. 185-188 (Jan. 1976).

Stereology and the automatic linear analysis of mineralogical materials, M. P. Jones and G. Barbery, *SP431,* pp. 189-19[illegible] (Jan. 1976).

A new opto-manual semi-automatic evaluation system, H. P[illegible] Rohr, *SP431,* pp. 193-195 (Jan. 1976).

Automated measurements for determination of the statistical nature of the distribution of inclusions in steel, G. A. Moore, *SP431,* pp. 197-198 (Jan. 1976).

Reconstruction from projections: A survey of applications, R. Gordon, *SP431,* pp. 201-202 (Jan. 1976).

Morphometric analysis of neurons in different depths of the cat's brain cortex after hypoxia, O. Hunziker, U. Schulz, C. Walliser, and J. Serra, *SP431,* pp. 203-206 (Jan. 1976).

Three-dimensional reconstruction from serial high voltage electron micrographs, L. D. Peachey, C. H. Damsky, and A. Veen, *SP431,* pp. 207-210 (Jan. 1976).

Determining three-dimensional intracellular structure data from scanning proton microscopy luminescence data, D. G. Oldfield, *SP431,* pp. 211-214 (Jan. 1976).

Artifacts in three-dimensional reconstruction from medical radiographic data, E. L. Hall, G. C. Huth, R. A. Gans, and I. S. Reed, *SP431,* pp. 215-218 (Jan. 1976).

Artificial stereo: A generalized computer algorithm for combining multi-channel image data, W. G. Pichel, R. L. Brower, D. R. Brandman, and R. J. Moy, *SP431,* pp. 219-220 (Jan. 1976).

Stereoscopic photomacrography and stereoscopic projection, Y. Fujimoto and Y. Ohta, *SP431,* pp. 221-222 (Jan. 1976).

Holographic methods for in-depth viewing of microscopic subjects, R. J. Schaefer and J. A. Blodgett, *SP431,* pp. 223-224 (Jan. 1976).

Evaluation of a new technique for determining the volume of the human left ventricle from one-plane radiographic measurements, R. Moore, I. Beranek, S. Kim, and K. Amplatz, *SP431,* pp. 225-228 (Jan. 1976).

Movie: Prim-9. Viewing high dimensional point clouds, J. W. Tukey, *SP431,* p. 229 (Jan. 1976).

Applications of quantitative microscopy in metal science, F. N. Rhines, *SP431,* pp. 233-244 (Jan. 1976).

Applications of stereological techniques to the quantitative characterization of wood microstructure, J. H. Steele, Jr., G. Ifju, and J. A. Johnson, *SP431,* pp. 245-256 (Jan. 1976).

Texture analyzer measurements and physical anisotropy of tropical woods, A. Mariaux, O. Peray, and J. Serra, *SP431,* pp. 257-260 (Jan. 1976).

Decision criteria in quality control of steel with respect to nonmetallic inclusions, S. Johansson, *SP431,* pp. 261-264 (Jan. 1976).

Automatic recognition of nonmetallic stringers in steel, D. Jeulin and J. Serra, *SP431,* pp. 265-268 (Jan. 1976).

Metallographic characterization of fracture surface profiles on sectioning planes, J. R. Pickens and J. Gurland, *SP431,* pp. 269-272 (Jan. 1976).

The equivalent foil thickness principle, S. M. El-Soudani, *SP431*, pp. 273-276 (Jan. 1976).

Stereological method for estimating relative membrane surfaces in freeze-fracture preparations, E. R. Weibel, G. A. Losa, and R. P. Bolender, *SP431*, pp. 277-280 (Jan. 1976).

Application of various stereological methods to the study of the grain and the crack structure of concrete, P. Stroeven, *SP431*, pp. 281-286 (Jan. 1976).

The use of quantitative metallography and stereological methods to describe composite materials, J. L. Chermant and M. Coster, *SP431*, pp. 287-290 (Jan. 1976).

A definition of the two-dimensional size of irregular bodies, G. M. Timčák, *SP431*, pp. 291-294 (Jan. 1976).

Stereometric microstructure and properties of two-phase materials, G. Ondracek, *SP431*, pp. 295-298 (Jan. 1976).

Use of mathematical morphology to estimate comminution efficiency, P. Cauwe, *SP431*, pp. 299-303 (Jan. 1976).

Microscopy, radial distribution analysis, and sortability, R. M. Doerr, *SP431*, pp. 305-308 (Jan. 1976).

Size distribution analysis in situ on individual or interconnected phases by image analyses, C. Gateau and J. M. Prévosteau, *SP431*, pp. 309-314 (Jan. 1976).

Stereological determination of the proportional volume of dendrites in cast iron by measuring plan micrographs, R. Wlodawer, *SP431*, pp. 315-318 (Jan. 1976).

Morphometry, stereometry and stereology applied to cancer development in the large intestine of man, H. Elias, D. Bokelmann, and R. Vögtle, *SP431*, pp. 321-326 (Jan. 1976).

Analysis of the heterogeneous composition of central nervous tissue, S. Eins and J. R. Wolff, *SP431*, pp. 327-330 (Jan. 1976).

Stereological analysis of the heterogeneous composition of central nervous tissue: Synapses of the cerebral cortex, J. R. Wolff, *SP431*, pp. 331-334 (Jan. 1976).

The development of myelinated fibers in the visual cortex of cats, H. Haug, *SP431*, pp. 335-336 (Jan. 1976).

The volumes of elastic tissue and smooth muscle cells in the arterial wall, V. Levický, *SP431*, pp. 337-340 (Jan. 1976).

Progress, success and problems in applying stereology in biological research, E. R. Weibel, *SP431*, pp. 341-350 (Jan. 1976).

Hexachlorobenzene-induced smooth endoplastic reticulum in rat liver: A correlated stereologic and biochemical study, T. Kuiper-Goodman, D. Kreweski, H. Combley, M. Doran, and D. L. Grant, *SP431*, pp. 351-354 (Jan. 1976).

Automated measurement of airspaces in lungs from dogs chronically exposed to air pollutants, D. Hyde, A. Wiggins, D. Dungworth, W. Tyler, and J. Orthoefer, *SP431*, pp. 355-358 (Jan. 1976).

Volumetric determinations of cells and cell organelles from two-dimensional transsections, L. G. Lindberg, *SP431*, pp. 359-362 (Jan. 1976).

Morphometric analysis of thymic cells during murine radioleukemogenesis, J. Boniver, R. Courtoy, and L. J. Simar, *SP431*, pp. 363-366 (Jan. 1976).

Studies on the partially-oriented surfaces of skeletal muscle mitochondria, N. T. James and G. A. Meek, *SP431*, pp. 367-370 (Jan. 1976).

Determination of the number of cells with multiple nucleoli in histological sections, A. Schleicher, H. J. Kretschmann, F. Wingert, and K. Zilles, *SP431*, pp. 371-374 (Jan. 1976).

Combined light and electron microscopy of serially sectioned cells and tissues, Y. Collan, *SP431*, pp. 375-378 (Jan. 1976).

Morphometric "organelle profiles" as metabolic indicators, S. Malamed and L. C. Zoller, *SP431*, pp. 379-384 (Jan. 1976).

A quantitative analysis of some ultrastructural aspects of seed development, C. E. Hughes and L. G. Briarty, *SP431*, pp. 385-388 (Jan. 1976).

The brain as a "stereological device," T. Radil-Weiss and J. Radilová, *SP431*, pp. 389-391 (Jan. 1976).

Stereological analysis of neural organogenesis in the chick embryo, O. Mathieu and P. E. Messier, *SP431*, pp. 393-396 (Jan. 1976).

Application of stereological methods to the study of preimplantation embryogenesis in mice, R. L. Deter, *SP431*, pp. 397-400 (Jan. 1976).

The determination of size distribution on lymphoblasts in acute leukemia, E. Feinermann and G. A. Langlet, *SP431*, pp. 401-404 (Jan. 1976).

A morphometric study of human placentae of different gestational ages from normal and triplet pregnancies, I. Bhargava, K. Kamashki, and Y. Dodge, *SP431*, pp. 405-408 (Jan. 1976).

The effects of optical resolution on the estimation of stereological parameters, H. J. Keller, H. P. Friedli, P. Gehr, M. Bachofen, and E. R. Weibel, *SP431*, pp. 409-410 (Jan. 1976).

Quantification of rarely occurring structures in electron microscopy, U. Pfeifer, *SP431*, pp. 411-414 (Jan. 1976).

The morphometry and stereology of cerebral arterial bifurcations, P. B. Canham, J. G. Walmsley, and J. F. H. Smith, *SP431*, pp. 415-418 (Jan. 1976).

Karyo-interkaryometry as a periodic control for clinical prognosis, E. C. Craciun and C. Tasca, *SP431*, pp. 419-422 (Jan. 1976).

Nucleic acids content-nuclear volume correlation as a quantitative parameter in cellular malignancy, C. Tasca and E. C. Craciun, *SP431*, pp. 423-426 (Jan. 1976).

Is there an unrecognized systematic error in the estimation of surface density of biomembranes?, A. Reith and T. Barnard, *SP431*, pp. 427-428 (Jan. 1976).

Quantitative studies with the optical and electronic microscope of the pathological cells of the acute leukemia and chronic lymphocytic leukemia, J. L. Binet, P. Debré, P. d'Athis, D. Dighiero, and F. de Montaut, *SP431*, p. 429 (Jan. 1976).

Simple devices for stereology and morphometry, H. Elias and E. Botz, *SP431*, pp. 431-434 (Jan. 1976).

The edema syndrome in motion pictures, O. C. Jaffee, *SP431*, p. 435 (Jan. 1976).

Overview, R. T. DeHoff, *SP431*, pp. 439-443 (Jan. 1976).

Probabilistic foundations of stereology, R. E. Miles and P. Davy, *SP431*, pp. 443-445 (Jan. 1976).

Volume fraction analysis, H. E. Exner, *SP431*, pp. 446-448 (Jan. 1976).

Surface area, E. R. Weibel, *SP431*, pp. 448-455 (Jan. 1976).

Length of lineal features in space, R. T. DeHoff, *SP431*, pp. 455-457 (Jan. 1976).

The area tangent count and the total curvature, R. T. DeHoff, *SP431*, pp. 457-459 (Jan. 1976).

Granulometry for isolated particles or connected media, J. Serra, *SP431*, pp. 460-461 (Jan. 1976).

Statistics of measurement, W. L. Nicholson, *SP431*, pp. 461-464 (Jan. 1976).

Introduction remarks, B. H. Kaye, *SP431*, pp. 467-468 (Jan. 1976).

Stereology and particle technology, H. E. Exner, *SP431*, pp. 469-470 (Jan. 1976).

Representation of particle size and shape, B. Scarlett, *SP431*, pp. 471-47 6(Jan. 1976).

The application of stereology to particle technology, B. Scarlett and P. J. Lloyd, *SP431*, pp. 477-482 (Jan. 1976).

Techniques for particle measurement using image analysis, R. R. A. Morton, *SP431*, pp. 483-486 (Jan. 1976).

Microscopic characterization of fine powders, P. Ramakrishnan, *SP431*, pp. 487-490 (Jan. 1976).

Stereology of paint films, B. H. Kaye and I. Robb, *SP431*, pp. 491-492 (Jan. 1976).

Concluding remarks, B. H. Kaye, *SP431*, p. 493 (Jan. 1976).

Estimation of linear properties of spherical bodies in thin foils from their projections, F. Piefke, *SP431*, pp. 497-498 (Jan. 1976).

On size distribution methods, F. A. L. Dullien and K. S. Chang, *SP431*, pp. 499-502 (Jan. 1976).

Size distribution of retained austenite phase in a quenched stainless steel, A. V. Samudra and O. Johari, *SP431*, pp. 503-506 (Jan. 1976).

Analysis of a set of spherical cells relative to their volume, P. d'Athis, *SP431*, pp. 507-508 (Jan. 1976).

Appendix—Basic stereology, E. E. Underwood, *SP431*, pp. 509-512 (Jan. 1976).

SP432. **NBS time and frequency dissemination services,** S. L. Howe, Ed., (Supersedes NBS Special Publication 236, 1974 and previous editions), *Nat. Bur. Stand. (U.S.), Spec. Publ. 432*, 32 pages (Jan. 1976) SD Catalog No. C13.10:432.

Key words: broadcast of standard frequencies; frequency calibration; high frequency; low frequency; standard frequencies; television color subcarrier; time calibration; time signals.

Detailed descriptions are given of the time and frequency dissemination services of the National Bureau of Standards. These services include the broadcasts from radio stations WWV, WWVH, WWVB, and WWVL, and new time and frequency calibration services using television. This publication shows the services available on January 1, 1976. It will be updated only when the services are revised or when new services are added. A list of other publications available about the Time and Frequency Division is also included.

SP433. **MFPG—Success by design: Progress through failure analysis.** Proceedings of the 21st Meeting of the Mechanical Failures Prevention Group, held at the National Bureau of Standards, Gaithersburg, MD, Nov. 7-8, 1974, T. R. Shives and W. A. Willard, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 433*, 229 pages (July 1976) SD Catalog No. C13.10:433.

Key words: design; engineering education; failure analysis; failure analysis case histories; failure prevention; reliability; safety.

These Proceedings consist of a group of twenty-two submitted papers and discussions from the 21st meeting of the Mechanical Failures Prevention Group which was held at the National Bureau of Standards in Gaithersburg, Maryland on November 7-8, 1974. The central theme of the Proceedings was improvement in design through failure analysis. Emphasis was on design philosophy, the use of failure analysis case studies as an educational tool, successful redesign through failure analysis, and design oversights. *These proceedings include the following papers (indented):*

Creative student engineering design, P. S. De Jong, *SP433*, pp. 3-5 (July 1976).

The designer's contribution in the development of new products, J. J. Lesko, *SP433*, pp. 7-14 (July 1976).

Successful redesign and launch performance of the ERTS/Nimbus adapter after an acceleration test failure, V. T. Sweet and W. B. Keegan, *SP433*, pp. 19-72 (July 1976).

Agricultural equipment for underdeveloped countries, C. W. Suggs, *SP433*, pp. 74-81 (July 1976).

Safety success through design, D. W. Logan, *SP433*, pp. 83-87 (July 1976).

Reliability, pollutants and aluminum raw material, V. D. Matney, *SP433*, pp. 89-101 (July 1976).

Rotor burst protection program, G. J. Mangano, *SP433*, pp. 103-119 (July 1976).

Airframe "crashworthiness" experiments, N. N. Shapter, *SP433*, pp. 122-128 (July 1976).

Redesign and assembly of anti-friction bearing housings for improved life, G. D. Xistris and D. C. Watson, *SP433*, pp. 131-142 (July 1976).

Case history of failures in a hammer mill, J. K. L. Baja, *SP433*, pp. 144-158 (July 1976).

Solution of an art restoration problem, E. Passaglia, *SP433*, pp. 159-161 (July 1976).

Elimination of failures of U-bolts in farm tractor dual wheel, B. P. Bardes, *SP433*, pp. 164-165 (July 1976).

Structural in-flight wing failures, M. L. Marx, *SP433*, pp. 166-177 (July 1976).

Use of cases in engineering education—Their special value, F. O. Fuchs, *SP433*, pp. 180-182 (July 1976).

What can be learned from cases, G. Kardos, *SP433*, pp. 183-187 (July 1976).

Student written design case studies, C. O. Smith, *SP433,* pp. 188-190 (July 1976).

Teacher feedback on the use of engineering case studies, B. J. Pelan, *SP433,* pp. 192-198 (July 1976).

Some thermal problems in the design of fluid film bearings, D. D. Fuller, *SP433,* pp. 205-211 (July 1976).

Never overlook notches, C. O. Smith, *SP433,* pp. 212-213 (July 1976).

Innovation or reliability, H. O. Fuchs, *SP433,* pp. 214-215 (July 1976).

The "model" designer, R. E. Maringer, *SP433,* pp. 216-217 (July 1976).

The misuse of tensile strength as a design parameter, T. J. Dolan, *SP433,* pp. 218-219 (July 1976).

Inspection consideration at the design stage, J. F. Erthal, *SP433,* p. 222 (July 1976).

SP434. **Hydrocarbons for fuel—75 years of materials research at NBS,** G. T. Armstrong, *Nat. Bur. Stand. (U.S.), Spec. Publ. 434,* 20 pages (May 1976) SD Catalog No. C13.10:434.

Key words: coal; energy; fuel; graphite; hydrocarbons; metering; methane; natural gas; petroleum; physical properties; standard reference materials.

In this historical review the NBS work on hydrocarbons is discussed in terms of the three major classes of natural hydrocarbonaceous fuels: natural gas, petroleum, and coal. The work done on the measurement of properties of the pure components has included measurement of the values of the properties themselves and development of practical and accurate measurement procedures and instruments. In addition, combustion energies, densities, viscosities, vapor pressures, refractive indices, elemental compositions and other parameters have been determined for complex fuel mixtures and correlated to find methods of estimating properties. Extensive standard reference data tables have been compiled and a number of standard reference materials have been developed.

SP435. **Laser induced damage in optical materials: 1975.** Proceedings of a Symposium sponsored by: National Bureau of Standards, American Society for Testing and Materials, Office of Naval Research, Energy Research and Development Administration, NBS Boulder, CO, July 29-31, 1975, A. J. Glass and A. H. Guenther, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 435,* 437 pages (Apr. 1976) SD Catalog No. C13.10:435.

Key words: avalanche ionization; IR windows and mirrors; laser damage; laser materials; multiphoton processes; self-focusing; thin films.

The Seventh ERDA-ASTM-ONR-NBS Symposium on Laser Induced Damage in Optical Materials was held at the National Bureau of Standards in Boulder, Colorado, on July 29-31 of this year. These Symposia are held as part of the activities in Subcommittee II on Lasers and Laser Materials, of the ASTM. Subcommittee II is charged with the responsibilities of formulating standards and test procedures for laser materials, components, and devices. The Chairman of Subcommittee II is Haynes Lee, of Owens-Illinois, Inc. Co-chairmen for the Damage Symposia are Dr. Arthur Guenther, Chief Scientist of the Air Force Weapons Laboratory, and Dr. Alexander J. Glass, Head, Theoretical Studies, Y Division, Lawrence Livermore Laboratory.

Over 150 attendees at the Symposium heard 42 papers on topics relating fabrication procedures to laser induced damage in optical materials; on metal mirrors; in infrared window materials; the multipulse, wavelength and pulse length dependence of damage thresholds; damage in dielectric films and at exposed surfaces; as well as theoretical discussions on avalanche ionization and multiphoton processes of importance at shorter wavelengths. Of particular importance was the sealing relations developed from several parametric studies relating fundamental properties (refractive index, surface roughness, etc.) to the damage threshold. This year many of the extrinsic influences tending to reduce a material damage resistance were isolated such that a measure of its egregious nature could be quantified. Unfortunately, it was evident that much still needs to be accomplished to improve processing and fabrication procedures to allow a measurable approach to a materials intrinsic strength to be demonstrated. *These proceedings include the following papers (indented):*

Fabrication of laser optics at Lawrence Livermore laboratory, N. J. Brown, *SP435,* pp. 3-9 (Apr. 1976).

Key words: chamfering; continuous polishing; grinding; metal polishing; optical fabrication.

This paper summarizes fabrication techniques in use at Lawrence Livermore Laboratory for laser discs, windows, and mirrors, and polishing techniques used with metal surfaces.

Standard industrial polishing of high energy laser optics, W. J. Spawr, *SP435,* pp. 10-13 (Apr. 1976).

Key words: copper; molybdenum; optician; polishing; surfaces; zinc selenide.

The polishing and figuring of optical materials to produce state-of-the-art surface quality is truly an art, a scientific art, but an art nonetheless.

To attain success, the optician must have a clear mental model of the processes and associated techniques, and use this model as his most important tool. Second only to that is the combination of discipline and determination that no harmful or deleterious influences are allowed to effect the processes. New sophisticated polishing machines used in "Metrology Laboratory" environments are of little or no assistance. Polishing machines built 50 years ago work as well as the latest designs.

Today, moderately skilled technicians routinely produce 30 Å RMS surfaces on copper, molybdenum, and zinc selenide. These surfaces are free of orange peel, scratches, and digs; and are produced on conventional polishing machinery. Such surfaces are shown to exhibit exceedingly high laser damage thresholds from 1.06 to 10 μm. This is accomplished on a daily basis in a time frame comparable to the commercial polishing of ordinary optical glasses.

Ion planing and coating of sodium chloride, R. A. Hoffman, W. J. Lange, and W. J. Choyke, *SP435,* pp. 14-19 (Apr. 1976).

Key words: arsenic trisulphide; ion planing; protective films; moisture resistance; sodium chloride.

Ion planing of single crystal sodium chloride, using low energy Xe ions at grazing incidence, is effective in removing scratches from surfaces when the sample is rotated. Surface features which develop, probably due to defects such as polishing grit and dislocations, can be minimized and the scratches eliminated by optimizing the amount of material removed. Ion planing and depositing overcoating films "in situ" greatly improves film adherence and protection of sodium chloride substrates against moisture attack.

Polishing studies and backscatter measurements on alkali-halide windows, M. J. Soileau, H. E. Bennett, J. M. Bethke, and J. Shaffer, *SP435*, pp. 20-28 (Apr. 1976).

Key words: alkali-halide; KCl; laser windows; optical figure; polishing; scattered light; surface absorption.

Surface absorption, optical figure, and optical scatter from windows are particularly important in high energy lasers. Surface absorption can result in window failure due to thermal distortion and in some cases catastrophic failure. Excellent optical figure is required for each component in the laser system optical train in order to maintain maximum on axis intensity of the focused laser beam. Backscatter from windows and other optical components can cause depumping of the active medium, and in the case of amplified chains, catastrophic damage to the laser amplifiers. A technique for polishing alkali-halide and quantitative measurements of backscatter for alkali-halide windows from the visible to 10.6 μm will be presented. This polishing procedure produces alkali-halide surfaces which have less than 1×10^{-4} surface absorption, are parallel to less than 3 seconds of arc and are flat to better than a quarter wave in the visible. Scattering levels below 10^{-4} at 10.6 μm have been achieved.

1.06 μm 150 psec laser damage study of diamond turned, diamond turned/polished and polished metal mirrors, T. T. Saito, D. Milam, P. Baker, and G. Murphy, *SP435*, pp. 29-40 (Apr. 1976).

Key words: copper mirror; damage threshold; dark field photography; diamond turned optics; 1.06 μm polishing.

Using a well characterized 1.06 μm 150 psec glass laser pulse we have studied the damage characteristics for diamond turned, diamond turned/polished, and polished copper and silver mirrors less than 5 cm diameter. Although most samples were tested with a normal angle of incidence, some were tested at 45° with different linear polarization showing an increase in damage threshold for S polarization. Different damage mechanisms observed will be discussed. Laser damage is related to residual surface influence of the fabrication process. Our first attempts to polish diamond turned surfaces resulted in a significant decrease in laser damage threshold. The importance of including the heat of fusion in the one dimensional heat analysis of the theoretical damage threshold and how close our samples came to the theoretical damage threshold will be discussed.

Pulsed laser damage to uncoated metallic reflectors, I. Goldstein, D. Bua, and F. A. Horrigan, *SP435*, pp. 41-48 (Apr. 1976).

Key words: angle of incidence; polarization; pulsed laser damage; thermal model.

Threshold damage measurements were made on a variety of polished bulk copper and thin gold film reflectors using a TEM_{00} mode Q-switched Nd:YAG laser. Results correlate well with a simple thermal model based on the assumed existence of a critical surface temperature. Direct confirmation of this thermal model was obtained through systematic variations of the polarization and angle of incidence of the incident laser beam and calorimetric measurements of the surface optical absorption coefficients. The "Damage Threshold" was defined through a careful procedure of attenuating the incident beam and varying all parameters (e.g., focus, position on the surface) until the sample no longer could be "damaged" as assessed visually with a microscope. In one striking case the damage threshold of two "identical" samples was shown to correlate with the measured surface absorption and not with the visual surface quality.

The implications of these results to the design of high power optical systems which use large angles of incidence (e.g., axicon or toric optical elements) are discussed. In particular, for the polarization associated with Brewster's phenomenon the damage threshold was found to remain constant over wide variations of the angle of incidence, e.g., from 0 to 70° or 80°.

Diamond-turned mirrors, H. E. Bennett, M. J. Soileau, and P. C. Archibald, *SP435*, pp. 49-56 (Apr. 1976).

Key words: diamond turning; laser damage; metal mirrors; micromachining; optical figure; scattered light.

Diamond-turned, micromachined metal mirrors offer a new approach to optical fabrication and may have significant advantages for use as laser components. A laser mirror must have (1) excellent optical figure, (2) low scattered light, (3) high reflectance, (4) high damage threshold, and (5) good environmental resistance. We have measured optical figures as good as 1/20th wave over a 3.86-cm diameter sample and better than a wave over a 10.2-cm diameter sample on micromachined mirrors produced by Oak Ridge National Laboratories. Scattered light levels in the infrared can be as low or lower than those obtained on conventional mirrors and values as low as 2×10^{-5} have been observed at a wavelength of 10.6 μm. Infrared reflectance values as high or higher than those of conventional evaporated or sputtered coatings have been achieved and one mirror had an absorption at 10.6 μm of 0.006. The laser damage threshold of micromachined mirrors may well be higher than that obtainable by other techniques, but this question and the environmental resistance and "coatability" of a micromachined surface require further investigation.

Results of optical measurements of surface quality and figure of diamond-turned mirrors, R. E. Sladky and R. H. Dean, *SP435*, pp. 57-65 (Apr. 1976).

Key words: blur circle; circular diffraction grating; diamond-turned mirrors; diffraction pattern; machine cusp; scattered light; surface figure.

During the past year, the Oak Ridge Y-12 Plant has diamond turned mirrors for the LASL High-Energy Laser and for other projects. The largest of these mirrors are flat, elliptical in shape, and 654 mm (25.5 in) on the major axis and 394 mm (15.5 in) on the minor axis. The concave mirrors are 394 mm OD. These mirrors were inspected for surface finish and figure. Results of this work will be summarized. In addition, blur circle was measured. Measurements of scattered light have also been made. In some cases, the diffraction pattern was related to the waves formed in the surface by the machining process. This information has been useful to the engineers doing research on the diamond turning of laser materials.

Dielectric coated diamond turned mirrors, J. R. Buckmelter, T. T. Saito, R. Esposito, L. P. Mott, and R. Standlund, *SP435*, pp. 66-74 (Apr. 1976).

Key words: adherence; diamond machining; dielectric mirror; electroplating; laser damage resistance; stress relief.

Adherence of multilayer dielectric enhanced mirror coatings to diamond turned metallic surfaces was discovered to be a problem. Initial coating results demonstrated peeling and erratic optical properties for a variety of coating designs deposited on ERDA diamond turned copper, silver, and gold. The same coating designs deposited on polished molybdenum had excellent adherence and consistent optical properties. The adherence problem was determined to derive from two factors intimately connected

with the diamond turning process, namely, oil adsorption and stress in the electroplated metal surface. These factors can be eliminated by stress relief in a heated oil bath followed by thorough clening in freon or trichloroethylene prior to coating. Procedures used to investigate dielectric coated diamond turned mirrors included absorption calorimetry, damage measurements with a 10 kW laser and Auger Spectroscopy.

Slide-position errors degrade machined optical component uality, J. B. Arnold, P. J. Steger, and R. R. Burleson, *SP435*, p. 75-89 (Apr. 1976).

Key words: controlled environment; diamond machining; machined optics; nondistortion part support; position errors; quality and compatible part material; quality diamond tools.

An ultraprecision lathe is being developed at the Oak Ridge Y-12 Plant to fabricate optical components for use in high-energy laser sytems. The lathe has the capability to produce virtually any shape mirror which is symmetrical about an axis of revolution. Two basic types of mirrors are fabricated on the lathe; namely, (1) the mirrors which are machined using a single slide motion (such as flats and cylinders), and (2) the mirrors which are produced by two-coordinated slide motions (such as hyperbolic reflectors; large, true-radius reflectors, and other contoured-surface reflectors). The surface-finish quality of typical mirrors machined by a single axis of motion is better than 13 nm, peak to valley, which is an order of magnitude better than the surface finishes of mirrors produced by two axes of motion. Surface finish refers to short-wavelength-figure errors that are visibly detectable. The primary cause of the inability to produce significantly better surface finishes on contoured mirrors has been determined as positional errors which exist in the slide positioning systems. The correction of these errors must be accomplished before contoured surface finishes comparable to the flat and cylinder can be machined on the lathe.

Ultrasonic cleaning of optical surfaces, W. E. K. Gibbs and A. D. McLachlan, *SP435*, pp. 90-97 (Apr. 1976).

Key words: laser damage; metal mirrors; subsurface structure; ultrasonic cleaning.

During the formal proceedings of the 1975 Symposium on Laser Induced Damage in Optical Materials, Dr. A. H. Guenther presented some recent results on the degradation of polished optical surfaces by ultrasonic cleaning procedures. This information was supplied to him by Dr's. W. E. K. Gibbs and A. D. McLachlan of the Materials Research Laboratories of the Department of Defense, Commonwealth of Australia. Materials studied included OFHC copper, beryllium copper, zirconium copper, stainless steel, kanigen and fused quartz. Results indicate that ultrasonic cleaning degrades polished surfaces, and if the cleaning process is vigorous enough for a sufficient duration of time, subsurface fracture introduced in the grinding process is made quite evident. At the conclusion of the transmission of this correspondence, a discussion on the subject of ultrasonic cleaning ensued.

Thermal diffusivity of germanium gallium arsenide and cadnium telluride over the temperature range 80 K-900 K, R. Doussain, H. P. le Bodo, *SP435*, pp. 98-106 (Apr. 1976).

Key words: cadmium telluride; gallium arsenide; germanium; laser flash method; laser windows; thermal diffusivity.

The laser flash technique was used to determine the thermal diffusivity of germanium, gallium arsenide and cad um telluride over the temperature range 80 K-1000 K. The main features of the experimental equipment are described. Values of thermal diffusivity (80-900 K) are reported.

Damage to 10.6 μm window materials due to CO_2 TEA laser pulses, K. M. Leung, M. Bass, and A. G. J. Balbin-Villaverde, *SP435*, pp. 107-117 (Apr. 1976).

Key words: KCl; NaCl; pulsed CO_2 TEA laser damage; transmitted pulse; waveform distortion; ZnSe.

Laser irradiation induced damage to several materials of interest for use as 10.6 μm laser system windows was studied. A pulsed CO_2 TEA laser, operating in the TEM_{00} mode was the irradiation source in these experiments. The light was focused onto the surfaces or into the bulk of the samples and the waveform of the transmitted pulse was monitored. Comparison of the incident and transmitted laser pulse waveforms shows the onset of laser induced damage as a distortion of the latter. Damage threshold data and a discussion of possible damage mechanisms for improved ZnSe, commercial and RAP grown KCl, and commercial NaCl are presented.

Improvements in the breakdown threshold in alkali halides at 10.6 μm, V. Wang, C. R., Giuliano, S. D. Allen, and R. C. Pastor, *SP435*, pp. 118-125 (Apr. 1976).

Key words: alkali halides; bulk damage; longitudinal mode control; pulsed 10.6 μm laser damage; RAP materials; transmitted pulse cutoff; variable pulse duration.

Evidence has been found that the threshold for laser-induced breakdown in the bulk of single crystals is strongly dependent upon processing. Potassium bromide, KCl, and NaCl have been examined over a range of pulse widths (from 0.2 μs to 6 μs) in selected cases and for a variety of pulse shapes using both single longitudinal mode and partially mode-locked multilongitudinal mode pulses. A breakdown threshold of over 12 GW/cm^2 (2.5 MV/cm) for KCl far exceeds the best values obtained in previously available commercial material at these pulse lengths. A comparison of breakdown threshold for conventional and reactive atmosphere processed (RAP) halides is made with comment upon the present ambiguities in breakdown mechanism. In addition to the measurement of damage thresholds of materials from different sources, the temporal profile of transmitted pulses at the time of damage was monitored.

Optical distortion by laser heated windows, J. S. Loomis and E. G. Bernal, *SP435*, pp. 126-141 (Apr. 1976).

Key words: infrared lasers; interferometry; stress birefringence; thermal distortion; windows.

The optical distortion introduced in a collimated He-Ne beam by windows irradiated with a CO_2 laser has been measured interferometrically. Materials measured included ZnSe, KCl, NaCl, CaF_2, SrF_2, and BaF_2. Flux densities from the CO_2 laser were in the range 10-60 KW/cm^2 with total powers from 250 to 1000 watts for the ZnSe and the halides. The changes in the interferometric patterns observed can be attributed to a) isotropic phase shifts proportional to the local temperature, b) anisotropic effects due to induced birefringence that affect both the symmetry of the interferometric pattern and the visibility of the fringes, c) localized phase shifts at the entrance and exit points due to surface absorption.

An analysis of the experimental observations is given using a scalar optics approach and temperature rise functions derived previously by the authors. Experimental comparisons of thermal sensitivity of various materials are given. Also, the relative value of the anisotropic changes in optical path as the window aperture is filled at constant flux density is calculated. This result allows the prediction of window behavior in large lasers from the results of interferometric tests with focused beams of the same flux density.

Thermal distortion studies of ZnSe windows by far field irradiance measurements, J. A. Detrio and R. D. Petty, *SP435*, pp. 142-147 (Apr. 1976).

Key words: far field intensity; laser windows; thermal distortion; thermal lensing; ZnSe.

We have experimentally measured the effect of thermal lensing in ZnSe windows on the far field irradiance (at 10.6 μm) as a function of input power and absorption coefficient. These preliminary measurements are compared to the theoretical predictions of the figures of merit analysis. The undesirable effect produced by interference between reflections from the sample faces is successfully minimized by the use of wedged samples and ratiometric detection techniques. Beam slewing, which may also mask the desired data, is minimized by the use of a scanning slit at a primary mirror focus and a detector preceded by a diffuser and integrating sphere.

Spectral emittance measurements with a cryogenically cooled instrument, D. L. Stierwalt, *SP435*, pp. 149-156 (Apr. 1976).

Key words: cryogenically cooled; spectral emittance.

We have been measuring spectral emittance of laser window materials for several years. The sensitivity of our apparatus was limited not by detector noise, but by background fluctuations caused by minute fluctuations in the temperature of the instrument. Because of this limitation a new instrument has been built which operates at 77°K. This greatly reduces the background radiation and allows us to take advantage of the higher sensitivity of a cooled detector. This instrument covers the spectral region from 2.5 to 14.0 microns with a spectral resolution of about 1-1/2 percent. The noise equivalent absorption coefficient appears to be about 10^{-6} cm^{-1} at 10.6 microns and about 10^{-5} cm^{-1} at 5.0 microns.

Several samples of NaF, NaCl, and KBr have been measured at temperatures from 200°K to 373°K. A number of bands were observed in these samples, some of which have been previously reported and some have not. These spectra will be presented as well as a description of the instrument.

Surface studies with acoustic probe techniques, J. H. Parks and D. A. Rockwell, *SP435*, pp. 157-163 (Apr. 1976).

Key words: acoustic probe techniques; infrared window laser absorption; KCl absorption; laser induced damage; surface absorption.

A new measurement technique will be discussed which utilizes acoustic surface waves to detect the surface depth dependence of radiative absorption. This will include a theoretical analysis of the detection process which relates these measurements to a quantitative model of surface absorption phenomena. This technique is generally applicable to study weak surface absorption at wavelengths for which a material is essentially transparent. Surface wave phase variations induced by the absorption of 10.6 μm radiation have been measured on KCl surfaces with a laser pulse energy of only ~50 mJ. The surface absorption σ of these samples were measured by calorimetry to be $\sigma \sim 2\times10^{-4}$, and acoustic probe measurements on the same samples yielded $\sigma \sim 1\times10^{-4}$. Initial results of recent studies on both polished and etched alkali halide surfaces are discussed.

Photoelastic constants of infrared materials, A. Feldman, D. Horowitz, and R. M. Waxler, *SP435*, pp. 164-169 (Apr. 1976).

Key words: birefringence; germanium; KCl; refractive index; single crystal; stress optic constants.

Optical distortion occurs in infrared laser windows due to thermal gradients established by the absorption of high power radiation. Principal sources of distortion are the stresses produced by the thermal gradients. Because of the photoelastic effect, these stresses, which vary from point-to-point in the material, produce changes in the refractive index. We are measuring the photoelastic constants of infrared window materials. The measurements employ null techniques which have several advantages over other techniques that have been employed in the past. We present data obtained on Ge, reactive atmosphere processed (RAP) KCl, and KCl doped with KI.

Refractive index and temperature coefficient of index of CVD zinc selenide, M. J. Dodge and I. H. Malitson, *SP435*, pp. 170-174 (Apr. 1976).

Key words: refractive index; temperature coefficient of refractive index; zinc selenide.

The refractive index of each of two prismatic samples of CVD ZnSe was measured from 0.5086 to 18.2 μm by means of the minimum-deviation method on a precision spectrometer. Data were obtained at temperatures near 20 and 34 °C and each set of data was fitted to a three-term Sellmeier-type dispersion equation, which permits refractive index interpolation within several parts in 10^{-5}. Using the data obtained at the two temperatures, dn/dT was calculated for both samples. A comparison of refractive index and dn/dT is made with other types of ZnSe.

Laser window test facility, J. L. Zar, *SP435*, pp. 175-188 (Apr. 1976).

Key words: diamond absorption coefficient; laser window heating; laser window testing; Type II diamond windows.

A test facility has been constructed for testing laser window material. This utilizes the focused beam from a 15 kW CW laser at 10.6 μm or other available lasers. Provision for cooling the window is included and also instrumentation for measuring optical and mechanical effects.

The irradiated area may be varied by positioning the specimen. The beam profile is very close to Gaussian. The intensity and beam profile is given as a function of diameter and distance from the focus.

Forty-seven natural diamonds have been tested to find the correlation between the UV absorption spectrum, the IR absorption spectrum and the absorption coefficient β at 10.6 μm. Transparency at 0.253 μm is roughly correlated with low values of β. A water cooled diamond window holder is also described.

Optical material damage from 10.6 μm CW radiation, C. A. Huguley and J. S. Loomis, *SP435*, pp. 189-201 (Apr. 1976).

Key words: CO_2 laser radiation; Cu; CW laser damage; grating; infrared windows; KCl; mirror; Mo; NaCl; window; ZnSe.

Damage studies of a variety of optical materials including KCL, SnSe, NaCl, Mo, and Cu substrates were conducted. Most of the samples were substrates with optical coatings, and several were gratings. Typically, a rectangular grid of thirty irradiation sites was used. An analysis of damage thresholds was accomplished.

10.6 μm component damage from a 20 μsec rapidly pulsed laser, A. B. Callender, *SP435*, pp. 202-206 (Apr. 1976).

Key words: mirror damage; pulsed lasers; window damage.

Extrinsic lower bound thresholds have been found for some window materials and coated and uncoated metal mirrors. The results differ from single shot data in that formation of breakdown plasmas in the vicinity of the components appear to be more likely after several high repetition rate shots have been made. No major conditioning effects have been observed.

Laser damage measurements at CO_2 and DF wavelengths, J. D. Porteus, M. J. Soileau, H. E. Bennett, and M. Bass, *SP435*, p. 207-215 (Apr. 1976).

Key words: Al mirrors; Auger spectroscopy; damage morphology; electron emission; electron imaging; ion emission; laser-induced damage; surface characterization; surface temperature.

Preliminary results from laser damage tests conducted with CO_2 and DF lasers on samples mounted in a newly constructed ultrahigh vacuum sample chamber are reported. The lasers operate single mode and the pulse lengths are 100 nsec for CO_2 and about 500 nsec for DF. A precise method of focusing which permits accurate determination of power densities is described. Incorporated in the test chamber are a scanning electron imager, an optical microscope, a profiling Auger system, and a charged particle collector for *in situ* analysis. Analytical results are presented and implications for physical damage processes are discussed. Measurements in nitrogen on aluminum samples indicate that the threshold for N_2 breakdown is reduced some 20 times in the vicinity of the aluminum surface. Laser supported gas plasma waves are formed which shield the surface, and no physical damage occurs for single 100 nsec pulses even at power levels of 10 GW/cm^2. However, in vacuum damage does occur at about the expected power levels. No significant difference between the damage threshold for polished and machined aluminum surfaces was found.

Single and multilongitudinal mode damage in multilayer reflectors at 10.6 μm as a function of spot size and pulse duration, V. Wang, C. R. Giuliano, and B. Garcia, *SP435*, pp. 216-229 (Apr. 1976).

Key words: absorbing inclusions; damage statistics; laser damage; reflectors; ThF_4; thin film; ZnSe; 10.6 μm.

An extensive series of measurements was carried out upon several high reflectivity multilayer dielectric (ZnSe/ThF_4) enhanced reflectors (typically 99.8%) using a CO_2 TEA laser. Measurements were made using smooth single longitudinal mode pulses, partially modelocked multilongitudinal mode pusles, and a range of pulse lengths extending from 0.6 μs to 6 μs. Studies were conducted at spot size diameters ranging from 50 μm to 255 μm. It is observed that damage thresholds are independent of pulse duration or pulse temporal shape (energy dependent) and evidence is presented that the damage is caused by inclusions, and that the average separation of inclusions, their absorption, and the film absorption can be inferred. A defect-limited damage threshold (90 J/cm^2) and a lower limit to the defect-free threshold (4.4 kJ/cm^2) for the film is established.

Temperature and wavelength dependence of the reflectance of multilayer dielectric mirrors for infrared laser applications, D. L. Decker, *SP435*, pp. 230-235 (Apr. 1976).

Key words: multilayer dielectric mirror; optical absorptance; reflectance; scattering; temperature dependence; wavelength dependence.

The absorptance of mirrors used in high energy laser applications is significant in determining the heat load which must be removed by cooling and the magnitude of the associated thermal figure distortion. For design purposes it is necessary to know the absorptance not only at room temperature, but also at temperatures up to and above the actual operating temperature of the mirror. The damage threshold is also related to the absorptance and to its variation with temperature, dA/dT. Since temperature and wavelength dependence is needed, it is most convenient to infer the absorptance from absolute reflectance and scattering measurements, rather than from direct measurement. The present paper describes instrumentation capable of making relative reflectance vs. temperature measurements with a precision and accuracy of 7×10^{-5}. Temperature dependence data over the range from 25 to 125 °C is presented and analyzed for several commercially obtained dielectric multilayer mirror designs intended for use at 3.8 μm. These mirrors have absolute reflectances above 0.997 and show a reflectance variation with temperature, $|dR/dT|$ of 5×10^{-5} or less.

Preparation and evaluation of ZnS/CeF_3 AR coatings for 10.6 micron KCl laser windows, A. Golubovic, W. Ewing, R. Bradbury, I. Berman, J. Bruce, and J. J. Comer, *SP435*, pp. 236-243 (Apr. 1976).

Key words: CeF_3; CO_2 pulsed laser damage; coating topography; KCl; laser window coatings; ZnS.

The possibility of using ZnS/CeF_3 as a 2-layer antireflection coating for 10.6 micron laser window materials was investigated. Both sputtered and sublimed layers of ZnS were deposited on well characterized Bridgman RAP grown KCl substrates. CeF_3 layers were thermally evaporated onto both bare and ZnS coated KCl substrates. The chemistry and structural quality of the coatings were examined by several characterization techniques including x-ray diffraction, electron microscopy and diffraction, scanning electron microscopy, Auger spectroscopy, Nomarski microscopy, and emittance spectroscopy. Pulsed laser damage studies at 10.6 microns were performed to evaluate the damage threshold of the coatings.

As_2S_3 coatings on KCl, A. D. Baer, T. M. Donovan, and M. J. Soileau, *SP435*, pp. 244-247 (Apr. 1976).

Key words: As_2S_3; coating deposition; index of refraction; laser windows; surface composition; 10.6 μm.

Potassium chloride (KCl) and quartz windows were coated with As_2S_3 at deposition temperatures of 80 and 22 °C. The index of refraction of As_2S_3 coatings is a function of deposition temperature for KCl windows, but not for quartz windows. Coatings deposited on KCl at 80 °C are more durable and less absorbing than those deposited at 22 °C. It is suggested that deposition temperature affects the properties of coatings on KCl because the composition of the surface of polished KCl windows changes with temperature. As_2S_3 coatings were produced with an optical absorption of 1.7 cm^{-1} at a wavelength of 10.6 μm, as compared with 1.1 cm^{-1} reported for bulk As_2S_3.

Design for high power resistance, A. L. Bloom and V. R. Costich, *SP435*, pp. 248-253 (Apr. 1976).

Key words: damage threshold; optical coatings; thin films.

The influence of materials parameters such as thermal conductivity, intrinsic stress, thermal expansivity, and Young's modulus on coating performance is discussed. Metal, metal-dielectric, and dielectric multilayer films at both 1.06 μm and 10.6 μm are considered. Calculations are presented for various combinations of coatings and substrates.

Influence of standing-wave fields on the laser damage resistance of dielectric films, B. E. Newnam, D. H. Gill, and G. Faulkner, *SP435*, pp. 254-271 (Apr. 1976).

Key words: damage thresholds; dielectric thin films; electric fields; electron-gun evaporation; picosecond pulses; rf sputtering; standing-wave patterns.

The influence of standing-wave electric fields on the damage resistance of dielectric thin films was evaluated for the case of 30-ps laser pulses at 1.06 μm. Single-layer films of TiO_2, ZrO_2, SiO_2, and MgF_2 were deposited by state-of-the-art electron-gun evaporation on BK-7 glass substrates with uniform surface preparation. The film thicknesses ranged from one to five quarter-wave increments.

The thresholds for TiO_2 films of odd quarter-wave thickness were greater than for even multiples which correlated well with the calculated internal maximum electric fields. Threshold variations for ZrO_2 films were apparent, but not as distinctly periodic with film thickness. Negligible variations were obtained for SiO_2 films, again correlating with electric-field calculations.

Additional tests allowed comparisons of thresholds for 1) back- and front-surface films for normal incidence; 2) S- and P-polarized radiation at an incidence angle of 60°; and 3) circular and linear polarizations for normal incidence. The thresholds were compared with calculated standing-wave field patterns at various locations in the films. A definite correlation was generally found between the internal field maxima and the thresholds, but in a few coatings defects apparently decreased or prevented any correlation.

Threshold ambiguities in absorptive laser damage to dielectric films, R. H. Picard, D. Milam, R. A. Bradbury, and J. C. C. Fan, *SP435*, pp. 272-283 (Apr. 1976).

Key words: damage threshold; dielectric films; heat conduction; laser damage; multiphoton absorption; rf sputtering.

The threshold energy density for laser-induced damage arising from homogeneous absorption in thin dielectric films is dependent upon the laser irradiance. This is illustrated by measurements of the time to breakdown of rf sputtered films irradiated by tightly focused square-waveform ruby laser pulses. We are able to show that the increase of threshold with decreasing irradiance is due to two mechanisms: (1) cooling of the film by conduction of heat to the substrate and (2) two-photon absorption in the film itself.

Time resolved study of laser-induced structural damage in thin films, N. Alyassini and J. H. Parks, *SP435*, pp. 284-288 (Apr. 1976).

Key words: adhesion effect; laser induced damage; optical probe technique; thin film; time resolved damage.

A time resolved optical probe technique reported previously was used to study laser induced structural damage in thin film dielectric coatings. Experimental data indicates that thin film damage frequently occurs without any detectable spark or distortion to the transmitted damaging ruby pulse and that structural damage to thin film can occur up to 40 nsec after passage of the damaging Q-switched ruby pulse through the site. In addition damage threshold of $\lambda/4$ ZnS single layer film indicates the presence of a film/substrate adhesion effect.

The importance of refractive index, number density, and surface roughness in the laser-induced damage of thin films and bare surfaces, J. R. Bettis, R. A. House, A. H. Guenther, and R. Austin, *SP435*, pp. 289-295 (Apr. 1976).

Key words: damage thresholds; laser damage; refractive index; surface damage; surface roughness; thin films.

Results of a laser-induced damage study to optical surfaces and thin-film coatings are reported. Ten different half wave films, placed on fused silica, sapphire, BK-7, and ZnSe, were subjected to 1.06 μm radiation in a 147 μm spot size. Nine different optical materials in bulk form including four glasses were also tested. The results were compared to a phenomenological equation relating threshold optical field to number density, refractive index, and root mean square surface roughness. The films were measured inhomogeneity and were deposited by r.f. sputtering, electron beam heating, and thermal evaporation. Very good correlation was obtained between predicted and observed behavior.

Investigation of the damage properties of multilayer dielectric coatings for use in high power Nd:glass lasers, C. E. Thomas, B. Guscott, K. Moncur, S. Hildum, and R. Sigler, *SP435*, pp. 298-304 (Apr. 1976).

Key words: coating damage; laser damage; mirrors; multilayer dielectric coatings; polarizers.

The development of high-power Nd:glass laser systems has reached a point where the damage in multilayer dielectric coatings limits the available energy from the laser. KMSF has initiated a testing program to identify the parameters that affect the damage levels of dielectric coatings. We will report the measured damage levels as a function of predeposition substrate cleaning, the dielectric material used (TiO_2 vs. ZrO_2), the substrate material (Pyrex vs. BK-7 or quartz), and the laser pulse length (80 to 480 picoseconds). Damage levels will be compared with the light-scattering properties of the coatings.

Correlation of laser-induced damage with surface structure and preparation techniques of several optical glasses at 1.06 μm, R. A. House, J. R. Bettis, A. H. Guenther, and R. Austin, *SP435*, pp. 305-320 (Apr. 1976).

Key words: damage thresholds; fused silica; ion polishing; surface damage; surface roughness; surface structure; thin films; ultrasonic cleaning.

An extensive experimental investigation has been conducted to correlate laser-induced surface damage with surface structural properties in a range of transparent dielectric materials. Materials investigated were Fused Silica (Corning and Optosil); BK-7 (Schott "P" quality); ED-2, ED-4, and Cervit (all Owens-Illinois). Samples were prepared using controlled grinding, conventional polishing, ion polishing, and bowl-feed polishing. Major parameters of interest were the polishing compound used, the rms surface roughness, the subsurface fracture zone, etching, flame polishing, overcoating with $\lambda/2$ of the substrate material, and the possibly deleterious effect of ultrasonic cleaning. The damaging radiation was a focused 1.06 μm laser beam of about 40 ns width in the TEM_{00} transverse mode. Target sites on a given sample were shielded from each other against blowoff and UV radiation.

Picosecond breakdown studies: Threshold and nonlinear refractive index measurements and damage morphology, W. L. Smith, J. H. Bechtel, and N. Bloembergen, *SP435*, pp. 321-330 (Apr. 1976).

Key words: avalanche ionization; dielectric breakdown; inclusions; laser damage threshold; morphology; nonlinear refractive index; picosecond laser pulses.

Single picosecond pulses from a well-calibrated Nd:YAG laser have been used to study the bulk dielectric properties of 14 transparent solids. Measured values of the breakdown thresholds and nonlinear refractive indices are presented. Photomicrographic data of the damage morphology yield information concering spatial and temporal microplasma growth from initiating electrons, and concerning the spatial density of initiating sites. The data indicate avalanche ionization is the damage mechanism. Preliminary results from a breakdown study at 0.53 μm are discussed.

Current status of electron-avalanche-breakdown theories, M. Sparks, *SP435*, pp. 331-346 (Apr. 1976).

Key words: electron-avalanche breakdown; dielectrics; frequency dependence; magnitude.

Evidence is presented that current theories of electron-avalanche breakdown in dielectrics are inadequate to explain existing data or to be predictive. Specific difficulties include the following: (1) The theoretical value of the ionization frequencies are too small, by tens of orders of magnitude in some cases, to explain the experimental damage results even when the large initial conduction electron densities in (4) below are assumed. (2) The theoretical result for the *frequency dependence* of the breakdown electric field $E_B \sim (1+\omega^2\tau^2)^{1/2}$ disagrees with experimental results. The explanation in terms of an anomalously small electron relaxation frequency is inconsistent with the value of τ required to explain the *magnitude* of E_B, with calculated values of τ (by two orders of magnitude), and with the difference between the dc and 10.6 μm experimental values of E_B. (3) The temperature dependence of E_B is incorrect. (4) The assumed value of the electron density $n_c = 10^8 - 10^{10}$ cm^{-3} required to initiate the avalanche is in conflict with results of photoconductivity measurements. Bounds on n_c set by estimates of the value of the electronic conductivity indicate that the probability of finding an electron in the focal volume during the pulse is less than 10^{-6}, possibly much less, in some cases. (5) The theories are not predictive. Tentative new theoretical results hold promise of explaining existing experiments and being predictive.

A statistical analysis of laser induced gas breakdown—A test the lucky electron theory of avalanche formation, D. Milam, R. A. Bradbury, and R. H. Picard, *SP435*, pp. 347-355 (Apr. 1976).

Key words: electron avalanche; laser-induced gas breakdown; photoionization.

It is shown that the statistical distribution of breakdown times of gas volumes irradiated with square waveform ruby laser pulses can be explained by accounting for the probability that initial electrons are reliably produced by photoionization. Furthermore, the nature of the statistics of gas breakdown are closely related to those predicted by the lucky electron theory, and to the experimentally observed statistics of breakdown in solid dielectrics. It is suggested, therefore, that the statistics of intrinsic breakdown in both gases and solids may be related to the probability of obtaining initial charge rather than purely a manifestation of the lucky electron statistical process.

Measurement of free electron density at the onset of laser-induced surface damage in BSC-2, N. Alyassini and J. H. Parks, *SP435*, pp. 356-361 (Apr. 1976).

Key words: damage electron density; electron density transient; free electron absorption; laser induced surface damage; optical probe technique; refractive index variation.

A study of transient processes which occur during laser induced surface damage to BSC-2 glass was conducted. An optical probe technique was employed in this study which used a He-Ne laser to internally probe the surface at the critical angle. The variations in the detected He-Ne beam revealed a decrease in the site specular reflectivity which precedes structural damage by as much as 2.4 nsec. This is shown to be the result of a laser induced increase in the free electron density at the irradiated surface site with a measured average build up time of 1.6 nsec, resulting in a detectable decrease in the site refraction index ($\Delta n = 10^{-5} - 10^{-3}$). From the measured specular reflectivity decrease, a calculation of the free electron density at the onset of damage indicates a density of $10^{18} - 10^{19}$/cm^3. It is shown that the resulting free electron absorption can transfer a damaging amount of energy from the laser pulse to the sample causing at least melting of the irradiated surface site.

Multi-pulse optical damage of NaCl, P. Bräunlich and P. Kelly, *SP435*, pp. 362-365 (Apr. 1976).

Key words: avalanche breakdown, intrinsic damage; mode-locked pulse trains.

Single-shot intrinsic laser damage of NaCl at 1.06 μm is caused by avalanche ionization. The reduction of the damage threshold of an order of magnitude in case the sample is exposed to a mode-locked train of ten pulses, observed by Penzkofer, was assumed to be caused by absorbing inclusions. In this paper we show that the dependence of the damage threshold on the number of pulses in a mode-locked train can be satisfactorily explained by the avalanche breakdown mechanism.

Do multi-photon induced collision chains lead to pre-breakdown material modifications in alkali halides?, A. Schmid, P. Bräunlich, and P. K. Rol, *SP435*, pp. 366-368 (Apr. 1976).

Key words: alkali halides; collision chains; halogen emission; intrinsic damage; multi-photon absorption.

Experiments are described that indicate the existence of a new phenomenon in certain alkali halides: the multi-photon induced collision chain along [211] and [110] directions of the halide sublattice at power densities below the one-shot damage threshold. A preliminary model description of the involved physical processes is given. The sequence of events starts with the multi-photon generation of self-trapped excitons and leads, via nonradiative exciton-decay, to the formation of new color centers and/or to the ejection of atomic species from the surface. Possible implications which these pre-breakdown material modifications may have on intrinsic optical breakdown are discussed.

Multiphoton absorption coefficients in compound semiconductors from ruby to CO_2 laser wavelengths, R. A. Shatas, S. S. Mitra, and L. M. Narducci, *SP435*, pp. 369-388 (Apr. 1976).

Key words: multiphoton processes; nonlinear absorption; nonlinear optical properties; semiconductor optical properties; two-photon absorption coefficients.

A critical review of multiphoton absorption coefficients for direct band semiconductors of interest in laser optical applications is presented. The two-photon nonlinear absorp-

tion coefficients have been calculated in the second order perturbation employing interconduction band transition model of Braunstein and Ockman, two-valence band intraconduction or intravalence band transition model of Basov et al., and the Keldysh electromagnetic field "dressed" valence and conduction band wave-function model. In all models, corrections to the original calculations were needed to account for effective masses, dielectric constants and the energy band dispersion relations. Comparison of theoretical predictions at 0.694, 1.06, 1.318, and 10.6 μm laser wavelengths shows that, in general, the Basov model slightly over-estimates, the Braunstein model substantially under-estimates the nonlinear absorption, and the Keldysh model yields second order nonlinear absorption about three times larger than Braunstein. It is shown that the second order nonlinear absorption coefficient in the photon energy range $E_g/2<h\omega<E_g$ where E_g is the forbidden gap width, can be as high as 10^{-5} cm W^{-1} and therefore under certain circumstances can exceed the linear absorption at laser flux intensities as low as 10^5 W cm^{-2}. In addition, nonlinear absorption coefficients up to the fifth order have been estimated from the Keldysh model. The utility of the Keldysh model is demonstrated by the surprisingly good prediction of the band-edge absorption in GaAs and InSb without any adjustable parameters.

Electroabsorption: A possible damage consideration, R. P. Benedict and A. H. Guenther, *SP435*, pp. 389-394 (Apr. 1976).

Key words: electroabsorption; IR optics; laser damage; multiphoton processes; uv.

Electroabsorption, also known as photon-assisted tunneling or the Franz-Keldysh effect, is the phenomenon in which the application of a large electric field produces a change in the absorption coefficient of a solid material. This effect has been proposed as a possible laser damage mechanism since the effective absorption coefficient will be dependent upon the laser intensity (optically related electric field) rather than the constant it is usually taken to be. The constant value is normally determined from low laser intensity calorimetric or emittance measurements.

A theoretical investigation of the interaction of an EM field with a material shows that the dc field limit is a tunneling effect and the high-frequency limit is multiphoton absorption so that electroabsorption is closely related to the latter. The result being that one should primarily consider multiphoton absorption rather than electroabsorption for potential damage implications in most situations. Calculations are presented that indicate the relative importance of multiphoton absorption for window materials for both visible and IR lasers. The results indicate that multiphoton absorption will usually be unimportant for IR materials except in cases of extremely high fields and no other competing damage mechanisms. For materials used with visible lasers, the phenomenon must be considered as a potential cause of damage.

Irradiance limits for vacuum ultraviolet material failure, C. J. Duthler and M. Sparks, *SP435*, pp. 395-405 (Apr. 1976).

Key words: nonlinear index of refraction; optical distortion; thermal fracture; two-photon absorption.

Calculated values of irradiance I at which materials fail in 7.2 eV pulses of 10 nsec duration by various mechanisms indicate that metallic mirrors melt at very low values, typically I≅20 MW/cm. Improving the aluminum, which is the only good metallic vuv reflector, would increase I by a factor of only three. The lowest of the thresholds for transparent materials are ~140 MW/cm² for the intrinsic reversible process of optical distortion caused by the conduction electrons generated by two-photon absorption and ~200 MW/cm² for the intrinsic irreversible process of thermal fracture by two-photon absorption. Other thresholds are: ~1 GW/cm² for fracture from enhanced stimulated Raman scattering in Raman-active materials; ~1.6 GW/cm² for melting from two-photon absorption; ~2 GW/cm² for optical distortion from the nonlinear refractive index (bound electrons); and ~100 GW/cm² for thermal fracture from extrinsic one-photon absorption with β=0.1 cm^{-1}. Included in the calculations are the Joule heating by the generated electrons, which is greater than the direct heating by the absorption process, and electron-avalanche multiplication. Thermally induced optical distortion has a higher threshold than that for the optical distortion by generated conduction electrons.

SP436. **Detection, diagnosis, and prognosis.** Proceedings of the 22d meeting of the Mechanical Failures Prevention Group held at Anaheim, Calif., Apr. 23-25, 1975, T. R. Shives and W. A. Willard, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 436, 366 pages (Dec. 1975) SD Catalog No. C13.10:436.

Key words: diagnostic case histories; diagnostic systems; failure detection; failure diagnosis; failure prevention; failure prognosis.

These Proceedings consist of a group of nineteen submitted papers and discussions from the 22nd meeting of the Mechanical Failures Prevention Group which was held at the Grand Hotel in Anaheim, California on April 23-25, 1975. Failure detection, diagnosis, and prognosis represent the central theme of the Proceedings. Technology and techniques, ongoing diagnostic programs, and coming requirements in the field of DD&P are discussed. In addition, several case histories are presented. *These proceedings include the following papers (indented):*

Signal analysis techniques for vibration diagnostics, D. R. Houser, *SP436*, pp. 3-15 (Dec. 1975).

A new technology for bearing performance monitoring, G. J. Philips, *SP436*, pp. 18-28 (Dec. 1975).

Bearing contact resistance as a diagnostic aid, R. L. Smith, *SP436*, pp. 31-41 (Dec. 1975).

Nondestructive tire inspection, M. J. Lourenco and L. H. Emery, *SP436*, pp. 43-75 (Dec. 1975).

Measurement of spectra in internal combustion engine cylinders, J. M. Marrs, *SP436*, pp. 78-82 (Dec. 1975).

Sonic analyzer—Case history, J. L. Frarey, *SP436*, pp. 97-102 (Dec. 1975).

Oil analysis in perspective, R. S. Miller (presented by M. Hoobchaak), *SP436*, pp. 104-112 (Dec. 1975).

Instrumentation for predictive maintenance monitoring, R. James, B. Reber, B. Baird, and W. Neal, *SP436*, pp. 114-122 (Dec. 1975).

Gas turbine engine diagnostic test results utilizing a thermodynamic analysis technique, R. L. Stenberg, *SP436*, pp. 137-149 (Dec. 1975).

Problem areas encountered in establishing a data baseline and evaluating the A-7E inflight engine condition monitoring system, A. J. Hess, *SP436*, pp. 151-161 (Dec. 1975).

Tri service oil analysis research and development program, P. B. Senholzi, *SP436*, pp. 165-181 (Dec. 1975).

Development of inspection and diagnostic equipment for motor vehicle equipment for motor vehicle inspection, G. L. Parker (presented by L. H. Emery), *SP436*, pp. 185-192 (Dec. 1975).

On vehicle mobility measurement and recording system, F. K. Chin and R. Watts, *SP436*, pp. 195-219 (Dec. 1975).

VIDEC ship propulsion system performance monitor, R. P. Wallace and W. L. McCarthy, *SP436*, pp. 221-256 (Dec. 1975).

An overview of current efforts to detect and prevent steel wheel failures, G. L. Leadley, *SP436*, pp. 261-287 (Dec. 1975).

Diagnostics for refrigerator car diesel generating sets, R. F. McKee, *SP436*, pp. 289-302 (Dec. 1975).

Using acoustic emission technology to predict structural failure, H. L. Dunegan, *SP436*, pp. 304-319 (Dec. 1975).

Applications of the shock pulse technique to helicopter diagnostics, J. A. George, T. C. Mayer, and E. F. Covill, *SP436*, p. 321-340 (Dec. 1975).

LST 1179 diesel diagnostic system feasibility study, M. B. Peterson, J. Frarey, D. Dominy, H. Hegner, and H. C. Burnett, *SP436*, pp. 342-354 (Dec. 1975).

SP437. **National Bureau of Standards Annual Report FY 1975.** P. A. Powell and S. A. Washburn, Eds., Nat. Bur. Stand. (U.S.), Spec. Publ. 437, 32 pages (Dec. 1975) SD Catalog No. C 13.10:437.

Key words: annual report; computer; energy; environment; measurement; product safety; research; science; standards; technology.

This publication highlights the major achievements of the National Bureau of Standards during FY75 and describes how resources were utilized during this period. In addition, the report will contain sections featuring the Bureau's interaction with the public and private sectors and emphasizing the historical perspective in relation to the Bureau's 75th anniversary and the nation's bicentennial. This publication will serve as (1) an annual accounting of major NBS activities and (2) promotional information on NBS services and capabilities.

Sections of the report feature: increasing measurement competence, sharing measurement techniques, exploring our energy options, expanding computer utilization, preserving environmental quality, promoting better materials use, improving product safety, providing information as a resource, organization, funds and facilities, people.

SP438. **Testing and certification for export products in industrializing countries.** Proceedings of a Regional Seminar held at the Regional English Language Centre and International House, Singapore, May 19-20, 1975, H. S. Peiser and R. S. Marvin, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 438*, 160 pages (Feb. 1976) SD Catalog No. C13.10:438.

Key words: certification; developing countries; exports; industrializing countries; labeling; seminar; South Asia trade; testing.

A regional seminar sponsored by the Singapore Institute of Standards and Industrial Research, the National Bureau of Standards, and the Agency for International Development was held in Singapore in May of 1975. The participants represented most of the countries in South Asia concerned with increasing their exports, and concentrated on various problems connected with the testing and certification of such exports. Most of the prepared papers reviewed the practice and future plans of these countries. During the discussion a number of specific problems and issues were raised, with a good deal of attention focused on the extent to which the standards and certification of goods by an exporting country can be and are recognized by the importer. This report includes both the prepared papers and a mildly edited version of the discussions following each. *These proceedings include the following papers (indented):*

Export testing, labeling and certification—An overview, W. E. Andrus, Jr., *SP438*, pp. 9-21 (Feb. 1976).

Testing and certification of export products in the Republic of China, W. Y. F. Ning, *SP438*, pp. 23-27 (Feb. 1976).

Pre-export testing and certification in Sri Lanka, R. T. Wijewantha, *SP438*, pp. 29-34 (Feb. 1976).

Development of a National infrastructure of support services for quality control for export, M. Probine, *SP438*, pp. 45-62 (Feb. 1976).

Metrology plan for Korean industrial development, K. Zae-Quan, *SP438*, pp. 69-78 (Feb. 1976).

Can data collection and analysis reduce the rejection of exported products?, J. Hilsenrath, *SP438*, pp. 83-89 (Feb. 1976).

The institution of a worldwide integrated system of testing facilities (WISTF), F. von Ranke, *SP438*, p. 95 (Feb. 1976).

Thailand's certification and quality marks program, K. S. Stephens, *SP438*, pp. 105-124 (Feb. 1976).

Basic export inspection policy in Korea, C. Jong Wan, *SP438*, pp. 127-131 (Feb. 1976).

Testing and certification of Philippine export products, V. F. Ranoa, *SP438*, pp. 133-135 (Feb. 1976).

Certification mark and export inspection in India, A. B. Rao, *SP438*, pp. 139-141 (Feb. 1976).

Quality certification in developing countries, R. Estrada, *SP438*, pp. 143-148 (Feb. 1976).

Pre-export quality control scheme for crumb rubber: Pilot project and experience of Indonesia, N. N. Sumantri, *SP438*, pp. 149-151 (Feb. 1976).

SP439. **The Center for Building Technology: A perspective,** M. Olmert, *Nat. Bur. Stand. (U.S.), Spec. Publ. 439*, 30 pages (Jan. 1976) SD Catalog No. C13.10:439.

Key words: building research; criteria; energy; engineering; industry construction; measurement techniques; standards.

The mission of the Center for Building Technology is threefold. They are (1) advance building technology by providing technical and scientific bases for criteria and standards that improve the usefulness, safety, and economy of buildings; (2) facilitate, for the public benefit, the implementation of improved building technology by providing technical assistance to all sectors of the building community; and (3) develop improved techniques by which the end-users in buildings, communities and industrial processes conserve energy. This report presents an overview of the Center for Building Technology's research areas through its accomplishments and ongoing projects.

SP441. **Successful experiences in teaching metric.** A Conference in Celebration of the One Hundredth Anniversary of the Metric Convention, 1875-1975, held at the National Bureau of Standards, Gaithersburg, MD, May 20-21, 1975, J. V. Odom, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 441*, 115 pages (Jan. 1976) SD Catalog No. C13.10:441.

Key words: education; International System of Units; metrication; metric education; metric system; training; Treaty of the Meter.

These proceedings contain the texts of the presentations made at a recent conference on Successful Experiences in Teaching Metric. Specific experiences in introducing the metric system in all areas of educational interest were presented. These ideas will be especially useful to educators just beginning to prepare for their change to the metric system. *These proceedings include the following papers (indented):*

The International System of Units, R. W. Roberts, *SP441*, pp. 1-3 (Jan. 1976).

Principles and practices of teaching the metric system in public schools, G. W. Bright, *SP441*, pp. 4-12 (Jan. 1976).

Metric in general (elementary) education, L. Smith, *SP441*, pp. 13-15 (Jan. 1976).

Metrication and the school librarian, P. Lawrence, *SP441*, pp. 16-17 (Jan. 1976).

Teaching the metric system through television and other audio visual means, N. F. Calhoun, *SP441*, pp. 18-22 (Jan. 1976).

Metric and mathematics education, S. A. Choate, *SP441*, pp. 23-29 (Jan. 1976).

Experiences in teaching the metric system in science classes, B. Logan, *SP441*, pp. 30-42 (Jan. 1976).

Metric gaming, C. R. Trueblood and M. Szabo, *SP441*, pp. 43-50 (Jan. 1976).

Metric in preservice teacher training, J. Lindbeck, *SP441*, pp. 51-54 (Jan. 1976).

Constructing metric education workshops—A model, P. T. Larsen, *SP441*, pp. 55-62 (Jan. 1976).

Metric for the blind, A. Nadash, *SP441*, pp. 63-66 (Jan. 1976).

Metric in sports and physical education, F. Burgee, *SP441*, pp. 67-68 (Jan. 1976).

Metrication and State departments of education, A. V. Buffington, *SP441*, pp. 69-71 (Jan. 1976).

Metrication in a local education agency, T. E. Rowan, *SP441*, pp. 72-76 (Jan. 1976).

Successful experiences in teaching metrics in home economics, C. A. Ford, *SP441*, pp. 81-84 (Jan. 1976).

Successful experiences in teaching metric conference, E. M. Schanbacher, *SP441*, pp. 85-89 (Jan. 1976).

A basis for successful teaching of vocational metric education, R. A. Dieffenderfer, *SP441*, pp. 90-96 (Jan. 1976).

What can we learn from the English and Australian experiences in metric education?, A. B. Chalupsky, *SP441*, pp. 97-100 (Jan. 1976).

SP442. **Report of the 60th National conference on weights and measures 1975,** S. J. Edgerly, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 442*, 272 pages (May 1976) SD Catalog No. C13.10:442.

Key words: calibration; communication; consumers; grain moisture measurement; laws and regulations; measurement; metric; packaging and labeling; police radar equipment; standards; supermarket automation; weights and measures.

This is a report of the proceedings (edited) of the Sixtieth N tional Conference on Weights and Measures, sponsored by th National Bureau of Standards, held in San Diego, Californi July 13-18, 1975, and attended by state, county, and city weigh and measures officials, the Federal Government, business, i dustry, and consumer organizations. *These proceedings inclu the following papers (indented):*

Guarding measurement integrity, S. D. Andrews, *SP442*, p 1-6 (May 1976).

Preparing for a metric America, F. K. Willenbrock, *SP44* pp. 6-12 (May 1976).

Petroleum—Engineering, measurement, marketing, J. Byrn *SP442*, pp. 14-25 (May 1976).

Why not unshackle measurement standards, L. T. Wallac *SP442*, pp. 25-28 (May 1976).

Intergovernmental communication mechanisms, R. J. Barr *SP442*, pp. 29-35 (May 1976).

The State of California measurement system, S. Kozic *SP442*, pp. 36-42 (May 1976).

Calibration of police radar instruments, D. W. Allan, *SP44* pp. 42-47 (May 1976).

Grain moisture measurements and the weights and measur community, F. E. Jones, *SP442*, pp. 52-58 (May 1976).

Impact of electronics in weighing, J. J. Elengo, Jr., *SP442*, p 59-65 (May 1976).

Weights and measures and the consumer, M. H. Becke *SP442*, pp. 67-72 (May 1976).

Representing the consumer interest in weights and measur law enforcement, H. E. Nelson, *SP442*, pp. 74-80 (May 197

Supermarket automation—UPC and the computeriz checkout counter, T. K. Zaucha, *SP442*, pp. 83-98 (May 197

Maintaining an economic balance during inflationary tim K. J. Simila, *SP442*, pp. 104-110 (May 1976).

Overview of consumer issues, C. A. Barrett, *SP442*, pp. 11 121 (May 1976).

The perfect formula and PMTD, A. J. Farrar, *SP442*, p 123-133 (May 1976).

American society for testing and materials—Voluntary co sensus standards, W. T. Cavanaugh, *SP442*, pp. 133-137 (Ma 1976).

International organization of legal metrology—The emergi U.S. role, W. E. Andrus, Jr., *SP442*, pp. 138-156 (May 197

Converting to metric standards in Canada, J. L. Armstron *SP442*, pp. 156-163 (May 1976).

SP443. **Hydraulic research in the United States and Canada, 197** G. Kulin and P. H. Gurewitz, Eds., *Nat. Bur. Stand. (U.S. Spec. Publ. 443*, 359 pages (June 1976) SD Catalog N C13.10:443.

Key words: fluid mechanics; hydraulic engineering; hydra lic research; hydraulics; hydrodynamics; model studie research summaries.

Current and recently concluded research projects in hydra lics and hydrodynamics for the years 1973-1974 are sur marized. Projects from more than 200 university, industri state and federal government laboratories in the United Stat and Canada are reported.

P444. **Wind and seismic effects.** Proceedings of the Sixth Joint Panel Conference of the U.S.-Japan Cooperative Program in Natural Resources, National Bureau of Standards, Gaithersburg, MD, May 15-17 (1974), H. S. Lew, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 444,* 462 pages (Apr. 1976) SD Catalog No. C13.10:444.

Key words: bridges; buildings; codes; disaster; dynamic analysis; earthquakes; modeling; soils; structural response; volcanoes; wind.

The Sixth Joint Meeting of the U.S.-Japan Panel on Wind and eismic Effects was held in Washington, D.C., on May 15-17, 974. The proceedings of the Joint Meeting include the opening marks, the program, the formal resolutions, and the technical apers. The subject matter covered in the papers includes exeme winds in structural design: assessment and experimental chniques for measuring wind loads; dynamics of soil structures id ground response in earthquakes; structural response to wind id earthquakes and design criteria; disaster mitigation against atural hazards; and technological assistance to developing ountries. *These proceedings include the following papers (inented):*

On the gust response of long-span suspension bridges, N. Narita and K. Yokoyama, *SP444,* pp. I-1 – I-20 (Apr. 1976).

Key words: bridge; design; field data; gust response; model; specifications; structure; theory; wind.

In the design of above-ground structures it is established practice to consider the effects of wind. For some structures, like long-span suspension bridges, the influence of wind may be the primary design control which will then govern the inherent safety of the structures and the final construction cost.

This paper, therefore, will describe the required changes in design specifications to incorporate the influence of gusts on long-span suspension bridges.

The necessary numerical calculations are illustrated in addition to some long-term observations on the Kanmon Bridge. The importance and necessity of studies on gust response are emphasized.

Extreme winds in hurricanes and possibility of modifying them, R. C. Gentry, *SP444,* pp. I-21 – I-33 (Apr. 1976).

Key words: cloud seeding; frequency distribution; hurricanes; typhoon; wind; wind intensities.

A hurricane (or similar storm called by other names) is the most destructive of nature's phenomena. This is partly because of the extreme winds associated with the storms (ranging up to 320 kilometers per hour), but also because the winds may continue blowing for several hours, and they are accompanied by rising ocean water, strong along-shore currents, and torrential rains.

Discussions will be presented of the frequency of hurricanes of various intensities, the rate at which the wind speeds decrease after the storm crosses the coast and moves inland, the effect of the winds on the storm surge, and the variation of the wind speed with height.

For several years, members of the United States Government have been experimenting to reduce the maximum intensity of the winds of hurricanes. Summaries will be presented of the progress and future prospects for this work.

Extreme winds in the United States, A. R. Hull and P. E. Hughes, *SP444,* pp. I-34 – I-39 (Apr. 1976).

Key words: building code; damage classification; extreme wind; tornado; wind loads.

The highest winds reported in the United States have been associated with tornadoes. Fujita (1971) has developed a tornado windspeed/damage classification system which permits extreme wind estimations without follow-up surveys. Fujita classifications of tornadoes for the 1965, 1971, and 1972 seasons, as well as extreme wind values associated with thunderstorms and extratropical cyclones during 1973 are reviewed as they relate to ANSI building code requirements for design loads. Next, a new observational tool, an acoustic, doppler-shift "sonar" capable of profiling low-level wind regimes at the actual building site, is briefly described. Finally, the proposed NOAA Severe Environmental Storms and Mesoscale Experiment (SESAME) is examined. SESAME is an observational/research effort to identify the processes and controlling parameters of extreme-wind generating severe weather systems such as squall lines, thunderstorms, and possibly tornadoes, and to aid in the development of conceptual and numerical models of these phenomena.

Wind tunnel experiments for studying a local wind, K. Suda, S. Soma, and K. Takeuchi, *SP444,* pp. II-1 – II-20 (Apr. 1976).

Key words: bridge; gust; meteorological data; topographical model; wind load; wind profile; wind tunnel.

In general, the study of the effects of local winds on structures is primarily based on data obtained from wind tunnel experiments. As an example of such studies, an investigation of air flow around Nakatojima Island relative to the wind resistant design of a long suspension bridge has been conducted and will be presented.

However, it is not reasonable to conduct such a study entirely related to wind tunnel experiments, as the similitude rule has not been established. Therefore, field observations have been made in parallel with the wind tunnel experiments and the data obtained by both sources are then compared. Thus, the results obtained from the wind tunnel experiment are more reliable.

A study of wind pressures on a single-family dwelling in model and full scale, R. D. Marshall, *SP444,* pp. II-21 – II-51 (Apr. 1976)

Key words: aerodynamics; boundary layers; buildings; codes and standards; wind loads; wind tunnels.

Wind pressures measured on a single-family dwelling are compared with results obtained from a 1:50 scale model placed in a turbulent boundary layer. It is shown that the fluctuating components of surface pressures far exceed the mean or steady pressures and are well correlated over sizeable roof areas. The consistently low fluctuating pressure coefficients obtained from the wind tunnel model are attributed to improper simulation of the lower portion of the atmospheric boundary layer. Comparisons between actual loads and specified design loads suggest that certain current provisions are marginal for tributary areas and excessive for localized areas such as ridges, eaves and corners. A procedure for expressing loads on both localized and extended roof areas in terms of mean pressure coefficients and a peak factor is described.

Nonlinear calculations of ground response in earthquakes, W. B. Joyner, A. T. F. Chen, and P. C. Doherty, *SP444,* pp. III-1 – III-12 (Apr. 1976).

Key words: elastic medium; engineering seismology; ground layer; numerical solution; shear wave.

The response of soil to strong earthquake motion involves a high degree of nonlinearity. Because of the difficulties in solving the nonlinear problem, most calculations of ground response are currently made by a method—variously characterized as "equivalent linear", "quasi-linear", or "strain-compatible"—that assumes the true solution can be approximated by the response of a linear model whose properties are chosen to accord with the average strain that occurs in the model during excitation. The average strain level is determined by iterative calculation. To solve the nonlinear problem directly, we have developed algorithms by which the hysteretic behavior of an individual soil element can be efficiently modeled in a computer. The algorithms enable us to model any reasonable set of hysteresis loops of the Masing type that laboratory experiments may dictate. We are experimenting with various numerical techniques for integrating the basic nonlinear differential equations, including the method of characteristics as described by Streeter, Wylie, and Richart. A comparison was made between the equivalent linear and the nonlinear solution (using the method of characteristics) for a 200-meter section of firm alluvium excited at its base by the N21E component of the Taft accelerogram multiplied by four. This excitation produced peak strains of several tenths of a percent. The nonlinear solution showed substantially higher spectral levels of response at five percent damping for periods between 0.1 and 0.6 seconds.

Observation and analysis of ground response in earthquakes, S. Hayashi and H. Tsuchida, *SP444*, pp. III-13—III-23 (Apr. 1976).

Key words: earthquake; field data; ground response; seismic waves; seismometer; soil-structure interaction.

In the field of port and harbor engineering, the ground response due to earthquakes is generally considered. However, there are many problems at present in idealization of the surface layer, input ground motions, and nonlinear behavior of the soil. In order to provide some design data in these areas, research has been conducted using six downhole seismometer arrays established in port areas in Japan. Typical observed acceleration time histories have been obtained and are shown and compared with those calculated by the multiple reflection theory. In order to investigate ground response relative to structures of large length, such as a tunnel, a two-dimensional seismometer array has been established. Examples of the considerations of the ground response required in practice are seen in microzonation in the earthquake proof design of a subaqueous tunnel.

Research study on liquefaction, W. F. Marcuson, III, *SP444*, pp. III-24—III-37 (Apr. 1976).

Key words: earthfill dams; earthquakes; ground shaking; liquefaction; soil density; stability.

A research program is being undertaken by the U.S. Army Corps of Engineers to evaluate the liquefaction phenomena relative to earthquake response of earth-filled dams. Present and future studies are summarized.

Estimation of liquefaction potential by means of explosion test, K. Yamamura and Y. Koga, *SP444*, pp. III-38—III-51 (Apr. 1976).

Key words: earthquake; explosion test; ground strength; ground vibration; liquefaction; pore-water pressure.

A series of field vibration experiments were performed order to estimate the liquefaction potential of sandy soil d ing earthquakes. Bore hole explosions were used as a vib tion source. A significant relation was found between t ground stiffness and the pore-water pressure as caused the explosion. A proposed method has been developed estimation of the liquefaction potential.

Landslide incidence and mechanisms during earthquakes, E. Ericksen, *SP444*, pp. III-52—III-71 (Apr. 1976).

Key words: avalanches; earthquakes; falls; flows; lar slides; mechanisms; slides.

Strong earthquakes affecting mountainous terrain a generally accompanied by hundreds or even thousands large potentially destructive landslides of certain typ earthquakes affecting areas of low relief cause fewer a generally different types of landslides, which, however, m be equally destructive to works of man. On steep slop among the many types of landslides that may occur, fal slides, and avalanches of rock and soil are most freque during earthquakes. These landslides take place whe slides are commonly part of normal mass-wasting process that affect hillslopes; the earthquake causes the reactivati of old slides as well as the formation of new slides. Surfa movement on faults may also cause landslides by the form tion of scarps that change slope stability although landslid of this type are relatively rare. In terrain of low reli failures by rotational slump, translatory sliding, and late spreading are frequent causes of destruction in towns and ties that have been constructed on unstable, generally wate saturated soil or unconsolidated sediment.

Landslides, with the exception of those classified as fal result from failure of earth materials under shear stre Earthquake accelerations trigger landslides by causing transitory increase in shear stress in earth materials at t site of the slide, and by causing a decrease in the she strength of certain materials, such as water-saturated so Most slide failure takes place along one or more planes weakness, except for flow or landspreading, wherein a give mass fails by loss of coherence. Among the most spectacul or earthquake-triggered landslides are large high-spee debris avalanches that move over a cushion of entrappe compressed air.

Stress condition effects on dynamic properties of soils, E. Ki ribayashi and T. Iwasaki, *SP444*, pp. III-72—III-83 (Ap 1976).

Key words: damping; damping coefficients; shear modulu soil; tests; torsional excitation.

In the engineering field, the evaluation of the dynam characteristics of soils and foundation subgrades has bee required in the course of studying vibrational problems an especially problems associated with earthquake engineerin The dynamic characteristics of soils have, therefore, bee obtained by laboratory tests, using a resonant colum method. These tests were conducted to evaluate the shea modulus and the damping characteristics in dry and satu rated specimens of various soils in Japan.

The hollow cylindrical samples tested were 25 cm i height, 10 cm outside diameter, and 6 cm inside diameter This arrangement permitted a more uniform deformation the sample cross-section. The specimens were fixed at th bottom, and at the top of the specimens oscillators wer fastened to a rigid mass, which supply a torsional vibration force to the system. A confining pressure, which was ap

plied equally to the outside and inside of the test sample, was supplied by air pressure. An axial load was also applied, and was independent of the confining pressure in order to produce an anisotropic stress condition.

After the sample was prepared and all proper alignments and forces imposed, the frequency of the torsional excitation was introduced and then varied until the oscillator specimen system resonated. The resonant frequency varied from 40 cps to 100 cps, depending upon the dimensions and density of the sample and the applied stress condition and the shearing strain amplitude. The strain amplitude varied from 5×10^{-6} to 5×10^{-4} for these tests. The shear moduli were calculated from the resonant frequencies and the other parameters, as given above. The damping characteristics were obtained by using the amplitude-time decay response curves of the free vibrations.

In the triaxial state of stress, the mean principal stress, p, is defined by $(\sigma_a+2\sigma_r)/3$ and the deviator stress, q, is given by $\sigma_a-\sigma_r$ are the axial and radial stresses, respectively. The test results indicate the following trends for the dynamic properties of soils;

(1) Under constant values of the other parameters, the shear moduli vary with 1/2 power of p and decreases with an increase in the void ratio and shearing strain amplitude. Furthermore, the damping capacity decreases with an increase in p and also increases with an increase of strain amplitude. However, the damping capacity remains constant irrespective of the change in the void ratio, when the other parameters remain constant.

(2) When the value of p is kept constant, the shear moduli are nearly constant irrespective of the value of q until the stress ratio, q/p, reaches a value of about 1.0. However, beyond this value of q/p, the shear moduli begin to decrease with an increase in q/p. This phenomenon is due to the anisotropic stress condition and the corresponding anisotropy in the inner structure of specimens.

Prediction of maximum earthquake intensities for the San rancisco Bay Region, R. D. Borcherdt and J. F. Gibbs, *P444*, III-84 – III-94 (Apr. 1976).

Key words: earthquake; empirical relation; Franciscan Formation; geological character; ground shaking; intensity.

The intensity data for the California earthquake of April 18, 1906, are strongly dependent on distance from the zone of surface faulting and the geological character of the ground. Considering only those sites (approximately one square city block in size) for which there is good evidence for the degree of ascribed intensity, the empirical relation derived between 1906 intensities and distance for 761 sites underlain by rocks of the Franciscan Formation is

$$\text{Intensity} = 2.30 - 1.90 \log (\text{Distance}).$$

For sites on other geologic units intensity increments, derived with respect to this empirical relation, correlate strongly with the Average Horizontal Spectral Amplifications (AHSA) determined from 99 three-component recordings of ground motion generated by nuclear explosions in Nevada. The resulting empirical relation is

$$\text{Intensity Increment} = 0.27 + 2.70 \log (\text{ASHA}).$$

Resulting average intensity increments for various geologic units are −0.29 for granite, 0.19 for Franciscan Formation, 0.64 for other pre-Tertiary, Tertiary bedrock, 0.82 for Santa Clara Formation, 1.34 for Older Bay sediments, 2.43 for Younger Bay mud. These empirical relations have been used to delineate areas in the San Francisco Bay region of potentially high intensity from future earthquakes on either the San Andreas fault or the Hayward fault.

A statistical approach to loading and failure of structures, R. G. Merritt, *SP444*, pp. IV-1 – IV-15 (Apr. 1976).

Key words: failure; probability theory; random process; safety; statistical analysis; structural engineering.

A fundamental problem of structural engineering is the examination and selection of loading criteria. It is imperative that any solution to the problem center around a rationale that relates information available on loading to selected criteria. Such available information is generally in the form of data. It is the purpose of this brief paper to abstract the problem and outline preliminary work on a rationale for addressing the problem.

The paper begins by defining the general nature of the problem. Solution to the problem is related to consideration of available information in the form of data. The next three sections of the paper discuss the initial stages of a rationale for consistent examination and selection of loading criteria. The first of the sections examines available information on structural load and the second examines available information on instances of structural failure. Classes of statistical methods are discussed in the third section. This section also includes discussion of a proposed method for assessing the overall information content of the available data. Finally, several illustrative examples of application of statistical methods to load and failure data are presented and the paper concludes with a discussion of future extension to this preliminary work.

Synthetic experimental research on the ductility of short reinforced concrete columns under large deflection, K. Nakano and M. Hirosawa, *SP444*, pp. IV-16 – IV-36 (Apr. 1976).

Key words: column; ductility; earthquake; reinforced concrete; shear tests; structural engineering; web reinforcement.

In general, short reinforced concrete columns will fail in a brittle manner. In order to create and establish better ductility in such columns, a synthetic research experimental program has been conducted. This program consisted of the testing of 125 short column specimens, subjected to multicycles of flexure-shear loadings. The result from these tests indicate the following:

1) The ductility of structural members is influenced by shear, bond, and buckling of the compression bars.

2) To prevent buckling of compression reinforcement, under small curvature, the spacing of the web reinforcement must be controlled.

3) In order to prevent a shear failure of structural members within reasonable ductility, an effective set of restrictions on the combination of axial force, tensile reinforcement ratio, and shear span ratio are required.

4) The bond failures which were observed in the test members, where deformed bars were used as axial reinforcement, consisted of bond-splitting of the cover concrete. The conventional method, which uses bond strength as an index to verify bond failure, is not effective for the bond-splitting failure mode. It is, therefore, necessary to restrict the tensile reinforcement ratio in order to prevent this type of bond failure.

Nonlinear analysis of a guyed tower, S. K. Takahashi and W. A. Shaw, *SP444*, pp. IV-37 – IV-54 (Apr. 1976).

Key words: finite element; guyed tower; structural analysis; structural engineering; vibration analysis; wind load.

The Civil Engineering Laboratory has performed an analysis of a tower at a Naval communication facility. The tower is about 600 feet high and is guyed at three levels. The upper guy level contains twelve wires; the middle and lower guy

levels have three wires each. The guy wires had numerous large electrical insulators attached, each weighing 510 pounds.

A nonlinear finite element analysis of the guyed tower was conducted. Separate finite elements were used for portions of the tower and the guy wires were modeled with a truss element. Deflections, forces, and stresses in the tower and guy wires were determined from dead load and an equivalent static wind load corresponding to 90 miles per hour.

Eigenvalue solutions were obtained for the first five mode shapes and natural frequencies of one of the top guy wires; the guy wire had concentrated masses at five different locations and was initially prestressed.

A standard for the structural integrity of prefabricated dwellings, K. Nakano, M. Hirosawa, and T. Murota, *SP444*, pp. IV-55 – IV-69 (Apr. 1976).

Key words: earthquake; housing; performance specification; prefabricated dwelling; standards; structural design.

In 1973, the Ministry of Construction of Japan presented a standard for the performance of prefabricated housing. The purpose of this standard was to provide consumers with an index for selecting their dwellings. The standards are related to fire, heat, sound, durability, and structural safety against earthquakes, winds, snow, etc.

The criteria for evaluating structural properties are outlined in this paper, as well as the history and present status of prefabricated dwellings in Japan. A typical prefabricated structural system is shown in the last section.

An analytical model for determining energy dissipation in dynamically loaded structures, J. F. McNamara and S. K. Sharma, *SP444*, pp. IV-70 – IV-89 (Apr. 1976).

Key words: analytical model; dynamic analysis; dynamic laoding; earthquake; energy dissipation; finite element; seismic response; structural engineering.

An analytical procedure is developed which predicts nonlinear cyclic structural response under large reversals of plastic strains. The structure is discretized by means of the finite element approximation, and the material behavior is simulated by a refined analytical model which describes the realistic hysteretic stress-strain curves of A36 steel under arbitrary cycles of load. In order to test the validity of this material model, some comparisons are made with experimental values of the inelastic response of a simply supported beam under cyclic bending. The model is subsequently used in the dynamic analysis of a portal frame subjected to a selected portion of the El Centro NS earthquake acceleration record. The improved cyclic response with the current approach is illustrated by comparing results with those obtained using a simple bilinear kinematic hardening material approximation. Comparisons are also made with values obtained using a commercially available nonlinear frame analysis computer program. Some final comments are made regarding the rate of solution convergence with integration time step size for two different temporal integration operators used in this analysis.

Design of pile foundations subjected to lateral loads, M. Nagao, T. Okubo, K. Komada, and A. Yamakawa, *SP444*, pp. IV-90 – IV-112 (Apr. 1976).

Key words: design; earthquake; highway bridges; lateral loads; pile head; piles; structural engineering.

This report presents a number of basic items relative to the design of pile foundations subjected to lateral loads, and deals with the present design status of highway bridges Japan. Also presented are items to be further studied for t design standardization of pile foundations subjected lateral loads. Such problems as the deformation mechanis of group-pile structures are examined.

This report presents the method by reinforcement of t pile-head.

Comprehensive seismic design provisions for buildings, C. Culver, *SP444*, pp. IV-113 – IV-126 (Apr. 1976).

Key words: building codes; buildings; design; earthquake structural engineering.

A review of the development of earthquake design pro sions for U.S. building codes is presented. Suggested re sions to the current provisions are noted. A cooperative pr ject directed toward developing comprehensive seism design provisions is described. The organizational structu for the project including a breakdown of the Task Comm tees required to develop the provisions and work statemer for each Task Committee are included.

Wind loading and modern building codes, E. Simiu and R. Marshall, *SP444*, pp. IV-127 – IV-144 (Apr. 1976).

Key words: building codes; buildings; deflections; dynam response; gust factors; structural engineering; wind loads.

The differences between the dynamic alongwi response, the gust factors, and the total alongwind respon obtained using various current procedures may in certa cases be as high as 200, 100, and 60 percent, respectivel The purpose of this paper is to investigate the causes of su differences. To provide a framework for this investigatio the paper presents an overview of the questions involved determining alongwind structural response, and a critic description of the basic features of procedures currently use. A comparison is made between alongwind deflectio of typical buildings selected as case studies, calculated b both new and traditional procedures, some of which a described in various building codes. The reasons for the di ferences between the respective results are pointed out. Th procedures were evaluated on the basis of a recent developed method which utilizes a logarithmic variation wind speed with height above ground, a height-depende expression for the spectrum of the longitudinal wind spee fluctuations. The method also allows for realistic cross-co relations between pressures on the windward and leewar building faces.

Seismic retrofitting of existing highway bridges, J. D. Coope R. R. Robinson, and A. Longinow, *SP444*, pp. V-1 – V-2 (Apr. 1976).

Key words: design; earthquakes; highway bridge retrofitting; soil-structure interaction; structural engine ing.

The retrofitting of existing highway bridges, to provide a added measure of protection against collapse due t earthquake ground motion, is of great importance. This i terest heightened in the United States following the San Fe nando earthquake of 1971, which caused extensive damag to a number of modern freeway structures.

Some of the specific concepts for retrofitting to be ex plored include: (1) widening of bearing supports, (2 motion restrainers across hinges, (3) ties across expansio joints, (4) the elimination of expansion joints, and (5 adding ties or reinforcing to existing columns.

The monetary savings, resulting from an effective retrof program in preventing collapse of structures, would far ex

ceed the cost of the research involved in generating feasible and practical retrofit details.

This is a progress report on research which will result in mathematical techniques to identify the seismically vulnerable bridge details and a catalog of retrofit techniques. Such techniques will permit strengthening of such weak links, in the total structure integrity.

Dynamic tests of structures using a large scale shake table, S. ıaba, *SP444*, pp. V-25 – V-34 (Apr. 1976).

Key words: dynamic tests; earthquake simulator; shake table; structural engineering; tests.

Since 1970, a large scale shake table located at the National Research Center for Disaster Prevention (NRDP) has been widely used for the dynamic testing of structures. This paper presents the results of some of those dynamic tests, using this jumbo earthquake simulator, and the results obtained from some other shake tables operated by other research institutes in Japan.

A methodology for evaluation of existing buildings against rthquakes, hurricanes and tornadoes, H. S. Lew and C. G. ulver, *SP444*, pp. V-35 – V-49 (Apr. 1976).

Key words: buildings; damage; disaster; dynamic analysis; earthquakes; hurricanes; natural hazards; structural engineering; tornadoes, wind.

A methodology is presented for evaluation of existing buildings to determine the risk to life safety from natural hazard conditions and to estimate the amount of expected damage. Damage to structural building components resulting from the extreme environments encountered in earthquakes, hurricanes, and tornadoes is considered. The methodology has the capability of treating a large class of structural types including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. Three independent but related sets of procedures for estimating damage for each of the natural hazards are included in the methodology. The first set of procedures provides a means for qualitatively determining the damage level on the basis of data collected in field surveys of the building. The second set utilizes a structural analysis of the building to determine the damage level as a function of the behavior of critical elements. The third set is based on a computer analysis of the entire structure. All three sets of procedures are based on the current state-of-the-art. The procedures are presented in a format which allows up-dating and refining.

Experimental research on the aseismic characteristic of spheral steel tank for liquid petroleium gas, K. Nakano and M. 'atabe, *SP444*, pp. V-50 – V-62 (Apr. 1976).

Key words: dynamic analysis; earthquake; seismic design; seismic response; spherical tanks; structural design.

The results of static and dynamic tests on a spherical steel tank are given in detail. A theoretical technique to explain the "sloshing" effect is presented. A proposal for a safer design procedure to replace the present aseismic design practice is presented.

Research on minimizing earthquake structural damage to sine-family dwellings, W. J. Werner, *SP444*, pp. V-63 – V-65 \pr. 1976).

Key words: building codes; construction practices; damage; earthquake; houses; residential dwelling.

This paper discusses proposed research work to be carried out by the Applied Technology Council of the Structural Engineers Association of California under the sponsorship of the Department of Housing and Urban Development. The objective of the project is to develop a manual of recommended construction practice for earthquake resistive dwellings, for use primarily by builders, building officials, field inspectors, plan checkers, and designers.

The manual is intended to explain the structural behavior of single-family dwellings and townhouses subjected to forces produced by earthquake shocks, illustrate the HUD Minimum Property Standards, building code earthquake requirements and sound practical construction methods and details for the reduction of single family dwelling damage. The paper discusses the need for this research, the various tasks the contractor will perform, and the final products expected to be achieved by the research program.

Earthquake engineering research supported by the National Science Foundation, C. C. Thiel, *SP444*, pp. V-66 – V-79 (Apr. 1976).

Key words: earthquake engineering; grant; RANN; sponsorship; structural engineering.

A summary of earthquake engineering research work conducted by various researchers throughout the United States under the sponsorship of the National Science Foundation is presented.

The wind engineering program, M. P. Gaus, *SP444*, pp. V-80 – V-82 (Apr. 1976).

Key words: research programs; sponsorship; wind engineering.

A summary of wind engineering research work conducted by various researchers under the sponsorship of the National Science Foundation is presented.

Preliminary report on present status and development project of volcanological observation and research in Indonesia, A. Suwa, *SP444*, pp. VI-1 – VI-15 (Apr. 1976).

Key words: field observation; Indonesia; Japan; technical aid; volcanoes.

Indonesia has about 130 active volcanoes and their eruptions are characterized by dangerous violent explosions, nuee ardente, and volcanic mud-flows. The Geological Survey of Indonesia (GSI), Ministry of Mines, has, therefore, been carrying out observations and surveillances of volcanic activities throughout the country.

The Government of Japan, in response to a request from the Government of Indonesia, has decided to give assistance in this field of science in the framework of the Colombo Plan. The Overseas Technical Cooperation Agency (OTCA), the executing agency for the Government of Japan, has, therefore, dispatched a preliminary survey mission, headed by the author of this report, Akira Suwa, of the Japan Meteorological Agency to Indonesia in 1972.

The mission stayed in Java and Bali from November 22 to December 23, 1972, and visited the Ministry of Mines at Djakarta, the GSI at Bandung, and eight active volcanoes (eleven observatories) in order to study the possible scope of cooperation in Volcanology between Japan and Indonesia. The mission recognized two serious problems in Indonesia: deficiency of experts in volcanology, and shortage of up-to-date volcanological instruments.

Therefore, the recommendation by the preliminary survey mission to both governments was as follows:

1. Dispatch for several years the following Japanese experts to Indonesia; a. Instrumental seismologist, b. Volcano physicist; c. Volcanological geologist/petrologist.

2. Train junior volcanologists of the GSI in Japan.

3. Provide Indonesia with the following instruments; a. Seismographs for permanent and temporary observations; b. Instruments for petrological and mineralogical laboratory.

Use of stabilized adobe block and cane in construction of low-cost housing in Peru, S. G. Fattal, *SP444*, pp. VI-16–VI-24 (Apr. 1976).

Key words: adobe; cane; earthquake; housing; Peru; technical aid.

A description of the use of adobe block and cane for construction of low-cost housing in seismic areas of Peru is described.

A comment on the technological aid to developing countries, M. Nagao and T. Okubo, *SP444*, pp. VI-25–VI-31 (Apr. 1976).

Key words: earthquake; Japan; natural disaster; storm; structural engineering; technological aid.

This paper describes the technological aid required in developing countries, after a natural disaster, as observed by the writer during surveys of storm and earthquake disasters in these developing countries.

The writer classifies the aid required after a natural disaster into three categories, that is, emergency aid, technological aid, and economic aid. The problems related to the scientific and technological areas in the developing countries after a natural disaster are discussed.

The technological aid is classified into short and long term aid.

Finally, the problems related to the required technological aid are discussed and then the necessary Governmental policy which has been prepared for implementation of a low-cost and disaster resistant housing system is described.

SP445-1. **The National Measurement System for Time and Frequency,** A. S. Risley, *Nat. Bur. Stand. (U.S.), Spec. Publ. 445-1*, 72 pages (June 1976) SD Catalog No. C13.10:445-1.

Key words: atomic frequency standards; aviation industry; electric power industry; National Measurement System, position location; shipping and boating industries; Standards laboratories; telephone industry and specialized carriers; time and frequency; time scales; users of NBS radio broadcasts.

The results of a study of the National Measurement System for Time and Frequency are given. The system is viewed from three vantage points: 1) The *Instrumentation* that provides sources of time and frequency (T&F). 2) The *Suppliers and Users* of T&F. 3) The *Calibration hierarchies* for T&F sources. An attempt is made to determine the technological, scientific, economic, and social effects of the system. Predictions are made about possible important changes in the system. The past, present, and possible future position of NBS in the system is described in detail.

SP446. **Building technology project summaries,** M. Olmert, *Nat. Bur. Stand. (U.S.), Spec. Publ. 446*, 108 pages (May 1976) SD Catalog No. C13.10:446.

Key words: building research; building technology; codes; criteria; project summaries; standards; technical bases.

The Center for Building Technology provides the technical and scientific bases for criteria and standards that improve the usefulness, safety, and economy of buildings while conserving building materials and energy. The Center's activities support the building technology program of the Federal, State and local government; assists design professions, building officials and th research community by developing design criteria that improv buildings; and assists manufacturers of building products b developing criteria for evaluating innovative building materials This report summarizes the Center's projects for calendar yea 1975. It enables individuals to get a clear impression of CB research activities.

SP447. **Weights and measures standards of the United States – brief history,** L. V. Judson, *Nat. Bur. Stand. (U.S.), Spec Publ. 447*, 44 pages (Mar. 1976) SD Catalog No C13.10:447.

Key words: history of measurement standards; measures metric system; standards; units of measurement; weights.

Two publications of the National Bureau of Standards, nov out of print, that deal with weights and measures have ha widespread use and are still in demand. The publications ar NBS Circular 593, The Federal Basis for Weights and Measure (1958), by Ralph W. Smith, and NBS Miscellaneous Publicatio 247, Weights and Measures Standards of the United States – Brief History (1963), by Lewis V. Judson.

To meet the current demand for information on the history c weights and measures in the United States, Miscellaneous Publi cation 247, referred to above, updated where needed to bring i into accord with current usage, is reprinted in this publication together with a brief addendum that discusses important event involving weights and measures of the period 1963-1975. NB Circular 593 is not being reprinted because of the significan overlap of material treated in the two publications.

SP448. **Automation technology applied to public service** Proceedings of a Conference on Automation Technology Ap plied to Public Service, held at the National Bureau of Stan dards, Gaithersburg, MD, May 21-22, 1974, E. G. Johnsen Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 448*, 87 pages (Sept 1976) SD Catalog No. C13.10:448.

Key words: automation technology; economic impact of au tomation; productivity improvement; public services; socia impact of automation.

The Conference on Automation Technology Applied to Publi Service, held in May 1974, was cosponsored by the National Bu reau of Standards, the General Accounting Office, the Nationa Science Foundation and the Urban Institute. The objectives o the conference were first, to explore the use of automatio technology as a means of increasing the efficiency of Govern ment in providing higher quality public services at lower cost and second, to explore the political, social and economic aspect involved in managing the public service applications of automa tion. Potential uses of automation technology discussed includ automating operations in environments hazardous to safety an health of people, such as fire fighting, and the automation of ser vices that are tedious, boring or demeaning for people to do. Th spectrum of potential applications of automation technology i public service ranges from garbage collection to aids to the han dicapped and from water treatment process control to the adap tive computerized regulation of traffic in urban areas. Some par ticipants warn that the way in which automation technology i applied must be carefully thought out and supervised in order t minimize disruptive economic and social effects. *Thes proceedings include the following papers (indented):*

Introductory address, R. M. Davis, *SP448*, pp. 1-4 (Sept 1976).

Keynote address: Automation Technology: Key to public ser vice productivity improvement, T. D. Morris, *SP448*, pp. 5- (Sept. 1976).

Economic and social view of automation: A labor view of automation technology, M. Roberts, *SP448*, pp. 8-9 (Sept. 1976).

Technology, humanity and the cities, L. H. Blair, *SP448*, pp. 9-10 (Sept. 1976).

Session I: Automation for urban public service operations, J. M. Carlson, C. F. Guarino, W. W. Isman, M. G. Stragier, D. S. Wasserman, and J. McManama, *SP448*, pp. 11-19 (Sept. 1976).

Session II: Automation for occupational welfare, J. H. Stender, R. L. Atwood, W. E. Bradley, W. R. Knowles, and R. J. Straw, *SP448*, pp. 20-28 (Sept. 1976).

Session III: Automation for the handicapped, J. M. Benjamin, Jr., K. R. Ingham, E. Kwatny, W. G. Holsberg, and J. S. Albus, *SP448*, pp. 29-35 (Sept. 1976).

Session IV: Recovery of ocean resources for public benefit, A. Spilhaus, M. G. Johnson, A. Mucciardi, E. J. Beck, R. W. Uhrich, G. Guenther, and R. H. Cassis, Jr., *SP448*, pp. 36-43 (Sept. 1976).

Session V: Recovery of underground resources for public benefit, W. B. Schmidt, W. C. Helt, and B. M. Goldwater, Jr., *SP448*, pp. 44-48 (Sept. 1976).

Session VI: Impact of automation on the public, W. Lepkowski, B. Bova, J. McCarthy, J. S. Albus, D. V. DeSimone, L. K. O'Leary, M. MacCoby, and G. Tyler, *SP448*, pp. 49-59 (Sept. 1976).

Session VII: Automation for transportation, R. H. Cannon, Jr., C. R. Peterson, J. D. Ward, D. Roos, and D. L. Cooper, *SP448*, pp. 60-64 (Sept. 1976).

P449. **Chemical kinetics of the gas phase combustion of fuels. (A Bibliography on the Rates and Mechanisms of Oxidation of Aliphatic C_1 to C_{10} Hydrocarbons and of Their Oxygenated Derivatives),** F. Westley, *Nat. Bur. Stand. (U.S.), Spec. Publ. 449*, 138 pages (Oct. 1976) SD Catalog No. C13.10:449.

Key words: bibliography; chemical kinetics; combustion; free radicals; gas phase; hydrocarbons; oxidation; oxygen; oxygenated organic compounds; ozone.

A reaction oriented list of references is provided for papers nd reports containing rate data for gas phase reactions of combustion and oxidation of aliphatic saturated or unsaturated C_1 to $_{10}$ hydrocarbons, alcohols, aldehydes, ketones, ethers, peroxles and their free radicals. The list also includes decomposition, isproportionation, atom transfer and recombination reactions f the oxygen containing species noted above. Pyrolytic reacons of hydrocarbons and their radicals are excluded. All the rocesses listed here have been reported to occur in the gas hase combustion of fuels. In addition, a list of critical reviews ealing with the reaction kinetics of the above processes and a st of papers dealing with generalized mechanisms of the same eactions are also included. More than 800 papers covering 540 eactions are listed. The period covered extends from 1902 rough June 1975.

P451. **Data base directions. The next steps.** Proceedings of the Workshop of the National Bureau of Standards and the Association for Computing Machinery, held at Fort Lauderdale, FL, Oct. 29-31, 1975, J. L. Berg, Ed., R. G. Canning, D. L. Adams, R. W. Bemer, G. Dodd, R. M. Gall, and C. D. Trigg, *Nat. Bur. Stand. (U.S.), Spec. Publ. 451*, 175 pages (Sept. 1976) SD Catalog No. C13.10:451.

Key words: auditing; cost/benefit analysis; data base; data base management; DBMS; government regulation; management objectives; privacy; security; standards; technology assessment; user experience.

What information about data base technology does a manager need to make prudent decisions about using this new technology? To provide this information the National Bureau of Standards and the Association for Computing Machinery established a workshop of approximately 80 experts in five major subject areas. The five subject areas were auditing, evolving technology, government regulations, standards, and user experience. Each area prepared a report contained in these proceedings. The proceedings provide guidance on steps managers should follow to prepare themselves and their organization for the installation of data base management concepts. The auditing working panel noted the increased vulnerability of organizations who integrate their formerly dispersed and redundant files into a data base and suggest actions to address this risk. The technology report noted several promising parallel developments but concluded that the future would see evolving, rather than revolutionary data base progress. Government regulations, particularly the drive for individual privacy rights, were seen to play an important role in determining data base directions and the panel's guidance on cost impact suggest that organizations would experience reduced costs with data base technology. Standards pervaded all issues and were found necessary in several sub-areas of data base technology but the panel saw no immediate likelihood of national data base standards. The user experience working panel noted that data base systems had impacted their organizations to the extent of reconsidering existing data flows, areas of responsibilities, and procedures. *These proceedings include the following papers (indented):*

Introduction, R. G. Canning, General Chairman, *SP451*, pp. 1-2 (Sept. 1976).

A manager's viewpoint, D. B. Magraw, Keynote Speaker, *SP451*, pp. 3-11 (Sept. 1976).

What experience has taught us, R. M. Gall, Chairman, *SP451*, pp. 13-28 (Sept. 1976).

Standards: A data base imperative, R. W. Bemer, Chairman, *SP451*, pp. 31-39 (Sept. 1976).

Auditing the data base, D. L. Adams, Chairman, *SP451*, pp. 41-64 (Sept. 1976).

Impact of government regulations, C. D. Trigg, Chairman, *SP451*, pp. 67-78 (Sept. 1976).

Data base technology—Present and future, G. Dodd, Chairman, *SP451*, pp. 81-103 (Sept. 1976).

Background, *SP451*, pp. 105-106 (Sept. 1976).

SP452. **MFPG—The role of coatings in the prevention of mechanical failures.** Proceedings of the 23d Meeting of the Mechanical Failures Prevention Group, held at the National Bureau of Standards, Gaithersburg, MD, Oct. 29-31, 1975, T. R. Shives and W. A. Willard, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 452*, 199 pages (Sept. 1976) SD Catalog No. C13.10:452.

Key words: barrier film; chemical coatings; failure prevention; mechanical failure; metal coatings; plated coatings; polymer coatings; solid film lubricants; sputtered coatings; wear.

These Proceedings consist of a group of eighteen submitted papers and discussion from the 23d Meeting of the Mechanical Failures Prevention Group which was held at the National Bureau of Standards in Gaithersburg, Maryland on October 29-31, 1975. The central theme of the Proceedings is the Role of

Coatings in the Prevention of Mechanical Failures, with emphasis on polymer coatings, metal coatings, solid film lubricants, and chemical coatings. *These proceedings include the following papers (indented):*

The friction and wear of polymeric coatings on metal, K. C. Ludema, *SP452,* pp. 3-13 (Sept. 1976).

Key words: adhesion; coatings; friction; metal; polymers; wear.

Polymeric coatings on metals wear and/or debond when rubbed. Information on wear is available from tests using bulk polymers which usually have a different structure than do thin films. The bond strength requirements for rubbing surfaces appear to be greater than that developed by the technology centered in adhesives and composite materials industries. Many of the factors involved in wear life and bonding are summarized in the paper. Recent and broad ranging references are given for each of the major points in the paper.

Performance studies of polymer processed mechanical and structural components, M. J. Devine, *SP452,* pp. 14-24 (Sept. 1976).

Key words: components, structural; dry powder painting; mechanical and structural components; polymer processed mechanical and structural components; structural and mechanical components.

A technique which has become known as "dry powder painting" is one of the major advances made in the application of coatings. This technique is based upon the deposition of specially formulated, thermoplastic or thermosetting, heat-fusible powders on metallic substrates. Since there are no solvents present, the coating can be cured immediately after application. One of the most obvious advantages of this method is the absence of pollution and safety problems associated with organic solvents that are used in most liquid paint systems. A second advantage is that coatings may be obtained by this process from materials that cannot be applied by liquid paint techniques because of their poor solubility in organic solvents. Dry powder techniques are readily adaptable to current production methods and are easily learned by product finishing personnel. Because of special requirements in particle size, particle size distribution, and other properties, dry powder coatings are generally more expensive than liquid paint systems. However, in view of the advantages of dry powder processes over wet painting techniques the overall cost differences are probably minimal. In addition as much as 95 percent of the dry powder material can be utilized if a powder recovery system is used.

Advantages similar to those reported for dry powder techniques are also claimed for electrocoating. This process can be compared to electroplating of metals, and, like the dry powder method, it also avoids the use of organic sovents.

Nylon 11 as a lubricant and corrosion preventative coating, R. G. Baker, G. H. Kitchen, and R. R. Wells, *SP452,* pp. 25-30 (Sept. 1976).

Key words: abrasion; corrosion protection; friction; marine environment; powder coating; salt water; solid lubrication.

The working bearing surfaces of Sea Plow IV, a vehicle designed to lay cable in a 4-ft trench in the ocean floor, must be protected from corrosion, internal friction plus abrasion from sand, mud and silt. Examination of this problem suggested that a coating of nylon 11, applied electrostatically as a dry powder, could afford protection against all of thes conditions. Conventional application techniques wer modified to permit application of the coating at dockside Results have been excellent as evidenced by Sea Plow IV more than one year of troublefree operation.

Mechanical design concepts for coated nuclear fuel particle J. M. Tobin, *SP452,* pp. 31-42 (Sept. 1976).

Key words: computer modeling on a microscal elastoplastic micropressure vessels; failure predictabilit through small size; microencapsulated coated fuel particle

Retention of fission products in microspherical coate particles depends upon the mechanical integrity of th coatings. Mechanical design concepts have been develope over a 15-year period which led to the fabrication of high successful multiple coated particles such as the TRIS coated particles. An overview of this development described.

Nickel-phosphorus alloy coatings for wear resistance, C. I Johnson, F. Ogburn, *SP452,* pp. 45-55 (Sept. 1976).

Key words: auto-catalytic nickel; auto-catalytic nicke hardness of; auto-catalytic nickel, wear of; electrole nickel; electroless nickel, hardness of; electroless nicke wear of; nickel, auto-catalytic; nickel, electroless; nicke phosphorus alloy; wear resistant alloy.

Electroless nickel coatings are nickel alloys generally wi a nominal composition of 8 wt percent phosphorus, applie to metal substrates from a nickel solution by an autocat lytic chemical process. They are used for protecting ste from corrosion and wear, and are generally more corrosic and wear resistant than electroplated nickel.

Heat treatments can increase significantly the wear r sistance and hardness of electroless nickel. This occurs b precipitation hardening and the precipitation of a nick phosphide. The hardness depends on the heat treatment an on the alloy composition and often attains a Knoop hardne of 900-1000, equivalent to the hardness of electrodeposite chromium.

Tests by several laboratories show improved wear r sistance with appropriate heat treatment and in some ci cumstances, the electroless nickel coatings have a high wear resistance than electrodeposited chromium. Wear r sistance of electroless nickel can also be improved by the i corporation of small particles and hard material into th coating during the plating process.

Chromium deposit structure has a profound influence on pr perties, W. H. Safranek, *SP452,* pp. 56-63 (Sept. 1976).

Key words: corrosion; crack-free chromium; electroplatin fast plating; fatigue strength; grinding; hardness; stress; te sile strength; wear.

The optimum structure of chromium electroplate shou be specified for each individual application. Crack-fr chromium supplies good corrosion protection and goo wear resistance for some applications. Customary ha chromium is preferred for resisting wear in other applic tions. High-crack-count chromium is mandatory for avoi ing harmful effects on the fatigue strength of high-streng steel substrates. Each of these structures can be deposit by a new process that is 25 to 50 times faster than the cust mary rate for chromium plating.

Plated coatings for electric contacts, M. Antler, *SP452,* p 64-71 (Sept. 1976).

Key words: contact lubrication; corrosion inhibitors; ele

trical contacts; gold plate; palladium; polymer in gold; porosity in gold; solder plate; tin-nickel alloy; tin plate; underplatings for gold; wear of gold.

Electrical contacts, such as those in separable connnectors, are required to have low and stable contact resistance. For high reliability connector applications in low voltage circuits, gold is the preferred contact material because of its chemical inertness. Recent studies have shown that the most common gold electrodeposits, which contain cobalt or nickel as hardeners, are complex materials, containing 10 percent or more by volume of organic polymers, potassium compounds, and other substances. Failure in service can occur if the deposit is porous, since films may form on the surface by reaction of the base substrate metal with air pollutants at pore sites. The use of underplatings and smooth substrates can reduce the thickness of gold required for low porosity; inhibitor coatings may suppress corrosion reactions, and galvanically inert substrates can even eliminate pore corrosion. Wear-induced porosity is also a failure process, and contact lubrication is effective in its control. Degradation by diffusion of substrate metals, such as copper, to the surface where films form is controlled by barriers, like nickel underplate. The high cost of gold has led to the search for alternate contact materials. Palladium plate and the soft base metals, tin and solder plate, have achieved limited acceptance.

Compatibility effects when soft metals are used as solid lubricants, E. Rabinowicz, *SP452*, pp. 72-83 (Sept. 1976).

Key words: compatibility; electropolated soft metal film coatings; metallurgical; metals; soft metals; solid lubricants.

The purpose of this study has been to test, mainly by means of metal cutting experiments, the extent to which the wear life of electroplated soft metal film coatings is governed by the metallurgical compatibility between the coating and the other sliding surface. Experiments have been carried out using hard steel tools coated with various soft metals, and cutting a number of different workpiece metals. Two different configurations were used, namely milling and shaping, and in some cases the lubricant was only applied once at the beginning of the test, while in other cases it was reapplied continuously. It was found that long tool life resulted when the soft metal had low metallurgical compatibility with the workpiece material but not otherwise. The other parameter investigated, namely relative mechanical strength between film and substrate was found to be much less significant. This is in contrast to the case of the friction coefficient, which has been found to be greatly influenced by the mechanical strength ratio.

Reduction of sliding wear by metallic coatings, S. Jahanmir and N. P. Suh, *SP452*, pp. 84-93 (Sept. 1976).

Key words: coatings, metallic; metallic coatings; sliding wear.

The role of soft metallic coatings in sliding wear has been examined experimentally. The results indicate that the tribological behavior of soft coatings is consistent with the delamination theory of wear, especially the critical nature of the plating thickness. It is shown that a reduction in wear rate of three orders of magnitude is possible when the coating material is softer than the substrate and thinner than a critical thickness. The optimum plate thickness was found to be less than 1 μm for cadmium, silver, gold or nickel plated on various steels. As the plate thickness is increased, wear by delamination within the plate occurs. Environmental effects are important in coating utilization.

The search for factors to prevent mechanical failures due to corrosion with solid film lubricants, M. K. Gabel and M. B. Peterson, *SP452*, pp. 97-105 (Sept. 1976).

Key words: corrosion; electrochemical; lubricants; salt-spray.

The failure of mechanical components of contemporary flight vehicles has frequently been attributed to the corrosion characteristics of solid film lubricants. An ongoing program at the Naval Air Development Center is investigating how some parameters affect corrosion between solid film lubricants and various aircraft alloys. This paper will summarize some of the findings of this study.

Rust-inhibited nonreactive perfluorinated polymer greases, J. Messina, *SP452*, pp. 106-119 (Sept. 1976).

Key words: chemisorption; corrosion preventives; inhibitor additives; LOX compatible greases; nonreactive lubricants; rust inhibited perfluoro greases; surface chemistry lubrication.

Perfluoroalkylpolyether fluids thickened with polytetrafluoroethylene were studied in connection with the development of rust-inhibited chemically inert greases for liquid-fueled rocket engines. It was found that 1.0 to 3.0 wt percent of a physically and chemically modified organophilic dimethyloctadecylbenzyl ammonium bentonite + sodium nitrite imparts very effective rust-preventive properties to perfluoro polymer grease mixtures. Data are given which show that the rust-inhibited greases are nonreactive on contact with conventional fuels and oxidizers, exhibit lubricating properties comparable to soap-thickened greases with a significant improvement in extreme pressure properties, and are nonreactive at high impact energies in the presence of LOX. The results of this work are applicable to all liquid-fueled rocket engines for missiles and space vehicles.

The role of coatings in the prevention of erosion damage, A. P. Thiruvengadam and A. A. Hochrein, Jr., *SP452*, pp. 120-123 (Sept. 1976).

Key words: adhesion; cavitation; coatings; design charts; elastomers; erosion; Hopkinson pressure bar apparatus; impedances; mismatching; stress wave interactions; substrates; tearing; vibratory apparatus.

Among the various methods available for protection against cavitation erosion, elastomeric coatings offer great potential. However, adhesion failures, tearing, and substrate mismatching are some of the problems to be solved for a successful application of protecting coatings. Basic studies in understanding this problem includes stress-wave interaction analysis, controlled experiments with a vibratory cavitation erosion apparatus and the generation of high strain data with the help of a Hopkinson pressure bar apparatus. It is hoped that such a coordinated approach would lead to the design and development of successful coating systems.

Solid film lubricant to prevent fretting damage in titanium engine components, B. D. McConnell, *SP452*, pp. 124-131 (Sept. 1976).

Key words: curing agent; fretting; silicone resin; solid lubricants; titanium; wear.

An air drying solid film lubricant originally developed for applications in the field has been found to be an excellent coating for prevention of fretting damage in titanium-titanium mated parts. This film, designated AFSL-41, is composed of molybdenum disulfide (MoS_2) and antimony triox-

ide (Sb_2O_3) carried in a methyl phenyl silicone binder. The film air dries without heat through the use of a curing agent, an amino-alkyl alkoxy-silane. A brief description of the formulation is presented along with laboratory evaluation data comparing its antifretting performance with other candidate materials. The performance on titanium led to its consideration as a candidate antifretting coating for titanium components. The various screening tests used to determine antifretting properties are described along with results which led to AFSL-41 being selected for full scale engine tests. Current use of AFSL-41 by two gas turbine engine manufacturers on a production basis is discussed and the types of applications (over 100 in one engine) are described.

A study of solid lubricated gears at elevated temperatures, A. J. Haltner, D. K. Snediker, K. E. Demorest, and G. C. Marshall, *SP452,* pp. 132-148 (Sept. 1976).

Key words: fluoride films; gears; molybdenum disulfide; solid lubricants; wear.

An experimental study has been made of the performance of advanced, state-of-the-art solid lubricants applied to spur gears expected to operate to high temperatures in reusable space vehicles (space shuttle). Tests of Inconel 718 gears covered the range 25-482 °C in air, and the lubricants studied included MoS_2 in several binders (glass, metal matrix, polyimide, and polyphenylene) and mixed fluoride compositions. All of the combinations demonstrated acceptable wear over portions of the temperature range, but the glass bonded films showed the most promise—particularly at higher temperatures.

Vapor deposition of wear-resistant coatings, W. J. Wilson, M. F. Browning, and J. M. Blocher, Jr., *SP452,* pp. 151-169 (Sept. 1976).

Key words: chemical; coating; deposition; vapor; wear.

Vapor deposition processes by which a variety of wear and environment resistant coatings are applied are described. Criteria for selecting coating/substrate systems are discussed in the light of economic and technological changes.

Several examples of vapor-deposited, wear-resistant coatings are given in addition to specific examples of commercial applications.

Barrier films for miniature bearings, M. K. Bernett and H. Ravner, *SP452,* pp. 170-176 (Sept. 1976).

Key words: barrier films; bearings; fluorinated polymers; lubricant migration; lubricants; spreading prevention.

Miniature bearings (less than 30 mm O.D.) are employed in large numbers by the Navy in synchro-servo motors, guidance systems and general instrument use. The most frequent cause of malfunction of these mechanisms is bearing lubricant failure; in the majority of instances, failure is induced by migration of the lubricant away from the balls and races, both during storage and service. As a result of long-term basic studies at NRL on wetting and spreading of liquids, a low-energy, nonwetting "barrier film" was developed, which when applied to bearing race surfaces, effectively prevented migration of the lubricant. The increasing use of these films has resulted in major reductions in replacement costs and maintenance, and has significantly increased the reliability of the mechanisms involved.

Potential of sputtered coatings for improved gas bearing instrument performance, L. L. Fehrenbacher, B. D. McConnell, C. Pellerin, and K. R. Mecklenburg, *SP452,* pp. 177-186 (Sept. 1976).

Key words: antimony trioxide; friction; molybdenum disulfide; spin axis gas bearings; sputtered coatings; surface characterization; wear life.

Sputtered coatings were applied to I-400 beryllium substrates to determine and eventually optimize their friction and wear performance relative to their potential for gas bearing inertial instrument applications. Solid lubricant-carbide basecoat combinations were sputter deposited under varying conditions of substrate bias and thicknesses. The surface morphology and chemistry of the coatings were characterized prior and after friction and wear evaluations using scanning electron microscopy and scanning Auger microscopy techniques. The friction and wear tests consisted of sliding a 1/8 inch TiC ball under load on the coated disc specimens rotating at 60 RPM. MoS_2-Sb_2O_3 solid lubricants were deposited on TiC, WC and B_4C sputtered undercoats at varying thicknesses and sputtering conditions. The solid lubricant combinations exhibited consistent wear life behavior showing moderate and strong dependency on the substrate bias and solid lubricant thickness, respectively, regardless of the underlying substrate. Correlations between coating chemistry, morphology, sputtering conditions and friction and wear performance are given.

Ferrography of polymer formation under lubricated rubbing contact—An exploratory investigation, A. A. Reda, *SP452,* pp. 187-191 (Sept. 1976).

Key words: ferrographic analysis; lubricated rubbing contact; polymer formation.

Ferrographic analysis of lubricant samples from a variety of operational machines and test rigs has revealed the presence of nonmetallic particles. Some of these particles have characteristic shapes and are composed of polymers. For example, under relatively high load nonmetallic particles shaped like rolling pins were formed when a lubricant per specification Mi 1-L-23699 was used. The same particles were produced when polyphenyl ether was used as lubricant.

It was speculated that under the conditions of the test the lubricant forms a polymeric film at the rubbing surfaces and it is rolled in the shape of rolling pins when it is pealed off. Furey has shown that polymer films are formed directly on rubbing surfaces and that these films are a factor in reducing wear. Furthermore, it is well known that different additive packages in lubricants meeting the same specifications lead to different wear rates under identical load conditions. It was considered useful to determine if ferrography could provide further information on the phenomena and to assess if ferrographyic analysis could be used to study the performance of lubricants.

SP453. **Ultrasonic tissue characterization.** Proceedings of a Seminar held at the National Bureau of Standards, Gaithersburg, MD, May 28-30, 1975, M. Linzer, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 453,* 274 pages (Oct. 1976) SD Catalog No. C13.10:453.

Key words: absorption; acoustic; A-scan; attenuation; B-scan; frequency; image; impedance; medical diagnosis; microscopy; pattern recognition; reconstruction; scattering; tissue characterization; tissue parameters, tissue signature; tumor; ultrasonic spectroscopy; ultrasound; velocity.

An international Seminar on Ultrasonic Tissue Characterization was held at the National Bureau of Standards on May 28-30, 1975. The meeting was cosponsored by the National Bureau of Standards, the National Science Foundation and the Nation

nstitutes of Health. This volume contains extended versions of 0 of the 21 talks presented at the Seminar. Topics covered include techniques for measurement of ultrasonic tissue parameters, the dependence of tissue properties on physical and biological variables (*e.g.*, ultrasonic frequency, temperature) and pattern recognition techniques. *These proceedings include the following papers (indented):*

The NSF (RANN) integrated program on medical ultrasonics, G. B. Devey, *SP453*, pp. 7-10 (Oct. 1976).

Key words: applied research; imaging; instrumentation technology; medical ultrasonics; NSF; RANN; R & D incentives; tissue characterization; tissue signature; ultrasonic diagnosis; ultrasound.

Recommendations made by the National Foundation (NSF) Survey Team on Ultrasonic Imaging for the conduct of a Medical Instrumentation Experiment to provide incentives to commercial firms and for the preparation of an R & D agenda for future developments in medical ultrasonics have been implemented. Projects emphasizing substantial improvements in resolution of medical ultrasonic images and investigations into ultrasonic tissue characterization are listed at high priority. The NSF (RANN) Instrumentation Technology program supports research in these areas. In addition to having good potential for making substantial technological advances, the funded projects must also develop the criteria which should be met before results of the research are introduced into clinical medicine. Successful results from a coordinated research and development program in ultrasonic tissue characterization could revolutionize medical diagnosis.

Challenges and opportunities in ultrasound, J. M. Reid, *SP453*, pp. 11-17 (Oct. 1976).

Key words: diagnosis; Doppler effect; optimization; resonance; scattering; tissue characterization; tissue parameters; tumor detection; ultrasound.

The scientific study of the ultrasonic properties of tissue is on the threshold of being able to contribute useful knowledge needed to improve the utility of ultrasonic medical diagnostic instruments. There is ample evidence to support these contentions and to guide our future course.

Ultrasonic attenuation, absorption, and velocity in tissues and organs, F. Dunn, *SP453*, pp. 21-28 (Oct. 1976).

Key words: absorption; attenuation; mammalian tissues; tissue parameters; ultrasound; velocity.

Propagation relations for compressional waves in isotropic, elastic media are described briefly and discussed with reference to ultrasonic propagation in biological structures. A selected review of experimentally obtained results from tissues and organs is presented. It is shown that characterization of tissues and organs by their acoustic parameters should be possible.

The scattering of ultrasound by tissues, J. M. Reid, *SP453*, pp. 29-47 (Oct. 1976).

Key words: blood; cross-section; diagnosis; scattering; standardization; tissue characterization; ultrasound.

Most ultrasonic diagnostic equipment is based on the observation of the waves scattered by tissues. Although these instruments generally perform useful clinical diagnosis, they do not provide quantitative measurements of the detailed characteristics of the scattered waves. Such measurements should significantly improve the diagnostic capability of medical ultrasound. The properties responsible for scattering have been shown to be differences in compressibility and density between adjacent tissue structures. The rationale of scattering measurements is considered through a review of direct measurements and substitution techniques which correct for wave shape changes. The necessity of correcting for apparatus parameters and the effects of overlying tissue attenuation is considered. Equations are derived which relate the scattered power to the scattering parameters of tissues and the measuring equipment constants for a number of useful cases.

Use of pattern recognition for signal processing in ultrasonic histopathology, K. Preston, Jr., *SP453*, pp. 51-59 (Oct. 1976).

Key words: analog-digital converter; A-scan; digitization; pattern recognition; speech spectrogram; ultrasound.

New developments in high-speed electronics have made possible real-time digitization of the ultrasonic A-scan as a block of binary words. This makes computer processing of such blocks feasible using techniques previously developed in time-series analysis for communications, speech processing, word recognition, etc. The research reported here is concentrating on: (1) advanced digitization techniques having variable block length and skip-block capability; (2) application of speech spectrogram representation and analysis to A-scan processing; and (3) use of human audition (of the recorded A-scan, properly frequency-translated) to assist in defining the features most useful for A-scan pattern recognition.

Quantitative A-scan analysis of normal and cirrhotic liver, P. N. T. Wells, R. A. Mountford, M. Halliwell, and P. Atkinson, *SP453*, pp. 61-70 (Oct. 1976).

Key words: A-scan; attenuation; computer analysis; impedance; liver cirrhosis; ultrasonics.

The development of quantitative methods of analyzing ultrasonic liver scans is reviewed. These methods are based on measurements of intrahepatic echo amplitudes or echo spacings. Simple techniques indicate that the echo amplitude tends to be increased in cirrhosis. Using a frequency of approximately 1-5 MHz, this was confirmed by computer analysis of the measurements of 100 consecutive cycles of the ultrasonic echo wavetrains in each of 30 separate scans from each of 30 individuals with normal livers, and 13 with cirrhosis. These data were acquired manually. In cirrhotics, the mean echo amplitude was 6 dB greater than in normals. Similar results were obtained with an automated system of data acquisition. The results are compatible with a model in which the observed structure is a random noise effect; the dimensions of the pulse determines the scale of the fluctuation which is observed. The echoes from cirrhotic liver, higher in amplitude but otherwise very similar to those from the normal, could be due to similar targets with greater characteristic impedance mismatches.

Digital A-scan analysis in the diagnosis of chronic splenic enlargement, K. J. W. Taylor and J. Milan, *SP453*, pp. 71-78 (Oct. 1976).

Key words: A-scan analysis; digital; grey-scale ultrasound; spleen; splenomegaly.

Before the availability of grey-scale ultrasound machines, signal processing only permitted the display of the layer echoes which were specularly reflected at large discontinuities of acoustic impedance. The enhanced signal-to-noise

ratio inherent in the grey-scale technique permits, in addition, the display of the internal structure of soft tissue. The amplitude of these low-level echoes is relatively independent of beam orientation and appears to be more dependent on the nature of the interface so that the pattern of the tissue may be specific to each pathology. From clinical observations, high-level echoes are usually associated with benign causes of splenic enlargement, while cellular infiltration, as in many malignancies, results in decreased echo amplitude. Digital A-scan analysis concerns and quantitates this difference.

Attenuation and velocity measurements in tissue using time delay spectrometry, D. H. Le Croissette and R. C. Heyser, *SP453*, pp. 81-95 (Oct. 1976).

Key words: attenuation; phase; swept frequency; time delay spectrometry; tissue; transmission; velocity.

A practical ultrasound system is described which is capable of making measurements of attenuation and velocity in tissue as a function of frequency. This method is based upon a technique known as Time Delay Spectrometry which employs a swept frequency signal and has the ability to provide anechoic ultrasonic measurements. A system operating between 2 and 3 MHz has already been shown to be capable of producing images in soft tissue with a resolution of less than 2 mm. Preliminary measurements on excised tissue using this system have indicated a frequency dependence of attenuation in pathological tissue that is substantially different from that of normal tissue. The method generates the time domain response simultaneously with the received frequency sweep. It is shown that the time response in the apparatus is available as a displayed phasor quantity and that the arrival time of the directly-received signal can therefore be measured to within a few nanoseconds.

Methods of tissue identification by ultrasonic spectra, A. Sokollu, E. W. Purnell, E. Holasek, W. Jennings, and A. Kaya, *SP453*, pp. 97-107 (Oct. 1976).

Key words: color-coded B-scan; Fourier transform; spectral analysis; tissue structure; ultrasound.

Ultrasonic spectral characterization of tissue is based on the retrieval of latent frequency information not normally detected in intensity-modulated B-scan displays. The results of tissue studies and tissue-model studies are presented and discussed. A method for color coding this frequency information into a B-scan display for clinical use is described.

Algebraic reconstruction of spatial distributions of refractive index and attenuation in tissues from time-of-flight and amplitude profiles, J. F. Greenleaf and S. A. Johnson, *SP453*, pp. 109-119 (Oct. 1976).

Key words: acoustic attenuation; acoustic velocity; breast tumor; computerized tomography; heart; reconstruction; refractive index; synthetic focus; tissues; ultrasound.

Two-dimensional distributions of refractive index and attenuation were measured in transverse sections through intact isolated organs, using reconstruction techniques. Profiles of time-of-flight (TOF) and/or amplitude of 10 MHz pulses through the specimen were obtained by rectilinearly scanning two opposing transducers along either side of the specimen in the plane of interest. The received pulses were digitized at a rate of one 8-bit sample per 10 ns for 512 samples, and were analyzed with a computer algorithm which calculated the TOF of the pulse to within ± 10 ns and/or its amplitude. Typically, 256 measurements of TOF and/or amplitude were made in each profile scan for each of 37 angles of view separated by 5°. TOF's through tissue, normalized by TOF through water, were used to calculate velocity and hence, refractive index within the specimen, using an algebraic reconstruction technique (ART). A similar approach was taken to calculate attenuation distributions. Images obtained represented acoustic velocities and/or attenuation in individual cross sections within the tissue specimen with a resolution of 64 by 64 elements ($< 2\text{mm}^2$). The disadvantage of TOF and attenuation reconstruction is that transmission scanning is required. Advantages over B- and C-scan imaging are: (1) dynamic changes in receiver gain are not required; (2) attenuation occurs on only one traversal through tissue; and (3) the absolute values of important acoustic parameters (velocity and attenuation) are determined which may have significant diagnostic value.

Measurement of ultrasonic tissue characteristics by direct and phase-contrast imaging, R. S. Mezrich, D. H. R. Vilkomerson and K. F. Etzold, *SP453*, pp. 121-133 (Oct. 1976).

Key words: attenuation; breast tissue; broadband; high resolution; imaging; large aperture; pathology; pellicle; phase-contrast; transmission; ultrasound; velocity.

This paper describes methods for measurement of the ultrasonic attenuation and acoustic velocity of biological tissue. Initial results are given for a series of measurements on excised breast tissue that quantitatively demonstrate the correlation between ultrasonic attenuation and pathologic state. A method for measuring changes in phase (due to velocity and thickness differences) in a wave as it passes through tissue, based on the phase-contrast technique, is described and demonstrated. The principal advantage of this method over other phase measurement techniques is that it is not as sensitive to the effects of structure overlying the region of interest.

Reflection techniques for measurement of attenuation and velocity, G. Kossoff, *SP453*, pp. 135-139 (Oct. 1976).

Key words: attenuation; breast; reflection techniques; ultrasound; velocity.

Pulse reflection techniques may be used for *in vivo* measurement of attenuation and velocity. Measurement of the two-dimensional distribution of pulse attenuation may be obtained based on the equalization of internal echoes while the differential pulse attenuation of encapsulated tissues is obtained by noting the difference in the echo from the posterior boundary at different frequencies. The average velocity in tissues may be measured by a simple technique if a reflector may be positioned at the posterior boundary. A reflection technique for measurement of local values of velocity in heterogeneous tissues using two forward transducers separated by a known distance is suggested.

Ultrasonically-induced transient thermal gradients: Their potential role in acoustic parameter characterization of tissue, J. Fry, *SP453*, pp. 143-151 (Oct. 1976).

Key words: absorption; attenuation; impedance gradient; transient thermal gradients; ultrasonics; velocity.

Induction of transient thermal gradients by ultrasonic means with concurrent detection by ultrasound offers the possibility of determining quantitatively some of the acoustic properties of live tissue. The transient thermal gradient is related to the inherent acoustic absorption property of the tissue. When used appropriately, this gradient can be used to determine acoustic absorption, attenuation, velocity, and to enhance acoustic impedance differences

certain interfaces. Additional work beyond that reported here is needed to explore essential application of this method in the area of acoustic parameter determination which could lead to an enhanced tissue differentiating capability.

TAST: A non-invasive tissue analytic system, T. D. Sachs, P. . Anderson, R. S. Grimes, S. J. Wright, Jr., and R. M. P. Donaghy, *SP453,* pp. 153-163 (Oct. 1976).

Key words: absorption; attenuation; brain; neoplasm; TAST; thermal effects; tissue; tumor; ultrasonic; velocity.

The Thermo-Acoustic Sensing Technique (TAST) uses two intersecting sound fields to measure the acoustic absorption of cerebral tissues at the point of intersection. A resolution of better than 1/8 inch was achieved in initial scans through the coronal plane of a fixed human brain. The sylvian and cortical fissures, basal ganglia, and ventricular boundaries appeared to be profiled by the TAST values. Conceivably, TAST may provide numerical tissue characteristics in 0.002 cubic inches of selected cerebral tissue. Should predictions based on current theory and data prove correct, TAST may become a repeatable noninvasive means of establishing intracerebral diagnosis.

Tissue characterization by ultrasonic frequency-dependent attenuation and scattering, P. P. Lele, A. B. Mansfield, A. I. Murphy, J. Namery, and N. Senapati, *SP453,* pp. 167-196 (Oct. 1976).

Key words: acoustic impedance; Bragg diffraction; computer processing; frequency-dependent attenuation; internal scattering; myocardial infarction; scattering; surface scattering; tissue characterization; ultrasonic spectroscopy; ultrasound diagnosis.

Studies conducted in this laboratory to explore the feasibility of utilizing acoustic impedance, attenuation, and scattering characteristics of tissues for enhancing the diagnostic capabilities of ultrasound are described. Frequency-dependent ultrasonic attenuation is found to be sufficiently greater in infarcted or otherwise necrotized tissues than in normal controls to permit their positive identification. Superficial and internal scattering properties of tissues hold the promise of being significant for diagnostic applications. The difficulties that will have to be overcome to successfully utilize these properties are discussed.

Frequency and angular dependence of ultrasonic scattering from tissue, C. R. Hill, *SP453,* pp. 197-206 (Oct. 1976).

Key words: Bragg diffraction; diagnosis; frequency dependence; orientation dependence; scattering; tissue characterization; ultrasound.

This paper reports on an ongoing program of work that, commencing in 1969, has been aimed at elucidating, and ultimately applying in clinical investigation, the processes by which ultrasound is scattered by volumes of human tissue. The report covers two related aspects of the work, concerned with the specific patterns of dependence of volume backscattering cross-sections on, respectively, acoustic frequency and the relative orientation between the axis of the interrogating ultrasonic beam and the backscattering structure. These two aspects of the subject have been treated from both theoretical and experimental points of view and both aspects show promise as possible bases for practical tissue characterization. Particular interest has centered in the orientation analysis approach, which constitutes an acoustic analog of Bragg diffraction of x-rays and has been shown to be capable of quantitatively significant differentiation between different human tissue types. The feasibility of applying this approach to *in vivo* tissue characterization has been demonstrated.

The scattering of ultrasound by red blood cells, K. K. Shung, R. A. Sigelmann, and J. M. Reid, *SP453,* pp. 207-212 (Oct. 1976).

Key words: angular dependence; blood; compressibility; density; distribution function; erythrocytes; hematocrit; scattering; ultrasound.

This paper reviews the experimental results obtained on the measurement of ultrasonic scattering properties of erythrocytes. The scattering is proportional to the fourth power of the frequency, as predicted by Rayleigh's scattering theory, for frequencies below 15 MHz. The scattering is not linearly dependent upon the hematocrit as would be expected for a single scattering process. Twersky's wave scattering theories are therefore applied to describe this result. The magnitudes of the monopole scattering due to compressibility and of the dipole scattering due to density are in good agreement with theory. Blood is the first tissue for which a nearly complete experimental and theoretical characterization of scattering exists.

Swept-frequency ultrasonic determination of tissue macrostructure, R. C. Waag, R. M. Lerner, and R. Gramiak, *SP453,* pp. 213-228 (Oct. 1976).

Key words: diffraction; Fourier transform; scattering; tissue characterization; ultrasound.

Ultrasound may be used to determine the acoustic structure of tissue on a scale corresponding to the wavelengths employed by using scattered signal to infer the organization of tissue elements. The underlying concept is the selective reinforcement or cancellation of certain frequencies depending on the relation of wavelength, reflector spacing, and orientation. A Fourier analysis of the received signal as a function of frequency or scattering angle reveals the acoustic variations corresponding to structure. By employing a swept-frequency ultrasonic signal, data similar to that obtained by angle scanning at a fixed frequency in x-ray diffraction has been obtained. Predicted deterministic interference patterns have been demonstrated for aluminum plates. Random scattering for two different sizes of dextran particles has also demonstrated predicted differences in scattering spectra. Pilot studies of liver specimens have shown marked variations in intensity-frequency distributions for individual disease processes.

Acoustic impedance profiling: An analytical and physical model study, A. C. Kak and F. J. Fry, *SP453,* pp. 231-251 (Oct. 1976).

Key words: attenuation; computer; deconvolution; impedance; impulse response; layer model; lucite; ultrasound.

Qualitative measurements of the acoustic impedance of tissue have been extensively exploited for medical diagnosis. In this paper, we report on an analytical and physical model study directed towards quantifying this parameter. The model selected is a medium having plane-parallel impedance interfaces which is insonified at normal incidence. Analytical expressions and computer algorithms are given for determining the impulse response of the medium and the impedance profile from this impulse response. Experimental data are presented which shows the accuracy with which the method can presently be applied.

Current problems in ultrasonic impediography, J. P. Jones, *SP453,* pp. 253-258 (Oct. 1976).

Key words: deconvolution; impedance profiling; impediography; impulse response; time-domain deconvolution.

The term impediography is used to describe a rather general class of signal processing operations which, when applied to pulse-echo ultrasonic signals, yield quantitative information concerning the physical properties of the system under study. The method uses deconvolution of acoustical impulses and their echoes to obtain the impulse response as a function of acoustical travel time. The integral of the impulse response can then be analytically related to various physical parameters such as the specific acoustical impedance. This paper provides a general discussion of the problems associated with the practical implementation of impediography and outlines a number of important research areas which require additional study. Major problem areas discussed include: (1) corrections for nonplanar geometry, (2) development of accurate deconvolution algorithms, and (3) corrections and/or development of impediographic processing procedures for attenuation and scattering.

Tissue characterization by means of acoustic microscopy, L. W. Kessler, *SP453,* pp. 261-267 (Oct. 1976).

Key words: acoustic imaging; acoustic microscopy; attenuation; frequency dependence; impedance; microstructural analysis; tissue; ultrasound; velocity.

The complete characterization of tissue is extremely important for objectively identifying abnormalities and disease states. Optical methods of microscopy have been exploited to a great degree and now the electron microscope is being used in search of diagnostic clues at higher magnification levels. It is well appreciated, however, that these methods provide only limited access to the physical properties of tissue. Furthermore, the physical nature of an abnormality may prohibit its ever being revealed with visual observation techniques. Acoustic microscopy, on the other hand, can reveal new information, the structural elastic characteristics of viable tissue. Acoustic microscopy can also provide quantitative data on these tissue characteristics. As this additional information should have great diagnostic value, a general discussion of the methods and procedures employed is presented.

SP454. **An annotated bibliography of compiled thermodynamic data sources for biochemical and aqueous systems (1930 to 1975). Equilibrium, enthalpy, heat capacity, and entropy data,** G. T. Armstrong and R. N. Goldberg, *Nat. Bur. Stand. (U.S.), Spec. Publ. 454,* 67 pages (Sept. 1976) SD Catalog No. C13.10:454.

Key words: aqueous systems; bibliography; biochemical systems; enthalpy data; entropy data; equilibrium data; Gibbs energy data; heat capacity data; partial molal properties; thermochemistry; thermodynamics; review articles; water pollution.

Contained herein is a selected and annotated bibliography of sources of compiled and evaluated chemical thermodynamic data relevant to biochemical and aqueous systems. The principal thermodynamic properties considered herein are Gibbs energy and equilibrium data, enthalpies of formation and reaction, heat capacities and entropies, and the corresponding partial molal properties. Derived quantities used in calculating the above are also included. Transport and mechanical data have also been identified to a lesser degree. Included in the annotations to the data sources are brief descriptions of the types of properties tabulated, the classes of materials dealt with, and the degree o completeness of the compilations.

SP455. **Electrocatalysis on non-metallic surfaces.** Proceedings o a workshop held at the National Bureau of Standards, Gaither sburg, MD, Dec. 9-12, 1975, A. D. Franklin, Ed., *Nat. Bu Stand. (U.S.), Spec. Publ. 455,* 372 pages (Nov. 1976) SI Catalog No. C13.10:455.

Key words: catalysis; characterization; chemisorption; elec trocatalysis; electrochemistry; electrode processes; non metals; photoelectrolysis; solid electrolytes; surfaces.

This book presents the proceedings of a Workshop on Elec trocatalysis on Non-metallic Surfaces, held at the National Bu reau of Standards, Gaithersburg, Maryland, on December 9-1 1975. The Workshop was sponsored by the Institute of Mater als Research, NBS, the Division of Materials Research of th National Science Foundation, and the Division of Conservatio Research and Technology of the Energy Research and Develop ment Administration. The purpose of the Workshop was t review the most recent experimental and theoretical investig tions on electrocatalysis on nonmetals and related topics, and t bring together electrochemists, surfaces scientists, and soli state physicists and chemists involved in research related to th topic. A total of 31 invited and contributed papers are he presented, together with a summary report of the final pan discussion. These proceedings are arranged to reflect, with son small exceptions, the program of the Workshop. The mai groupings of papers are: I. Theory of Electrocatalysis and R lated Topics; II. Characterization; III. Electrochemic Processes on Non-metallic Surfaces; and IV. Electrochemist at Solid Electrolyte Interfaces. In addition, a final panel discu sion (V) considered major problems, advances and opportuniti revealed by the Workshop. *These proceedings include the fo lowing papers (indented):*

Electron transfer and electrocatalysis, H. Gerischer, *SP45.* pp. 1-19 (Nov. 1976).

Key words: chemisorption; electrocatalysis; electrc transfer theory; multistep redox reactions; semiconduct surface states.

Non-catalyzed electron transfer is reasonably defined a an electron exchange between an electron donor or accept and an electrode under the condition of very weak intera tion between the reactants and the electrode. The case strong interaction between reactants and electrodes analyzed with respect to its catalytic effect on electrc transfer. It is pointed out that strong interaction may ofte inhibit electron transfer for a single electron transfer step its individual equilibrium potential. Electrocatalysis is hov ever found in multistep electron transfer reactions when th adsorption of intermediates in the reaction path brings th individual standard potentials of the single electron transf steps closer to that of the overall redox potential. Example for this effect of adsorptive interaction are given for met and nonmetallic electrodes. It is further analyzed where th electron energy levels of the adsorbed reactants are locate with respect to the characteristic energy levels in the meta lic or nonmetallic electrodes and in the nonadsorbed speci in solution. The important role of surface states at a no metallic electrode for chemisorption and electrocatalysis emphasized.

Surface states, chemisorption and catalytic processes transition metal oxides, T. Wolfram, F. J. Morin, and R. Hurs *SP455,* pp. 21-52 (Nov. 1976).

Key words: catalysis; chemisorption; cluster states; electronic structure; energy bands; perovskites; surface states; transition metal oxides.

A discussion of the bulk and surface electronic states of transition metal oxides such as the perovskites is presented. The factors which determine the surface electronic structure are described and several examples of surface states and surface energy bands are presented using both cluster and energy band models.

The role of d-electron surface states in chemisorption and catalytic processes on transition metal oxides is considered. Several examples of surface reactions are given using a cluster model for the substrate. These examples include the chemisorption of OH^- ions, the dissociative adsorption of H_2 and the hydrogenation of ethylene.

A detailed description of a Green's function theory for surface reactions is given in which both the reacting molecule and the solid are described by local basis states. The concept of the spectral weight function (local density of states) is used to describe delocalized bonding of molecules to a solid surface. As an example of the application of the theory the formation of localized electronic states associated with the adsorption of OH^- ions is considered.

Hartree-Fock calculations of hydrogen adsorption on nickel, copper, and magnesium oxide, A. B. Kunz, M. P. Guse, and R. J. Blint, *SP455*, pp. 53-58 (Nov. 1976).

Key words: adsorption; catalysis; copper hydride; magnesium oxide; molecular structure; nickel hydride.

The potential energy curves for NiH, HNiH, CuH, and HCuH resulting from the ground and first excited state atomic configurations are calculated using the unrestricted Hartree-Fock and generalized valence bond methods. NiH bonding in the $3d^84s^2$ configuration and CuH bonding in the $3d^94s^2$ configuration is by means of an sp hybrid orbital which comes from the $4s^2$ shell leaving a singly occupied orbital free to bond to another hydrogen atom. The bonding in the NiH$3d^94s$ and CuH$3d^{10}4s$ configurations is to the 4s orbital leaving in NiH a hole in the nickel 3d shell which interacts with another hydrogen only weakly and in CuH a closed 3d shell resulting in a repulsive potential energy curve. The interaction of hydrogen with a cluster representing a magnesium oxide surface V_I center was calculated using UHF. The lowest energy results when the Mg and O are singly ionized rather than doubly as in the bulk resulting in a surface radical. The hydrogen is bound over one of the oxygen atoms.

Stark model of the excitonic surface states observed on MgO[1], H. J. Zeiger, V. E. Henrich, and G. Dresselhaus, *SP455*, pp. 59-65 (Nov. 1976).

Key words: bulk excitons; electron loss spectroscopy; ionic crystals; Madelung potential; Mg^+; Mg^{2+}; MgO; Stark spectrum; surface excitons.

Using the energy and angle-of-incidence dependence of the electron energy loss spectra of MgO, we have separated the excitonic transitions from the Mg core levels to the excited states into those of bulk and surface origin. The bulk transitions are very nearly those of the free Mg^{2+} ion. The (100) surface-state transitions can be described by Stark-splitting of the energy levels of the surface Mg^{2+} ions in the intense Madelung electric fields at the crystal surface. The observations on other crystal faces of MgO and in amorphous MgO, however, suggest the possibility of the presence of surface Mg^+ ions.

Quantum chemistry and catalysis, R. P. Messmer and K. H. Johnson, *SP455*, pp. 67-86 (Nov. 1976).

Key words: catalysis; chemisorption theory; metal clusters; molecular orbitals; quantum chemistry; transition metal complexes.

A number of recent theoretical calculations on model systems relevant to chemisorption and catalysis is discussed. The approach taken is basically chemical in nature, emphasizing the local active site concept and employing a cluster of atoms to represent the substrate which interacts with the molecular or atomic adsorbate. The computational procedure used in these studies has been the self-consistent-field Xα scattered wave (SCF-Xα-SW) method.

Relationship between electronic structure and catalytic behavior of transition metal carbides, D. R. Jennison, D. L. Klein, A. B. Kunz, K. M. Hall, and W. S. Williams, *SP455*, pp. 87-92 (Nov. 1976).

Key words: adsorption; catalysis; electronic structure; surface states; transition metal carbide.

We have studied the electronic structure of TiC within the unrestricted Hartree-Fock approximation. We find that strong covalent bonding occurs between the carbon 2s and 2p and the metal 3d orbitals. An absence of strong metal-metal bonding was noted. We tested various configurations on the metal atoms and found $4s^o3d^n$ energetically favored. Thus the formation of the carbon-metal bonds results in a loss of 4s character in the electronic structure. Cluster calculations confirm that the strength of the $\overline{b}$onds is sufficient to prevent the reestablishment of 4s character on a surface. The recent studies of Kunz, Guse, and Blint indicate that H bonds strongly to the 4s level, but not to the 3d. Although Ti metal can dissociate H_2, our results explain why the carbide apparently cannot. Similar results are anticipated on WC, suggesting a carbon deficient surface may have properties intermediary to W and WC.

The study of electrode surfaces by electrochemical methods, B. E. Conway and H. Angerstein-Kozlowska, *SP455*, pp. 107-124 (Nov. 1976).

Key words: atomic layers; chemisorption; cyclic-voltammetry; electrochemical adsorption; monolayers; surface processes.

Electrochemical methods for the study of surfaces are reviewed. Unlike high-vacuum techniques, they measure changes in the state of surfaces by virtue of occurrence of electrode surface processes, rather than giving information on the state of the surface itself. However, electrochemical procedures have high sensitivity down to 2 percent of a monolayer and multiple states of chemisorption can be distinguished with an energy resolution of 100-200 small calories. Interactions in the ad-layer can also be derived from the form of electrical transients. Combination of electrochemical methods with optical techniques, such as relative reflectivity and ellipsometry, provides a new dimension for studies in electrochemical surface science.

Electroreflectance study of the defect states in reduced n-type titanium dioxide, S. S. M. Lu, F. H. Pollak, and P. M. Raccah, *SP455*, pp. 125-131 (Nov. 1976).

Key words: defect states; *d*-electrons; electrolyte electroreflectance; surface states; titanium dioxide; transition-metal oxides.

We have investigated the electroreflectance spectrum of reduced n-type TiO_2, particularly below the fundamental absorption edge (~ 3 eV), in aqueous electrolyte, metal-semiconductor and metal-oxide-semiconductor configurations. We have observed for the first time in electroreflectance features in the spectrum for $h\omega < 3$ eV which are related to the defect states. It is found that this structure is strongly dependent on the applied bias electric field. One optical peak appears at about 1.7 eV, an energy region in which structure has been observed in various other measurements which are related to both bulk (optical transmission, photoconductivity) and surface (electrochemical, electron loss spectroscopy) states. The intimate relationship between the bulk defect levels introduced by reduction and surface states will be discussed. Our results will be interpreted in terms of a recent model of Morin and Wolfram for *d*-electron surface states in transition metal oxides.

Electron energy loss spectroscopy of surface states on titanium and vanadium oxides, V. E. Henrich, H. J. Zeiger, and G. Dresselhaus, *SP455*, pp. 133-138 (Nov. 1976).

Key words: adsorption; electron spectroscopy; ligand-field splitting; surface excitons; surface states; transition-metal oxides.

Using electron energy loss spectroscopy, we have studied the surface electronic structure of TiO_2, Ti_2O_3, $TiO_{0.87}$ and V_2O_3. A surface-state transition in the region of 1.5 to 2.5 eV is present in all of these materials when the surface is reduced by Ar-ion bombardment. Subsequent exposure of the surfaces to oxygen or water vapor reduces or completely eliminates this transition. The origin of the transition in terms of d-electron population of surface cations is discussed.

Dislocations in ZnO as channels for electron transfer from surface species, S. R. Morrison and T. Freund, *SP455*, pp. 139-148 (Nov. 1976).

Key words: dislocation; electrochemical; exchange current; semiconductor; traps; zinc oxide.

The results reported show that dislocations strongly affect the properties of the ZnO electrode and that with the help of electrochemical measurements a fairly complete picture of the electrical and chemical behavior of dislocations can be developed. It is shown that dislocations in ZnO act as hole or electron traps in the space charge region, as recombination centers, as points of electric breakdown under anodic polarization, and as current paths leading to exchange current even in an indifferent electrolyte. The dislocations can be passivated by annealing or by precipitation of impurities. A qualitative model is presented that can account for the observed effects of dislocations on the solid state and electrode properties.

Characterization of semiconductor electrodes in nonaqueous solvents, S. N. Frank, D. Laser, K. L. Hardee, and A. J. Bard, *SP455*, pp. 149-152 (Nov. 1976).

Key words: acetonitrile; cyclic voltammetry; electrochemistry; nonaqueous; semiconductor; silicon; titanium dioxide.

The large number of simple and reversible redox couples available in nonaqueous solvents allows convenient investigation of the band structures of semiconductors using electrochemical techniques. Comparisons of the cyclic voltammetric behavior of these couples at platinum and a semiconductor permits estimation of the relative energy levels of the conduction and valence bands and provides a means of mapping the gap region for intermediate levels and surface states. This technique is demonstrated with TiO_2 and n-type Si semiconductors. In spite of the large difference in band gaps between these semiconductors, their electrochemical behavior is similar and is ascribed to a similarity in the energies of their respective conduction bands and the energies of an intermediate energy level in TiO_2 and the valence band in Si.

Chemical theory of chemisorption and catalysis on the surfaces of non-metals, R. L. Burwell, Jr., *SP455*, pp. 155-166 (Nov. 1976).

Key words: catalytic hydrogenation; catalytic oxidation; chemisorption; cus; heterogeneous catalysis; surface coordinative unsaturation.

This paper surveys chemisorption and catalysis on nonmetals primarily from the point of view of localized, coordinatively unsaturated surface (cus) sites and with use of analogies to the chemistry of coordination and organometallic complexes. Topics covered include chemisorption on oxides of main group elements and of transition elements, heterogeneous catalytic hydrogenation and oxidation on oxides of transition elements, and chemisorption on group IV elements and group III-V compounds.

Electrocatalysis at transition metal oxide and carbide surfaces, P. Stonehart, *SP455*, pp. 167-174 (Nov. 1976).

Key words: electrocatalysis; heteropolyanions; phosphotungstate complex ions; "spillover" effect; transition metal carbides; transition metal oxides; tungsten bronze; tungsten carbide.

Due to the cost of noble metal electrocatalysts, significant research has been carried out to find nonnoble metal electrocatalytic materials. Transition metal oxides, usually doped tungsten oxides (bronzes), have been postulated previously due to their favorable electronic conductivity and stability in electrolytes. The surface chemistry of such electrocatalysts has been largely neglected but interesting parallels exist for the electron injection and extraction with heteropolyanions in solution. The heteropolyanions exhibit electrochemical properties of "bronze" crystals and can be considered to be microcrystallites. Optical studies show correlations between absorbance in the visible region and the electron density per transition metal atom. By and large, the transition metal oxide electrocatalysts have not yet fulfilled their expectations.

A related research direction has examined the activity of transition metal carbides for hydrogen oxidation in acid. Here it was found that tungsten carbide was the most active material but that it required a pretreatment. Surface studies established that the active form of the tungsten carbide electrocatalyst was slightly carbon deficient.

Adsorption and oxidation of bromide ion on tin oxide electrodes, H. Yoneyama and H. A. Laitinen, *SP455*, pp. 175-181 (Nov. 1976).

Key words: adsorption; anodic oxidation; electrocatalysis; semiconductor electrode; tin oxide electrode; transparent electrode.

Adsorption of bromide ion on a tin oxide electrode proceeded at such a slow rate that adsorption equilibrium took longer than two days to be reached. The electrode became active for oxidation of bromide ion depending on the extent of soaking in an acidic bromide solution. It was found that hydration of the electrode is an important factor to determine its activity for electro-oxidation of bromide ion. An electrode having a high activity lost its activity owing to

surface oxidation upon polarization into the discharge potential region of bromide ion.

Cathodic pyrophosphate-lead dioxide electrode reaction properties, C. O. Huber, T. A. Berger, and R. E. Reim, *SP455*, pp. 183-189 (Nov, 1976).

Key words: amperometry; cyclic voltammetry; electrosorption; Langmuir; lead dioxide; pyrophosphate; Temkin; wax-bound electrode.

In the vicinity of +0.4 volts *vs.* S.C.E. in pH 8 solution pyrophosphate yields a cathodic current selective over orthophosphate at the lead dioxide electrode. Several aspects of this response were examined using α-electroplated lead dioxide on a platinum base and using mixed α-β wax-bound lead dioxide electrodes prepared from the powdered material. Scanning electron microscope results indicated the topographical nature of the wax-bound electrodes. Current-voltage plots indicated an absence of a limiting current and relatively high residual currents as the potential becomes more cathodic. Scanning cyclic voltammetry suggested adsorption of reactive species. Capacitance and coulometric studies indicated clear evidence of adsorption and showed that the current was necessary to the desorption step. Current *vs.* concentration studies allowed fits to electrosorption models within certain concentration ranges. From these data estimates of some thermodynamic quantities were made. An electrode reaction process involving quasi equilibrium adsorption of the electron transfer product followed desorption of a plumbous-pyrophosphate complex is discussed.

Electrolysis by foreign metal monolayers, R. R. Adžić, A. R. Despić, D. N. Simić, and D. M. Dražić, *SP455*, pp. 191-200 Nov. 1976).

Key words: electrocatalysis; foreign metal monolayers; Fe^{2+}/Fe^{3+} reaction; formic acid oxidation; oxygen reduction; underpotential deposition.

Catalytic effects of foreign metal monolayers deposited at underpotentials have been found in the case of Fe^{2+}/Fe^{3+} redox reaction on gold, oxygen reduction on gold, and oxidation of some small organic molecules on platinum. It was found that the catalytic effects of foreign metal monolayers originate in the change of surface electronic properties and the change of energy of adsorption of oxygen or oxygen-containing species for Fe^{2+}/Fe^{3+} and oxygen reduction respectively. In the case of formic acid oxidation foreign metal monolayers decrease the hydrogen adsorption on platinum thus preventing the formation of the main poisoning species.

Mechanisms of electrochemical reactions on non-metallic surfaces, E. Yeager, *SP455*, pp. 203-219 (Nov. 1976).

Key words: carbon; electrocatalysis; nickel oxide; oxide electrodes; oxygen electrochemistry; semiconductor electrodes.

Oxygen electrocatalysis has assumed new importance because of the involvement of the O_2 electrode in various fuel cells and electrolyzer systems. For O_2 electroreduction to proceed at reasonable current densities requires the adsorption of the O_2 molecule or ion on the electrode surface. Various models for the interaction of such O_2 species with surfaces and the corresponding pathways for the electroreduction are considered. Generally peroxide mechanisms are predominant in aqueous solutions on non-metallic as well as metal surfaces but this leads to less favorable operating potentials for O_2 cathodes. A number of reasonably effective O_2 electroreduction catalysts have been identified for alkaline solutions but so far only high area platinum appears to combine reasonable activity and stability in acid electrolytes. Various electrocatalysts for which results have been reported in the literature are summarized. The electrochemical behavior of various carbons and graphites, lithiated NiO and various defect metal oxides including RuO_2/Ti is considered in some detail relative to O_2 generation as well as reduction kinetics.

Photoelectrolysis of water, J. G. Mavroides, D. I. Tchernev, J. A. Kafalas, and D. F. Kolesar, *SP455*, pp. 221-227 (Nov. 1976).

Key words: energy levels; photocatalytic electrodes; photoelectrolytic cells; photogalvanic cells; quantum efficiency; solar energy.

The photoelectrolysis of water has been investigated by experiments on cells consisting of an illuminated n-type semiconductor anode, an aqueous electrolyte, and a platinized-Pt cathode. It has been found that such cells operate either in the photogalvanic mode (no H_2 evolved) or in the photoelectrolytic mode (H_2 evolved at the cathode by decomposition of water), depending on whether or not the electrolyte surrounding the cathode contains dissolved oxygen. In both cases, current flows through the external circuit and O_2 is evolved at the anode. For operation in the photogalvanic mode, maximum values of 80-85 percent for the external quantum efficiency (η) for current production have been measured at $h\nu \approx 4$ eV with both single-crystal and polycrystalline TiO_2 anodes. Similar results have been obtained with $SrTiO_3$ anodes. The internal quantum efficiencies, corrected for reflection and absorption losses, are close to 100 percent, indicating that the band bending in both cases under photogalvanic conditions is sufficient to separate the electron-hole pairs generated by photon absorption and also that the oxygen overvoltage for charge transfer at the semiconductor-electrolyte interface is negligible for illuminated anodes. For operation in the photoelectrolytic mode, η is only 1-2 percent for TiO_2 and ~ 10 percent for $SrTiO_3$ if the anode and cathode are shorted together, but the efficiency can be greatly increased by applying a bias voltage. All the observations, including the increased efficiency for $SrTiO_3$, can be given a straightforward explanation in terms of the energy levels of the electrodes and the electrolyte.

Electrochemical processes on strontium titanate electrodes, D. M. Tench and D. O. Raleigh, *SP455*, pp. 229-240 (Nov. 1976).

Key words: flat band potential; hydrogen evolution; oxide electrode; perovskite surface composition; rotating electrode voltammetry; semiconductor electrode.

The electrochemical properties of n-type single-crystal $SrTiO_3$ electrodes (10^{18}-10^{19} carriers/cm^3) were investigated in acidic sulfate solutions, with special attention to the hydrogen evolution reaction. AC impedance measurements, together with the voltammetric behavior of the ferro-ferricyanide couple and the onset of anodic photocurrent, established that the flat band potential, U_{fb}, lies about 250 mV cathodic to the reversible hydrogen electrode potential.

Slow-sweep cyclic voltammetry with a rotating electrode assembly established several hydrogen discharge mechanisms in moderately acidic solutions. Anodic to U_{fb}, chemical desorption ($H_{ads} + H_{ads} \rightarrow H_2$) appears to be rate limiting. At more cathodic potentials, electrochemical desorption ($H_3O^+ + e^- + H_{ads} \rightarrow H_2 + H_2O$) dominates. At

still more cathodic potentials, where proton discharge becomes diffusion-limited, hydrogen discharge from H_2O appears to dominate. Anomalous current behavior at low pH values (~ 0.5) suggests possible proton diffusion into the electrode. ESCA measurements showed that the first few atomic layers of the $SrTiO_3$ surface, when brought in contact with aqueous solutions, become depleted in Sr.

Electrochemical activity of polymeric and monomeric iron phthalocyanines as a function of their spectral properties, A. J. Appleby and M. Savy, *SP455*, pp. 241-251 (Nov. 1976).

Key words: electrocatalysis; electronic structure; hydrogen peroxide; iron phthalocyanines; Mössbauer; optical spectra; oxygen; reaction mechanisms; ring-disk electrodes.

Samples of monomer and polymer iron phthalocyanines, prepared both in situ on carbon supports or in the form of thin films, using a gas-phase synthesis method, and by dissolution of liquid-phase preparations in sulfuric acid followed by reprecipitation on carbon, were examined by optical and Mössbauer spectroscopy. Their electrochemical activities for oxygen reduction were examined under steady-state conditions using the ultra-thin porous electrode technique, as a function of O_2 partial pressure, pH (11.8 – 16.4) and H_2O_2 additions. In addition, rotating ring-disk electrode experiments were conducted. Analysis of reaction orders and comparison of activities with those of the support have allowed the most probable mechanism to be determined, in which the rate-determining step is a chemical dissociation of the O-O bond. Correlations between electrochemical activities and spectral properties indicate the role of polymerization and of the spin configuration of the central iron atom in promoting catalysis. These effects result from reoxidation of $Fe^{II}iS$ to $Fe^{II}HS$ or iS, which is favorized by interaction between the polymer π electrons and the d electrons of the iron.

Electrocatalytic activity of phthalocyanines for oxygen reduction, R. J. Brodd, V. Z. Leger, R. F. Scarr, and A. Kozawa, *SP455*, pp. 253-258 (Nov. 1976).

Key words: ferric phthalocyanine; kinetics; oxygen reduction; phthalocyanine catalysts.

A survey of the activity of phthalocyanines as catalysts for oxygen reduction has identified several metal phthalocyanines with good activity. The central metal ion evidently controls the overall activity of the phthalocyanines for oxygen reduction. Ferric phthalocyanine had the best overall activity and approaches platinum in ability to catalyze the oxygen reduction reaction. The structure also influences the phthalocyanic activity. For copper as the central ion the order of activity is: polycopper phthalocyanine > copper phthalocyanine > copper porphyrazine. The substrate also influences the activity of the phthalocyanine as does solution composition. A mechanism for oxygen reduction is proposed which includes a hydrogen peroxide adsorption-desorption step. Rotating ring-disk results satisfactorily fit this model.

Continued growth of anodic oxide films at platinum and the mechanism and catalysis of oxygen evolution, A. Damjanovic, *SP455*, pp. 259-266 (Nov. 1976).

Key words: anodic films; dual barrier, electrocatalysis; oxygen evolution; platinum anodes; reaction mechanism.

It is shown on the example of oxygen evolution at platinum that thin anodic oxide films may profoundly affect kinetics and mechanism of an electrochemical reaction. At any potential above 1.OV an "insulating" oxide film grows over the electrode surface. The potential difference across the anode is then divided into the potential difference across the oxide film and that across the electrolyte double layer. The film is a barrier to electron transfer and together with the reaction across the double layer controls the kinetics and mechanism of the reaction. The exchange current density of the reaction decreases exponentially with thickness of the film. Only when the distribution of potential across the oxide film and double layer is taken into account, it is possible to explain the observed fractional reaction order with respect to activity of hydrogen ions and to propose a mechanism of the reaction that explains this reaction order. In the proposed mechanism a chemical step that follows first electrochemical step controls the rate in the double layer.

Electrochemical surface reactions on non-metals, R. Memming, *SP455*, pp. 267-280 (Nov. 1976).

Key words: anodic decomposition; cathodic decomposition; electrochemistry; inorganic bronze electrodes; metal electrodes; semiconductor electrodes; stability, surface layers; surface reactions.

Various surface reaction of semiconductors during electrochemical polarization are investigated which are of interest in connection with catalytic and photo-electrocatalytic processes. Examples for the anodic and cathodic decomposition are given and discussed with regard to the stability of electrode materials. In addition the formation of semiconducting layers on metal electrodes is described and their analysis and characterization investigated as far as electron transfer is concerned. Reactions at bronze electrodes leading to semiconducting surface films are included.

Oxygen evolution on semiconducting oxides, A. C. C. Tseung and S. Jasem, *SP455*, pp. 281-288 (Nov. 1976).

Key words: nickel cobalt oxides; oxygen evolution, Pourbaix diagram; semiconducting oxides; spinels; teflon bonded electrodes.

The oxygen evolution reaction is of particular interest to secondary metal air batteries and water electrolysis plants. However, most of the earlier work has been on precious metals and there are no guidelines for the choice of semiconducting oxides as oxygen evolving electrodes. In this study, the role of the metal/metal oxide or the lower metal oxide/higher metal oxide couple in determining the minimum voltage required for the evolution of oxygen is emphasized, together with other essential requirements such as electrical resistivity electrode microstructure, corrosion resistance and catalytic properties. A survey of various metal oxides based on the above criterion suggested that $NiCo_2O_4$ is of particular interest and teflon bonded electrodes based on this material gave over 13,000 A/m² at 1.63 V vs DHE, 70 °C, 5N KOH.

Mixed oxides as oxygen electrodes, G. Singh, M. H. Miles, and S. Srinivasan, *SP455*, pp. 289-296 (Nov. 1976).

Key words: electrocatalysis; nickel-cobalt oxide; nickel oxide; oxide electrodes; oxygen electrode reaction; ruthenium dioxide/titanium dioxide; spinel.

The irreversibility of the oxygen electrode reaction on metals and alloys is the main cause of efficiency losses in fuel cells, water electrolysis cells and some battery systems. Oxygen evolution always occurs on oxide covered surfaces while the reduction reaction generally takes place on bare metallic surfaces but can do so on oxides. Since the most likely candidates for reversible oxygen electrodes are oxides, mixed oxides or compound oxides, three types of

oxides – NiO_x, $NiCo_2O_4$ and RuO_2ǀTiO_2 were examined as oxygen electrodes in KOH solution. When these oxide electrodes were prepared by thermal decomposition of their salts on a substrate, ratios of true to apparent surface areas of the electrodes were quite high (over 200) and the transfer coefficients, obtained from the Tafel lines for oxygen evolution in the temperature range 25-100 °C, were 1.5, as compared with about half that value on nickel electrodes. Above 100 °C $NiCo_2O_4$ and RuO_2ǀTiO_2 electrodes corroded in the strong (50%) KOH environment. Mixed oxides are more stable than simple oxides in the region of potential where oxygen reduction occurs. From the values of the Tafel slopes and exchange current densities for oxygen evolution and reduction $NiCo_2O_4$ (a spinel) and RuO_2ǀTiO_2, it is clear that reversibility of this electrode reaction was not obtained. Other mixed oxides (including spinels and perovskites) will have to be investigated with the aim of developing reversible oxygen electrodes.

Surface and electrocatalytic properties of tungsten bronzes, . F. Weber and H. R. Shanks, *SP455*, pp. 297-303 (Nov. 976).

Key words: Auger electron spectroscopy; electrocatalyst; oxygen reduction; sodium depletion; Tafel plots; tungsten bronzes.

Tafel plots have been obtained for the oxygen reaction in acid solution on several alkali tungsten bronzes having different crystal structures. Platinum doped sodium tungsten bronze crystals were studied and the results compared with those of platinum free crystals of the same composition. In both cases sodium tungsten bronzes were found to be poor electrocatalysts for the cathodic reduction of oxygen. Similar results are reported for other alkali tungsten bronzes and for tungsten trioxide. Anodic treatment of the crystals affected the electrocatalytic activity of only the sodium tungsten bronze and the effect was a negative one. Cyclic voltammetry was employed to study the effects of the anodic treatment which created a sodium depletion layer on the sodium tungsten bronze surface. The existence and depth of the sodium depletion layer was determined by an Auger Electron Spectroscopy depth profile.

The electrochemistry of molybdenum oxides, J. Horkans, M. . Shafer, and R. Peekema, *SP455*, pp. 305-312 (Nov. 1976).

Key words: electrochemistry; molybdenum oxides; orientation effects; oxygen reduction.

The general electrochemistry of four oxides of molybdenum, MoO_2, Mo_4O_{11}, Mo_8O_{23}, and Mo_9O_{26}, and the reduction of oxygen on these oxides, in 1 N H_2SO_4 have been investigated on natural faces of single crystals. These compounds are found to undergo electrochemical oxidation and reduction in the potential range between 0.13 and 0.73 V vs NHE. Oxygen does not influence the oxidation of MoO_2 and Mo_4O_{11}, but promotes the anodic dissolution of Mo_8O_{23} and Mo_9O_{26}. Oxygen reduction is supported on all these oxides at low currents and high overpotentials. Large effects of crystal orientation are observed. The chemical composition of the crystal has a much smaller effect. This is apparently due, at least in part, to a change of surface composition with changing electrode potentials. Thus, at a given potential, the composition of the surface layers of all samples may be similar.

Titanates as oxygen electrodes, U. Bertocci, M. I. Cohen, J. . Mullen, and T. Negas, *SP455*, pp. 313-321 (Nov. 1976).

Key words: electrocatalyst; hydrogen evolution; lanthanum titanate; oxygen electrode; photo-assisted electrolysis; rutile.

Single crystal or polycrystalline compacts of five, TiO_2-based, oxide materials were investigated as oxygen electrodes. Potentiostatic and potentiodynamic measurements were accomplished at room temperature using neutral borate or 5M H_3PO_4 and inert (Ar) or oxygen environments. Observations of electrochemical behavior during illumination also were made.

Materials display slow, but continuous, changes in features of potentiodynamic scans, as well as changes in current with time at constant potential. Failure to attain steady-state conditions is attributed to specimen mechanical/chemical inhomogeneities and changes prior to and during measurement, variable surface conditions, together with electrode pre-treatment. For example, cathodic currents for O_2 reduction tend to increase after cathodic polarization, while H_2-evolution is hindered by dissolved O_2. Illumination increases the current density for O_2 reduction at very negative potentials while current decreases are apparent during H_2-evolution in Ar.

Results indicate that these oxides are not promising as electrocatalysts for O_2-reduction, although for a definitive assessment, well-defined and closely controlled surface conditions are necessary.

Ionic transport and electronic exchange at solid electrolyte interfaces, M. W. Breiter and G. C. Farrington, *SP455*, pp. 323-340 (Nov. 1976).

Key words: charge transfer processes; conduction mechanisms; interfacial phenomena; solid electrolyte.

Interest in highly conductive solid electrolytes, compounds that display conductivities comparable to aqueous electrolytes at room temperature, is great because of their many potential applications. This paper reviews conduction mechanisms and charge transfer at solid electrolytes having fast ionic transport. For the discussion, solid electrolytes have been grouped into stoichiometric compounds, doped compounds and nonstoichiometric compounds; interfaces are classified as two-phase and multi-phase boundaries.

Influence of water on beta alumina interfacial ion transport, G. C. Farrington, *SP455*, pp. 341-349 (Nov. 1976).

Key words: beta alumina; blocking electrode; interface; solid electrolyte; water.

Water, adsorbed on a beta alumina surface, significantly influences the nature of Na^+ ion transport across a nonaqueous electrolyte/beta alumina interface and the behavior of a Pt/beta alumina interface. Na^+ interfacial exchange current at 23 °C between beta alumina and propylene carbonate decreases with increasing surface hydration. Adsorbed water undergoes a number of faradaic reactions at a Pt/beta alumina interface, which otherwise should approximate an ideally polarizable or "blocking" electrode. This paper discusses the effects of adsorbed water on ion and electron transport at these two interfaces.

Overvoltage phenomena in solid-oxide electrolyte cells at elevated temperatures, W. L. Worrell, *SP455*, pp. 351-358 (Nov. 1976).

Key words: copper electrodes; interfacial resistance; metal-metal oxide electrodes; oxygen transport; steady-state overvoltages.

To develop a more quantitative understanding of the factors which establish overvoltages in solid-oxide electrolyte cells, constant currents have been passed through two types of symmetrical cells. At temperatures between 800 and 1000 °C, constant and reproducible cell overvoltages are obtained when the imposed current is less than 50 μA. The cell overvoltage (η) is directly proportional to the current (I), and the interfacial resistance, defined as equal to η/I, is constant for each cell at constant temperature. Assuming that oxygen concentration gradients in the metal portion of the electrodes establish the cell overvoltages, a quantitative expression has been derived to calculate the interfacial resistance for each cell. Reasonable agreement between calculated and experimental values of the interfacial resistance is obtained for cells having two-phase metal-metal oxide electrodes. This agreement indicates that oxygen is transferred between metal particles and the electrolyte rather than through oxide particles in the electrodes. For cells with oxygen-saturated copper electrodes, the solubility-diffusivity product of oxygen in solid copper has been calculated from the overvoltage data.

SP456. **Measurements for the safe use of radiation.** Proceedings of an NBS 75th ANNIVERSARY Symposium held at the National Bureau of Standards, Gaithersburg, MD, Mar. 1-4, 1976, S. P. Fivozinsky, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 456,* 437 pages (Nov. 1976) SD Catalog No. C13.10:456.

Key words: calibrations; environment; measurements; medical; radiation; standards.

These proceedings are the compilation of papers presented at the Symposium, "Measurements for the Safe Use of Radiation," held in Gaithersburg, Maryland, March 1-4, 1976. The symposium addressed the present status and future requirements for measurements of ionizing and nonionizing radiation. Emphasis was placed on the needs for standardization and measurement assurance activities in medical, environmental, and personnel protection applications. *These proceedings include the following papers (indented):*

Historical development of the need for radiation protection and measurements in the United States, L. S. Taylor, *SP456,* pp. 5-11 (Nov. 1976).

Key words: radiation exposure; radiation measurement; radiation protection.

Early means of radiation measurement included photographic film, chemical compounds, selenium and ionization of air, and all were uncertain and inaccurate until about 1920. By 1930, ionization measurements between different laboratories and countries agreed within 2 or 3 percent. Also, quantitative limits for the exposure of radiation workers had been proposed and based on air ionization measurements—the roentgen. Accuracy requirements are ±5 percent for radiation therapy but to maximize the benefits to patients greater attention must be given to measurement assurance or traceability. Accuracy for protection purposes will vary with the dose levels involved, for example, ±10 percent at maximum permissible dose levels for radiation workers to perhaps ±200 percent at the level of 10 mrems in a year for the population.

The standards laboratory and the radiation measurement system, R. S. Caswell, *SP456,* pp. 13-24 (Nov. 1976).

Key words: ionizing radiation; measurements; standards, uses of radiation.

In connection with a broad NBS study of the National Measurement System, the measurement system for ionizing radiation has been investigated. Eight classes of radiation users were considered: medical, nuclear power, industrial radiation processing, defense, environmental, science, chemical analysis, and miscellaneous radiation applications. System structure including regulators, standards laboratories, manufacturers, as well as final users of radiation was studied.

Several common threads were observed in these studies for the various classes of users: (1) While there is often a need for new NBS standards where no standards exist, where NBS standards do exist their accuracy is generally sufficient for present needs. (2) There is a great need for measurement assurance, especially where regulatory requirements are involved. (3) A need exists to help users with training, convenient laboratory standards, and handbooks for guidance. In other cases, new or augmented institutional structures within the system (e.g. secondary standards laboratories) are needed.

The federal regulatory agency and the radiation measurement system, R. H. Schneider, *SP456,* pp. 25-29 (Nov. 1976).

Key words: federal regulating agency; Food and Drug Administration; radiation measurements.

The official actions of a federal regulatory agency can have unique health and economic impacts. It is often not feasible for other parties to review the processes leading to such actions in detail and appeal is tedious and expensive. As a matter of equity it is incumbent on the agency to assure that the errors associated with facts on which actions are based are sufficiently small as not to affect the course of such actions. When radiation measurements are used as part of the factual basis for regulatory action this means that these measurements must be an integral part of the national radiation measurements system. The manner in which this has been achieved within the Food and Drug Administration as part of the implementation of the Radiation Control for Health and Safety Act of 1968, (P.L. 90-602) is described.

State responsibilities and the radiation measurement system, M. W. Parrott, *SP456,* pp. 31-36 (Nov. 1976).

Key words: abstract; compromise; ineffectiveness; measurements; radiation; regulations; states.

The states' radiation control programs have attempted to respond to public health need through a radiation measurement system that requires much more than instrument calibration. Few federal agencies can cover their responsibilities without state assistance. This paper explains these areas from one Radiation Control Director's point of view which may be shared by several others. Recommendations for some improvements are made.

Ionization chamber for absorbed-dose calibration, J. S. Pruitt and R. Loevinger, *SP456,* pp. 37-39 (Nov. 1976).

Key words: absorbed dose; calibration; cavity chamber; graphite chamber; ionization chamber.

A cavity ionization chamber has been constructed for in-phantom calibration in terms of absorbed dose. Its principle characteristics are the following: a smooth external shape, allowing insertion in the phantom without unnecessary air gaps; a large collecting electrode and a small internal air gap (1.3 mm), to meet Bragg-Gray cavity requirements; a uniform collecting potential gradient, allowing high potential

gradients and low recombination loss; a guard electrode design which results in a stabilization time of a few seconds; construction of all three electrodes from pure graphite; and a day-to-day precision of about 0.1 percent. The chambers have been used to make the high-precision depth-dose measurements in water and graphite needed to transfer calorimetric absorbed-dose calibration in graphite to absorbed-dose calibration in water.

The development and application of monoenergetic x-ray sources, J. H. Sparrow and C. E. Dick, *SP456,* pp. 41-45 (Nov. 976).

Key words: detector calibrations; fluorescence x-ray sources; K x-ray sources; pulsed x rays; radiographic imaging; steady-state x rays.

High flux standard x-ray beams have been developed in the energy range from 1- to 100-keV. These beams which are produced by direct excitation of characteristic x rays in elemental targets are useful for the investigation of phenomena associated with radiological imaging and the calibration of radiation detectors. The design and performance of the sources and some applications to radiation measurement systems will be discussed.

The design of a mobile radiation calibration laboratory, R. C. Placious and J. C. Humphreys, *SP456,* pp. 47-51 (Nov. 1976).

Key words: mobile laboratory; radiation calibrations; radiation control; radiation measurement assurance; radiation standards.

A mobile x and γ-ray standards laboratory with facilities for calibration and testing of radiation instruments has been proposed as an effective method for propagating the national standards for exposure directly to state agencies responsible for local radiation control. NBS studies indicate that this can be accomplished by equipping a trailer truck with various sources of radiation, reference class instrumentation, and power generating equipment. The trailer described here incorporates radiation shielding which will be optimized in relation to beam collimation, direction, scattering, and maximum weight. The design provides all proper safeguards prescribed by federal or state agencies for transport over the nation's highways.

Automated calibration and recordkeeping system for x-ray survey instruments, T. R. Ohlhaber, F. J. Prevo, and T. L. Miller, *SP456,* pp. 53-57 (Nov. 1976).

Key words: automation; calibration; computer; recordkeeping; x ray.

A system for monitoring and controlling the calibration process for x-ray survey meters has been designed. A minicomputer with a real-time operating system and on-line disk storage provides the acquisition, reduction, and control parameters for the process and also maintains the recordkeeping for instruments dispersed over the country. The system is designed to rapidly provide information to multiple terminals about the calibration and availability status of survey instruments in order to facilitate the use of large numbers of instruments.

Standardization of a nationwide gamma radiation calibration system, E. F. Williams, Jr., P. V. Barrans, and G. H. Brodie, *SP456,* pp. 59-63 (Nov. 1976).

Key words: calibration; exposure rate; geometry; instrument; ion chamber; roentgen; standard; γ radiation; γ response.

A standardized γ radiation calibration system has been developed and is presently being used to provide uniform γ radiation fields for the calibration of ~ 500,000 γ measuring, civil defense survey instruments. The instrumentation, procedures, data handling techniques and secondary standards developed to make the system directly traceable to National Bureau of Standards are described and discussed. A simple test and evaluation of the total system is described. The test data obtained appears to show that the true roentgen is probably being provided to 48 maintenance locations with an accuracy of better than ± 6 percent and that the instruments can be calibrated to within ± 14 percent of the true exposure rate at one point on each detection range.

A reliable calibration program for ionizing radiation measurement, A. Jacobsen, *SP456,* pp. 65-69 (Nov. 1976).

Key words: calibration; dosimetry; ionization chamber; secondary standardization.

The recent availability in this country of the N.P.L. No. 2560 Secondary Standard instrument has afforded a new dimension to instrument calibration procedures. A description is presented of the accuracy, stability, and utility of the N.P.L. No. 2560 for calibration of various instruments to measure a wide range of ionizing radiation energies.

AIF-NBS radioactivity measurements assurance program for the radiopharmaceutical industry, R. Collé, *SP456,* pp. 71-76 (Nov. 1976).

Key words: assurance; measurement; radioactivity; radiopharmaceutical; standards; traceability.

The National Bureau of Standards supervises and administers on behalf of the Atomic Industrial Forum (AIF) a radioactivity measurements technology quality assurance program for the radiopharmaceutical industry. The program provides for a monthly distribution of both millicurie-and microcurie-level Standard Reference Materials to each of eight participating commercial radiopharmaceutical manufacturers. A number of the standards are distributed as "blind" samples to establish traceability to the national radioactivity measurements system. In addition to identifying measurement discrepancies, assistance is provided to the participants in eliminating the sources of difficulties, and in correcting errors in their measurement techniques. In this report, results for the "blind"-sample traceability exercises are given, and a discussion of identified sources of measurement errors and recommendations are also presented.

American National Standards Institute quality assurance program in radioactivity measurements, C. W. Seidel and J. M. R. Hutchinson, *SP456,* pp. 77-82 (Nov. 1976).

Key words: detectors; germanium; ion chamber; liquid scintillation; sodium iodide; standard.

The ongoing ANSI N42.2 program of writing procedural standards for radioactivity measurements with NaI(Tl) and Ge(Li) detectors, liquid scintillation counters and ionization chambers is described.

Filtered beams at the NBS reactor, R. B. Schwartz, I. G. Schroder, and E. D. McGarry, *SP456,* pp. 83-85 (Nov. 1976).

Key words: monoenergetic neutrons; neutron beams; neutron filters; neutrons; reactors; resonant scatterer.

Using a combination of resonant scatterers and filters, we are producing high intensity, very pure beams of 2 keV, 25 keV, and 144 keV neutrons at the NBS reactor. These beams have low background, are well calibrated and very stable, and are intended for use as calibration standards.

Neutron source calibrations at NBS for calibration checks of neutron radiation instruments, V. Spiegel, *SP456,* pp. 87-89 (Nov. 1976).

Key words: calibration; manganous sulfate; neutron source; radiation instruments.

The manganous sulfate bath method of neutron source calibrations at the NBS is described together with the corrections applied for neutron capture in the source itself, capture by competing nuclei of either fast or thermal neutrons, and thermal neutron leakage. The advantage of commercially available Am-Be (α,n) neutron sources as a calibration check for radiation instruments in the MeV range is stressed.

Ultrasonic measurements and calibration, H. F. Stewart, M. E. Haran, and B. A. Herman, *SP456,* pp. 91-97 (Nov. 1976).

Key words: calibration; diagnostic ultrasound; ultrasonic measurements; ultrasonic techniques.

In the past few years ultrasound techniques have become well known and are receiving widespread acceptance in clinical practice. For example, diagnostic ultrasound is rapidly finding use as a compliment to other techniques and often is the modality of choice for visualization of structures within the body supplanting procedures involving the use of ionizing radiation. Some of the main areas of application at the present time are visualization of abdominal organs, pregnant uterus, and the heart. It is estimated that approximately 35 percent of the pregnant women in the United States currently undergo ultrasonic insonations and that by 1980 this number will increase to about 90 percent. Along with the increasing use of this modality come the responsibility for the assessment of the risk that may be involved with its use. This requires the measurement and characterization of ultrasonic fields by researchers engaged in the evaluation of biological effects associated with ultrasonic exposures. There is also the need to determine parameters of the ultrasonic field from fields produced by commercial ultrasonic devices in order to evaluate the potential risk their use may present on the basis of biological effects data. These measurements are especially necessary in view of the wide proliferation of such devices. In addition the establishment of any necessary performance criteria requires the quantification of the ultrasonic fields involved and calibration of measurement devices used.

Methods for the evaluation and calibration of microwave survey instruments, M. L. Swicord, H. I. Bassen, and W. A. Herman, *SP456,* pp. 99-105 (Nov. 1976).

Key words: microwave power density; microwave radiation measurement.

A facility has been established for the evaluation and calibration of microwave power density instrumentation. It includes an anechoic chamber with a precisely positionable cart for measuring gain and chamber standing waves. The operable frequency range is from 900 MHz to 10 GHz. A laser provides a means of aligning antennas. The absolute calibration of distance and microwave power are performed by NBS. The radiated electric field strength is then established by BRH as a primary standard using precise antenna gain measurement methods. An instrument evaluation facility includes an absorber-lined temperature chamber, a probe/slot-source positioning system, and devices for measuring the polarization response, modulation response, and the linearity of the microwave survey instruments.

NBS ultraviolet radiometric standards, W. R. Ott, *SP456,* pp. 107-110 (Nov. 1976).

Key words: detectors; NBS; radiometry; sources; standards; survey; ultraviolet.

A brief review of the standard sources and detectors available as services from NBS will be given. Emphasis will be on the use of such standards to calibrate the radiant power of unknown sources or the response of radiation detectors and spectral radiometers at wavelengths less than 400 nm. The following standards, listed in order of decreasing wavelength, are or will soon be available: the tungsten filament quartz-halogen lamp (above 250 nm); the tungsten strip lamp (above 225 nm); the low pressure mercury vapor lamp (253.7 nm); the deuterium arc lamp (165 to 350 nm); the argon "mini-arc" (115 to 400 nm); photodiode detectors (20 to 254 nm); and the synchrotron radiation source, SURF-II (5 to 400 nm). The relative strengths and limitations of these radiometric standards with respect to accuracy, reliability, convenience, and intensity and wavelength range will be discussed.

Quality assurance for measurements in therapy, R. J. Shalek, P. Kennedy, M. Stovall, J. H. Cundiff, W. F. Gagnon, W. Grant, III, and W. F. Hanson, *SP456,* pp. 111-118 (Nov. 1976).

Key words: medical physicist; radiation measurement; radiation therapy; tumor dose; quality control.

Recommendations regarding quality control in physics relating to radiation therapy are derived from experience with the Radiological Physics Center which is a national review program, and the Texas Regional Medical Physicists, which is a regional consultation activity.

Quality assurance measurements in diagnostic radiology, M. P. Siedband, *SP456,* pp. 119-130 (Nov. 1976).

Key words: diagnostic radiology; pass-fail tests; quality assurance measurements; x-ray quality control.

The concatenation of elements in an x-ray system necessitates a two level approach to system evaluation. The first level tests determine the weakest links of the chain while the second level tests provide more precise measures of elemental performance. Several types of first level pass-fail tests are described in terms of their utility in a routine quality assurance program for use in hospitals and in their relation to the second level tests. The requirements for accuracy and precision of the measurement apparatus are discussed.

Quality assurance for measurements in nuclear medicine, B. A. Rhodes, W. B. Hladik, and J. H. Gallagher, *SP456,* pp. 131-138 (Nov. 1976).

Key words: gamma camera; nuclear medicine; quality assurance; radiopharmaceuticals; ^{99m}Technetium.

This report reviews the measuring systems currently in use to assure safe and effective medical use of radioisotopes. One group of control tests measure the accuracy and precision of *in vitro* radiometric assays. Another group of measurements is applied to *in vivo* studies. This group includes measurements of quantity and quality of administered isotopes, performance of nuclear imaging devices and even the performance of physicians who interpret the images. Measures of overall system performance are also employed. The use of feedback loops to control and improve the quality of nuclear studies is an area of current exploration.

State and federal regulatory measurement responsibilities round medical facilities, L. H. Lanzl, *SP456,* pp. 139-146 Nov. 1976).

Key words: diagnosis; measurement accuracy; medical facilities; regulatory; therapy; traceability.

Radiation exposure to man is due chiefly to diagnostic x-ray procedures, in which radiation is intentionally directed toward a patient. Radiation therapy presents a lesser problem because a smaller percentage of the population is subjected to such treatment. Recently, some innovative steps were taken in the State of Ill ois to reduce patient exposure in four diagnostic procedures without reducing the benefits derived therefrom. However, if these procedures are to be carried out properly, it is necessary to increase the precision and accuracy of radiation exposure measurements to the order of ±2 percent. The usual accuracy and precision of radiation protection measurements are of the order of ±20 percent. Thus, should the Illinois radiation protection rules become widely adopted, our national dosimetry network will need to upgrade exposure measurement techniques.

Nationwide evaluation of x-ray trends (next) program—And adiation measurements in the state, J. W. Shaver, *SP456,* pp. 47-152 (Nov. 1976).

Key words: diagnostic; nationwide evaluation; physician; technologist; x-ray departments; x-ray trends.

A Task Force of state and Bureau of Radiological Health representatives has applied the "standard man" concept as a method of evaluating the impact of government control efforts on medical x-ray exposure. Exposure data are collected using standardized procedures and equipment, and Organ Dose Index values are obtained for selected critical organs. It is expected that these data can be correlated with governmental agency radiological health activities.

Low level environmental radiation measurements with a lastic scintillation detector system, A. P. Hull and G. S. evine, *SP456,* pp. 153-157 (Nov. 1976).

Key words: low level environmental radioactivity measurements scintillation detector.

A plastic scintillation detector-photomultiplier combination, operated in the current mode, has been developed at Brookhaven National Laboratory for the measurement of low level environmental radiation. Its output is digitized and processed by semiconductor circuits, which also provide for hourly compensation of variation in gain utilizing a built-in calibration source.

The instrument has been tested in the field for the past two years to establish its response capability to diurnal and longer term variation in background radiation, as well as small increments produced by a distant γ-field irradiation source. (Supported by U.S. ERDA.)

Precise environmental gamma-ray measurements utilizing tandard Ge(Li) detectors, R. M. Keyser, G. V. Walford, and . A. Cooper, *SP456,* pp. 159-167 (Nov. 1976).

Key words: environmental gamma-ray measurements; environmental samples; gamma-ray measurements; Ge(Li) detectors.

The analysis of environmental samples for radionuclides is fast becoming a large segment of the gamma-ray analyses performed. Many research laboratories and routine testing stations encounter a large number of samples. Some of these are relatively complex. In this paper we are concerned with the physical parameters of the measuring system; that is the characterization of the detector, the sample-detector relationship and the multichannel analyzer (analog to digital converter) and how these characteristics affect the accuracy of the measurement.

The counting sensitivity of a system can be used as a figure of merit for that system and can be defined as the minimum detectable limit or minimum acceptable limit. There are five factors affecting the sensitivity of a system. These are: the background, the system energy resolution, the detector efficiency and sample shape, the time allotted for the measurement, and the accuracy required for the result. We will discuss these parameters and their measurement and how they affect sensitivity for a series of standard germanium detectors.

The minimum-detectable-activity concept, J. C. Lochamy, *SP456,* pp. 169-172 (Nov. 1976).

Key words: background; critical level; detection limit; determination limit; less-than level; minimum detectable activity; statistical.

Various definitions of "minimum detectable activity (MDA)" are discussed and statistically valid representatives are presented. The methods of Currie are given primary emphasis and include development of the Critical Level, Detection Limit, Less-Than Level, and Determination Limit in terms of count-rate.

Use of NBS mixed-radionuclide gamma-ray standards for calibration of Ge(Li) detectors used in the assay of environmental radioactivity, B. M. Coursey, *SP456,* pp. 173-179 (Nov. 1976).

Key words: environment: gamma-ray measurements; Ge(Li) detectors; radioactivity; standards.

The NBS mixed-radionuclide gamma-ray emission-rate standards were first distributed in 1972 for use in calibrating Ge(Li) detectors used for measuring environmental radioactivity. These sources allow the user to prepare full-energy-peak efficiency vs. γ-ray energy curves for the detector from measurements made with a single standard. This paper will discuss the development of these standards and examine their current use in the assay of radioactivity in liquid, gaseous, and soil samples.

The safety and reliability of decentralized TLD, C. O. Widell, *SP456,* pp. 181-185 (Nov. 1976).

Key words: decentralized TLD; dosimeters; TLD reliability; TLD systems.

Decentralized reading of personnel TLD is in Sweden performed at the different nuclear power stations. The TLD results are automatically processed in the central dose register at Studsvik. In order to check and correct the readers, reference dosed dosimeters are used in each batch of TLD to be read. The reference dosed results are processed by the computer and will show the status of the different TLD readers. The reference dose irradiation is done with a Sr-90 source, which is placed above a rotating table in a brass shielding. The dosimeters are placed on this rotating table and will get a dose equivalent to 300 mrem gamma. In addition to this procedure a serie of calibration dosimeters is irradiated at a central calibration facility each month and read in the local TLD-reader.

Error analysis of environmental radiation measurements made with integrating detectors, G. de Planque Burke and T. F. Gesell, *SP456,* pp. 187-198 (Nov. 1976).

Key words: environmental radiation measurements; error; integrating detectors; TLD.

Proper use of integrating detectors (e.g., TLDs) for environmental monitoring, particularly around nuclear facilities, requires a high degree of measurement accuracy and a meticulous assessment of measurement errors.

Mathematical expressions for the dose in air at a site are formulated in terms of factors affecting the measurement including detector efficiency and calibration techniques as well as characteristics inherent to the detector such as energy dependence and contributions to the total during storage and transport of the detector. The assessment of errors for individual terms in the equations is discussed and errors are combined to determine the accuracy of the estimated dose.

Radio-frequency electromagnetic radiation from portable and mobile telecommunication transmitters, J. F. Thiel, *SP456,* pp. 199-202 (Nov. 1976).

Key words: antenna specifications; mobile telecommunication transmitters; RF radiation.

The increasing number of sources of electromagnetic radiation in the environment has placed more emphasis on the evaluation of such sources. Several of the more common sources of electromagnetic radiation to which individuals and equipment are exposed have been surveyed in an attempt to assess potential personnel hazards from the radiated fields. Measurements and examples of several typical types of antenna and transmitter combinations are presented.

An automated measurement system for determining environmental radiofrequency field intensities II, R. A. Tell, N. N. Hankin, J. C. Nelson, T. W. Athey, and D. E. Janes, Jr., *SP456,* pp. 203-213 (Nov. 1976).

Key words: antenna; microwave; minicomputer; radiofrequency; RF exposure; spectrum analyzer.

A measurement system is described which is used to measure environmental RF exposure levels. The system uses a spectrum analyzer interfaced to a minicomputer for data acquisition and is contained within a van for nationwide use. Special antenna systems allow isotropic field intensity measurements in selected bands between 0.5 MHz and 10 GHz.

The measurement of optical radiations: Selected practical considerations, R. W. Peterson, J. M. Coakley, K. Mohan, and R. James, *SP456,* pp. 215-221 (Nov. 1976).

Key words: calibrations; calorimeters; detectors; lasers; radiometry.

This paper describes the measurement capabilities for coherent and incoherent optical radiations at the Bureau of Radiological Health and discusses some problems that arise in developing a program of measurements required for enforcing compliance with Federal standards and for related regulatory responsibilities.

X-ray leakage from conventional and high voltage electron microscopes, D. F. Parsons, V. A. Phillips, and J. S. Lally, *SP456,* pp. 223-224 (Nov. 1976).

Key words: electron microscopes; health hazards; high voltage electron microscopes; x-ray leakage.

A survey of the x-ray leakages from the electron microscopes used by members of the Electron Microscopy Society of America has been carried out. Few, if any, out of several thousand long term microscope users received an exposure detrimental to health. However, a sufficient number of design errors, and accidental over exposures have occurred to make standardization of maximum allowed leakage desirable. The radiation hazards of high voltage electron microscopes are also discussed.

Intercomparison of personnel dosimeters, H. W. Dickson, W. F. Fox, and F. F. Haywood, *SP456,* pp. 225-232 (Nov. 1976).

Key words: dosimetry; gamma; intercomparison; neutron; personnel; reactor.

The first intercomparison of personnel monitoring dosimeters at Oak Ridge National Laboratory's DOSAR Facility was conducted during the period May 14-16, 1974. Ten independent laboratories and companies participated in an intercomparison of neutron and gamma-ray dosimeters used for routine personnel monitoring. The dosimeters, which were sent through the mail, were exposed at the Health Physics Research Reactor in three "standardized" radiation fields, which have been used for the past several years for intercomparing nuclear accident dosimeters. In addition, a 14-MeV neutron field was used as a fourth exposure condition. The results of the intercomparison show widely varying dose estimates; e.g., reported values of neutron dose equivalent have standard deviations ranging from 47-102 percent of the mean. A second intercomparison was conducted in a similar manner on February 18-19, 1976; however, only a few preliminary results are available at this time.

Environmental radiation measurements, J. E. McLaughlin, *SP456,* pp. 233-248 (Nov. 1976).

Key words: calibration; environmental gamma-rays; field testing; instruments; source distributions.

Determinations of radiation dose rates and radionuclide concentrations depend on systematic considerations of detector characteristics and instrument system calibrations, as well as the composition, source distributions, and flux-energy and angle distributions of the environmental radiation field. Routine *in situ* measurements around nuclear facilities are made primarily to monitor changes in certain radiation parameters. Even these measurements should be based on absolute determinations in order to attribute changes correctly to the source. The systematic considerations required for monitoring environmental sources are discussed and realistic examples of gamma-ray measurements are presented along with a suggestion for beta ray measurement.

Environmental measurements and regulatory responsibilities, J. M. Matuszek, *SP456,* pp. 249-261 (Nov. 1976).

Key words: environmental samples, laboratories; quality assurance; radioactive effluents; radioanalytical data; regulations.

During recent years, federal and state regulatory agencies have exhibited a propensity for issuing environmental radiation regulations regardless of the quality of the data base available for derivation of the standards. Particular examples of this trend are the AEC/NRC Regulatory Guide 4.3, EPA's Federal Safe Drinking Water Regulations, and some state and local edicts. Though the federal agencies appear to be improving in their efforts to obtain a sound environmental data base in certain areas, recent estimates of health effects attributable to ^{14}C effluents show that some interest continues for the "estimate and speculate" method of arriving at environmental radiation standards. Some state and local regulatory agencies, more closely attuned to political and media pressure, have rendered decisions or made statements which are not readily supported by the data obtained

from environmental measurements. Environmental radiochemical laboratories, on the other hand, have found that quality assurance requirements ordinarily acceptable for routine surveillance programs are not always sufficient at low radioactivity levels for the regulatory needs developed. As even more stringent analytical requirements are imposed, the staffs of both the laboratories and the regulatory agencies must be fully cognizant of the statistical limitations of environmental data developed at very low radioactivity levels and respond accordingly in making regulatory decisions or setting environmental regulations.

Environmental radioactivity standards, A. N. Jarvis and D. . Easterly, *SP456*, pp. 263-265 (Nov. 1976).

Key words: calibration; intercomparison studies; quality assurance; quality control; radioactivity; reference methods.

Policy decisions concerning environmental quality must be based on valid and comparable data. The distribution of radioactive reference samples and conducting interlaboratory studies aids in the critical evaluation of such data and helps assure that measurements are correctly made, accurate, traceable to national radiation standards, and comparable. Standards distribution and intercomparison studies are discussed. Traceability studies between the National Bureau of Standards and the U.S. Environmental Protection Agency are reviewed. Identification and documentation of potential radioactive pollutants that could result from expanded energy programs are also discussed.

Personnel monitoring measurements, R. V. Griffith, *SP456*, p. 267-276 (Nov. 1976).

Key words: betas; calibrations; dosimetry; gammas; neutrons; plutonium; x rays.

A personnel monitoring program must include a well integrated combination of dose determination methods, and should not depend on a single dosimetry system. Many of the necessary techniques have become well developed and dependable, such as the personnel gamma dosimeters in use today. However, other monitoring methods are still not adequate. The two most important personnel monitoring problems remaining are development of personnel neutron dosimeter and in-vivo measurement of plutonium at sublung burden levels. Although there are a few techniques under development to attack these problems, satisfactory long-term solutions will require much more work. As the developments in nuclear power and medicine continue, the need for solutions to these problems will intensify.

Personnel monitoring performance standards, B. H. Weiss, *P456*, pp. 277-284 (Nov. 1976).

Key words: film badges, TLD, HPS working group; personnel dosimeters.

Efforts in the United States to provide some measure of uncertainty to the interpretation of routine personnel monitoring badge results have received the attention of various groups, individuals and governmental agencies for over 20 years. However, in general, health physicists and the users of these personnel monitoring devices still do not have great confidence in the results. This paper will review the history of the significant activities in trying to develop a system for testing the performance of personnel dosimetry services. This will also include a discussion of the current published standards and those in draft with respect to their different approaches and objectives. In particular, the paper will describe activities of the Nuclear Regulatory Commission in considering mandatory performance testing of personnel dosimetry and the work of a Health Physics Society Working Group which could be the basis for an NRC proposed rule.

Optical interferometric measurements of ultrasonic radiation and its applications to medicine, M. E. Haran and H. F. Stewart, *SP456*, pp. 285-297 (Nov. 1976).

Key words: optical interferometric measurements; ultrasonic medicine; ultrasonic radiation.

A modified Michelson interferometer is currently being used to map particle displacement amplitude within a beam of pulses ultrasound. One leg of the interferometer is raster scanned across a 4 micrometer thick, opaque gold coated membrane upon which the sound is incident. The reference leg of the interferometer has been modified to provide stability. Sensitivity has been found to be at least 10 picometers which corresponds to 1.0 micro watts/cm^2 at 1.5 MHz. Particle displacement amplitude is displayed in two modes: 1) displacement vs. position for each horizontal scan, 2) displacement vs. position for an entire frame by Z-axis modulation of a CRO. Frame rates of 2/sec. can be achieved. This system has been used to determine measured ultrasonic field patterns. Parameters of interest include peak intensity, intensity distribution, ratio of peak to average intensity and calculation of beam area. Methods for specifying beam areas will be discussed as well as the application of the system to evaluate medical diagnostic and therapy transducers. This system was developed by RCA Laboratories, Princeton, New Jersey.

Photon mass energy-absorption coefficient air/medium ratios for ionometric dosimetry 0.1 keV to 20 MeV, J. H. Hubbell, *SP456*, pp. 299-306 (Nov. 1976).

Key words: attenuation coefficient; cross section; dosimetry; energy-absorption coefficient; gamma-ray; photon; x ray.

The determination of photon absorbed dose in a medium by means of an air-ionization chamber depends in part on the ratio of the mass energy-absorption coefficient μ_{en}/ρ for air to that for the chamber wall material, to account for the differing atomic compostions. In this paper, mass attenuation coefficients μ/ρ developed at the National Bureau of Standards by the X-Ray and Ionizing Radiation Data Center from the latest theoretical cross section data are compared with measurements for selected low-Z elements of dosimetric interest. From this cross section data base, mass energy-absorption coefficients μ_{en}/ρ are derived for air and selected media, along with air/medium ratios, over the photon energ yrange 0.1 keV to 20 MeV including values at the cesium-137 and cobalt-60 energies. Comparisons are made with earlier published μ_{en}/ρ values and air/medium ratios.

Electron dosimetry with ionization chambers, M. J. Berger, S. M. Seltzer, S. R. Domen, and P. J. Lamperti, *SP456*, pp. 307-312 (Nov. 1976).

Key words: calorimeter; dose/ionization conversion; dosimetry; electrons; ionization chamber; stopping-power ratios.

This paper describes work at NBS dealing with the conversion of ionization measurements to absorbed-dose values in high-energy electron dosimetry. This work was done by two approaches: experimentally, through the comparison of calorimeter and ionization-chamber measurements in a gra-

phite phantom, for incident-beam energies from 15 to 50 MeV; theoretically, via transport calculations of electron flux spectra and application of Bragg-Gray cavity theory, for beam energies from 1 to 60 MeV and for various media including water, tissue, graphite and plastics. The pertinent dose/ionization conversion factor has been determined with an estimated accuracy of 1 percent as a function of the beam energy and of the depth in the phantom. Experimental evidence has also been obtained on the influence of lead scattering foils on the value of the conversion factor.

Dose profiles in tissue and in air for therapeutic electron beams, G. Osman, *SP456*, pp. 313-326 (Nov. 1976).

Key words: dose profiles; electron dosimetry; pencil beam; therapeutic beam.

Electron dose profiles in body tissues and in air were obtained in this work theoretically and experimentally for 3 to 30 MeV incident beam energies. A knowledge of dose profiles in air is necessary for any extended SSD treatments or air gap beyond the end of collimator. Theoretical dose profiles were predicted at various depths in tissue using the Osman's Model for therapeutic electron beams. Experiments were carried out with unfiltered beams in air and in tissue equivalent materials and results were compared with those predicted from our theoretical model. During the initial depth of penetration in muscle, fat, bone, lung and air, the electron dose profiles showed flat-top distributions within the geometrical configuration of the beam. At considerable depths in air or tissue (comparable to the range and field size), electron dose profiles have shown Gaussian distributions of various half-widths. Between the two extremes, electron dose distribution experiences a gradual transition from flat-top to the Gaussian. Slopes of these Gaussian curves varied inversely with the incident electron energy. The Gaussian dose distributions in tissues are generally not clinically acceptable. The flat distributions, however, can be obtained by proper design of scattering foils and electron cones. Tissue dose profiles as obtained from our model could provide useful input data for programming treatment planning with high energy electron beams, using mini-computers. It is expected that the predicted dose distribution by our model could also account for cone design and body-inhomogeneity.

Calorimetric dose measurements in fast neutron and cobalt-60 gamma-ray fields, J. C. McDonald, J. S. Laughlin, and L. J. Goodman, *SP456*, pp. 327-333 (Nov. 1976).

Key words: calorimeter; dosimetry; fast neutron; tissue equivalent.

A portable calorimeter, constructed of A-150 tissue equivalent (T.E.) plastic, was employed to measure dose in a cyclotron-produced fast neutron field and in a ^{60}Co gamma-ray field. The precision of these measurements ranged from $\pm$ 1-2 percent depending upon dose rate and signal to noise ratio. The absolute accuracy of measurements in the neutron field is estimated to be $\pm$ 5 percent and those in the ^{60}Co field to be $\pm$ 2 percent. A method for determining the magnitude of endothermic radiochemical effects which occur in T.E. plastic will be described along with other sources of uncertainty in calorimetric dosimetry.

Scattered radiation from a neutron collimator, F. H. Attix, L. S. August, and P. Shapiro, *SP456*, pp. 335-341 (Nov. 1976).

Key words: albedo; collimation; dosimetry; ion chambers; n-γ dosimetry; neutrons; scattering.

Fast-neutron beams are being employed in radiotherapy trials and associated radiobiology studies at numerous centers in the U.S., Europe, and Japan. Since collimated beams of various sizes and shapes are employed, it is desirable to know the composition of the scattered radiation component contributed by the collimator. A simple method is shown for deducing the field composition in terms of a 3-component model, from measurements made with three ionization chambers (tissue-equivalent, graphite, and magnesium). The dose contributed by the scattered radiation in the present example was found to be predominantly due to fast neutrons indistinguishable from those in the primary spectrum (from 35-MeV D^+ on Be). This method may prove useful for measurements in phantoms as well.

Dose control in radiation therapy, K. R. Kase, B. E. Bjarngard, B. J. Maddox, and G. K. Svensson, *SP456*, pp. 343-350 (Nov. 1976).

Key words: dosimetry; ion chamber; patient; precision; therapy; TLD.

Accurate and precise dose delivery is necessary in radiation therapy because of the steep tissue response-dose curve. This paper discusses the precision of dose measuring devices, therapy machines, patient dose delivery at the Joint Center for Radiation Therapy. Ion Chambers used for therapy machine calibrations show a precision of 0.7 to 1.3 percent while a thermoluminescent dosimetry (TLD) system shows a precision of 1.5 percent. Thereapy machines are calibrated on a weekly schedule and the variation in dose delivery between calibrations varies from 1 to 2 percent. Daily constancy checks on the linear accelerators using TLD show a variation of about 2 percent from day to day. Patient dose measurements using TLD at orthovoltage energies appear to have a precision of about 5 percent except for very small treatment fields where it is about 12 percent. Patient dosimetry at megavoltage x-ray energies shows a precision of 3.5 percent while at megavoltage electron energies it is about 5 percent.

Dosimetry procedures at the Northwest Medical Physics Center, D. Jones, D. Schumacher, and J. Washington, *SP456*, pp. 351-358 (Nov. 1976).

Key words: calibration; megavoltage radiotherapy; quality assurance.

The Northwest Medical Physics Center provides physics support to 28 radiotherapy institutions in the Northwest from a central location. The methods employed in on-site physical measurements, organization of data and long-term quality assurance are described.

Intercomparison of prescription dose delivery in the New England region, J. S. Blinick, J. Spira, D. Cail, and P. Plazeski, *SP456*, pp. 359-363 (Nov. 1976).

Key words: dosimetry; intercomparisons; radiation; supervoltage; therapy.

An intercomparison of radiation dosimetry among 16 institutions within the New England area was performed using a hand carried water phantom-ionization chamber system. Participants were asked to deliver 200 rads using their own beam data and computations to the chamber for each of eight field size and depth combinations. Average measured doses ranged from 200 to 204 rads. For all combinations, the standard deviation of the measured values was 3 percent.

Electron-therapy dosimetry, M. Ehrlich and P. J. Lamperti, *456*, pp. 365-370 (Nov. 1976).

Key words: dosimetry; electrons; impact; improvement; performance; radiation therapy; service.

A service for checking the dosimetry of electron beams in the energy range from 5 to 50 MeV was established in 1967, mainly for use by radiation-therapy departments. Since then, 34 radiation-therapy departments and several other groups have participated, a relatively large number of them only intermittently or for a total of only a few tests. There has been little improvement of overall performance over the years, less than one-half of the total number of irradiated dosimeters involved in any one test showing agreement to within 5 percent between the dose reported by the participants and the NBS dose interpretation, and up to one-quarter of the dosimeters showing disagreements of more than 10 percent. Only in a few exceptional cases was there an improvement in individual performance with continuing participation. It is concluded that means must be sought, in collaboration with the therapy community, to secure a more favorable impact of this service on electron-therapy dosimetry.

Thyroid monitoring and minimizing I-125 uptake, M. M. abel, K. W. Price, and G. R. Holeman, *SP456*, pp. 371-379 Nov. 1976).

Key words: bioassay; I-125 uptake; thyroid monitoring.

A method is described for the quantitative determination of I-125 uptake by the thyroid gland of all users of I-125. Causes for uptake are discussed and the need for monitoring is illustrated.

Attenuation phantoms for patient exposure measurement dur-ıg radiographic examinations utilizing phototiming techniques, . J. P. Lin, *SP456*, pp. 381-388 (Nov. 1976).

Key words: attenuation; exposure; phantoms; phototiming; radiographic examination; x-ray tube potential.

Aluminum phantoms have been obtained for patient simulation in radiographic procedures utilizing phototiming techniques. Thickness of these phantoms have been determined by (a) monitoring radiographic parameters of phototimed examinations and (b) attenuation measurements of x-rays in aluminum. Four of the eight selected radiographic procedures, namely (1) A-P cervical spine, (2) Lateral lumbar spine, (3) A-P abdomen, and (4) A-P skull examinations, have been subject to patient exposure limitation in the State of Illinois since January 1, 1975. Use of these aluminum phantoms in compliance testing and estimation of patient exposure are discussed.

Effects of measuring apparatus on x-ray attenuation measure-ıents, T. J. Morgan, L. B. Smith, and Z. R. Hashmi, *SP456*, p. 389-394 (Nov. 1976).

Key words: chamber energy response; geometry effects; half-value layer; photon attenuation.

Measurements of x-ray exposure are affected by the photon energy dependence of instrument response, and measurement geometry.

The effects of these factors on measured x-ray attenuation curves and estimates of first half-value layer in aluminum under certain test conditions are described, and estimates of the magnitudes of the effects are given.

A method for correcting half-value layer estimates obtained under less than ideal, but well-controlled, conditions is discussed.

kVp measurement for dental x-ray units, M. S. Moroz and J. A. Vukan, *SP456*, pp. 395-401 (Nov. 1976).

Key words: dental; kVp; x ray.

The kVp measurement of a sealed x-rav system using filtered radiation from a scatterer is discussed and compared to direct voltage measurement techniques.

National ionizing radiation standards, J. E. Leiss, *SP456*, pp. 403-416 (Nov. 1976).

Key words: ionizing radiation; measurement assurance; radiation users; standards.

Ionizing radiation in its many forms is used in an increasing number of ways to help solve important problems of our technological society. As these applications become more mature, the needs for reliable radiation measurement continue to increase, both to achieve the maximum benefit from the radiation use and also to assure that these applications are carried out safely. To meet these measurement needs, the National Bureau of Standards provides a wide variety of measurement standards and services. New standards are also being developed to meet a variety of new needs.

It is recognized that these radiation measurement standards by themselves are of limited usefulness unless they can be related to measurements made at the user level. Various mechanisms exist for this, including measurement calibrations, measurement traceability testing, and measurement assurance programs. The National Bureau of Standards carries out an increasing number of activities of this type. In some cases new or augmented institutional arrangements within the national measurement system for ionizing radiation appear necessary.

Non-ionizing electromagnetic radiation standardization, R. C. Baird and A. A. Sanders, *SP456*, pp. 417-425 (Nov. 1976).

Key words: calibrations; laser calorimeters; measurement assurance programs; non-ionizing EM radiation hazards; RF and microwave measurements; standards.

Calorimeters have been developed by NBS as accurate (± 1%) standards for calibrating laser power and energy measuring devices. A pilot measurement assurance program (MAP) is underway, with 12 industrial organizations participating. The anticipated accuracy is ± 5 percent. A formal MAP service will be announced about July 1976. Accurate standards for rf and microwave fields are not as well developed because of the inherently greater difficulty in measuring these fields caused by diffraction, interference, reactive fields, modulation, etc. NBS has developed accurate measurement and calibration techniques which will be fully implemented about August 1976 when a new anechoic (reflection-free) chamber will be completed. NBS is also developing stable transfer standards suitable for measurement assurance programs, and a pilot MAP with uncertainties of about ±0.5 dB (±12%) is anticipated during FY 1977.

SP457. **Building technology publications 1965-1975,** J. R. Debelius, S. G. Weber, and K. N. DeCorte, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 457*, 107 pages (Dec. 1976) SD Catalog No. C13.10:457.

Key words: abstracts; Center for Building Technology; key words; publications.

This report presents the National Bureau of Standard's (NBS) Center for Building Technology (CBT) publications of the past decade. Publications constitute a major end product of CBT's efforts. They appear in several publication series (Building Science

Series, Technical Note, NBS Report, NBS Interagency Report, Handbook, Special Publication, the Journal of Research, and the Consumer Information Series).

SP459. **Performance evaluation of programmable robots and manipulators.** Report of a Workshop held at Annapolis, MD, Oct. 23-25, 1975, T. B. Sheridan, Ed., *Nat. Bur. Stand. (U.S.), Spec. Publ. 459,* 213 pages (Oct. 1976) SD Catalog No. C13.10:459.

Key words: guidelines; industrial robots; manipulator; performance evaluation; programmable robots; specifications.

The Workshop brought together representatives of industry, academic institutions and government agencies, including the potential designers, suppliers and users of a new generation of manipulators and robots which include varying degrees of control by both people and computers. The Conference was motivated by the lack of common bases for comparing one such device with another in terms of performance, or one task with another in terms of how well a given device will perform it.

The Workshop concluded that there is a need for (1) common definitions of many terms which now are the source of pervasive confusion, (2) common test codes, (3) checklists, guidelines, and specifications to help users and suppliers better communicate with one another, and (4) common tests for demonstration and exhibition of new research and development in this field. Conference participants emphasized that once these needs were met to allow communication in the field, actual performance testing should be left to the user and supplier in the free marketplace. *These proceedings include the following papers (indented):*

Evaluation of tools and tasks: Reflections on the problem of specifying robot/manipulator performance, T. B. Sheridan, *SP459,* pp. 27-37 (Oct. 1976).

Performance evaluation of manipulators from a kinematic viewpoint, B. Roth, *SP459,* pp. 39-61 (Oct. 1976).

Performance evaluation of ROMANSY from the viewpoints of mechanics and control, A. E. Kobrinski, *SP459,* pp. 63-68 (Oct. 1976).

Performance measurement and evaluation of general purpose manipulators, R. L. Paul, *SP459,* pp. 69-83 (Oct. 1976).

Manipulator system performance evaluation: Problems and approaches, N. L. Shields, Jr., T. B. Malone, and M. Kirkpatrick, *SP459,* pp. 83-90 (Oct. 1976).

Research on remote manipulation at NASA/AMES research center, W. L. Verplank, *SP459,* pp. 91-95 (Oct. 1976).

Experience and remarks on manipulator evaluation, J. Vertut, *SP459,* pp. 97-112 (Oct. 1976).

Performance evaluation of industrial robots, J. F. Engelberger, *SP459,* pp. 113-119 (Oct. 1976).

Robots for automated production of conventional ammunition, D. A. Morlock, *SP459,* pp. 121-122 (Oct. 1976).

Servicing of industrial robots—The modular concept, M. S. Konstantinov, *SP459,* pp. 123-129 (Oct. 1976).

A computer-aided robot operation systems design (Part 1), Y. Hasegawa, I. Masaki, and M. Iwasawa, *SP459,* pp. 131-139 (Oct. 1976).

Characteristics and evaluation of "Master-Slave Manipulators", D. G. Jelatis, *SP459,* pp. 141-146 (Oct. 1976).

Design and performance requirements for fuel recycle manipulation systems, J. G. Grundmann, *SP459,* pp. 147-154 (Oct. 1976).

Master slave manipulators and remote maintenance at the Oak Ridge National Laboratory, R. G. Jenness and C. D. Wicker, *SP459,* pp. 155-157 (Oct. 1976).

Performance evaluation studies at JPL for space manipulator systems, A. K. Bejczy, *SP459,* pp. 159-174 (Oct. 1976).

Performance measurement for undersea systems, A. J. Pesch and W. R. Bertsche, *SP459,* pp. 175-197 (Oct. 1976).

Contributions to forming criteria for the evaluation of robots and manipulators, M. Vukobratovic, *SP459,* pp. 197-203 (Oct. 1976).

SP460. **Use of Monte Carlo calculations in electron probe microanalysis and scanning electron microscopy.** Proceedings of a workshop held at the National Bureau of Standards, Gaithersburg, MD, Oct. 1-3, 1975, K. F. J. Heinrich, D. E. Newbury, and H. Yakowitz, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 460,* 169 pages (Feb. 1977) SD Catalog No. C13.10:460.

Key words: electron probe microanalysis; electron-solid interactions, magnetic domains; Monte Carlo electron trajectory calculations; particle analysis; scanning electron microscopy; thin film analysis.

This book is the formal report of the Workshop on the Use of Monte Carlo Calculations in Electron Probe Microanalysis and Scanning Electron Microscopy held at the National Bureau of Standards, October 1-3, 1975. The papers cover a wide range of topics within the field: the history and development of Monte Carlo methods for use in x-ray microanalysis; the study of the distribution of electron and x-ray signals by Monte Carlo techniques; the effect of the choice of scattering models on the calculations; techniques for considering the distribution of energies of the beam electrons propagating in the specimen; evaluation of ionization cross-section models; and applications of Monte Carlo techniques to the study of particles, thin films, and magnetic domain images. The contributions include reviews of general interest as well as papers treating specific topics. The volume should be of wide interest to workers in the fields of scanning electron microscopy, electron probe microanalysis, electron physics, and other fields involving the interaction of electrons with solids. *These proceedings include the following papers (indented):*

The history and development of Monte Carlo methods for use in x-ray microanalysis, H. E. Bishop, *SP460,* pp. 5-14 (Dec 1976).

Key words: electron probe microanalysis; electron scattering; electron-specimen interactions; Monte Carlo electron trajectory calculations; scanning electron microscopy; x-ray microanalysis.

Green in 1963 first demonstrated the usefulness of Monte Carlo calculations to the understanding and development of the theory of x-ray microanalysis. As his calculations was based on experimental scattering data it was of relatively limited application. By 1965, at the 4th International Conference on X-Ray Optics and Microanalysis in Paris, papers from Japan and the United Kingdom demonstrated that a more general approach based on theoretical cross-sections was possible. Since then many further developments have been reported and a number of Fortran programs have become available.

Monte Carlo calculations may be divided conveniently into two classes; those aimed at a general understanding of the electron scattering process leading to x-ray production and those intended to solve particular problems. For conventional quantitative microprobe analysis of a flat specimen, uniform over the analyzed volume, the first class is the most important as it should lead to improvements in the conventional ZAF procedures. In a situation where there are special boundary conditions, such as thin surface films or particles, the second class is useful in predicting or interpreting the observed results. In this paper, the various approaches to Monte Carlo calculations are reviewed and their suitability for different applications is discussed.

Studies of the distribution of signals in the SEM/EPMA by onte Carlo electron trajectory calculations—An outline, D. E. ewbury and H. Yakowitz, *SP460*, pp. 15-44 (Dec. 1976).

Key words: backscattered electrons; electron probe microanalysis; Monte Carlo electron trajectory simulation; scanning electron microscopy; secondary electrons; x rays.

Monte Carlo electron trajectory calculations provide a powerful technique for the study of the characteristics and distributions of the various signals generated in electron-specimen interactions. This paper is a review of the diverse applications of Monte Carlo techniques to the calculation of signal distributions. The following topics will be considered: extent of the primary interaction volume; lateral, depth, angular and energy distributions of backscattered and secondary electrons; the extent of the x-ray generation volume, and the depth distribution of characteristic and continuum x rays. Numerous examples of these calculated distributions are drawn from the literature and compared, when possible, with appropriate experimental results.

The effect of scattering models on the results of Monte Carlo alculations, L. Reimer and E. R. Krefting, *SP460*, pp. 45-60 Dec. 1976).

Key words: electron microscopy; electron probe microanalysis; electron-specimen interactions; Monte Carlo electron trajectory simulation: scanning electron microscopy; x-ray generation.

A special Monte Carlo model is presented considered Mott scattering for scattering angles $\zeta > 10°$, a mean angular deviation caused by multiple scattering for $\zeta < 10°$, individual inelastic scattering events with energy loss $\Delta E >$ 200 eV and a continuous energy loss for $\Delta E < 200$ eV. Results of the Monte Carlo calculations are compared with experimental results of the backscattering coefficient, the angular and energy distribution of backscattered electrons and the transmission of thin films. Some calculations of the depth distribution of x-ray emission are reported. Parts of the program are changed to see which parts of the model influence the results.

Characteristics of a Monte Carlo program for microanalysis tudy of energy loss, J. Heńoc and F. Maurice, *SP460*, pp. 61-76 (Dec. 1976).

Key words: electron energy loss; Landau electron deceleration theory; microanalysis; Monte Carlo electron trajectory calculations; scanning electron microscopy; x-ray microanalysis.

The x-ray depth distribution curves obtained by the Monte Carlo method are in disagreement with the experiment. For this reason, Bishop proposed in his thesis the use of the theory of Landau, which takes into account the statistical nature of the energy loss of the electrons. This procedure gives a more realistic description of the events. We have taken into account, in this way, the effects of electron straggling upon the function $\phi(\rho Z)$ and the energy loss distribution of electrons passing through thin films. The general solution of the problem of electron trajectory simulation is straightforward, but it requires lengthy and expensive calculations. The procedure can be reduced in length by means of two simplifications, one of which was proposed by Bishop. Different treatments affect in different ways the statistical distributions of the variables which are being studied. In addition, the importance of the parameters and physical models which govern the diffusion of electrons (step length, diffusion model, screening parameter, etc.) will be discussed.

Evaluation of formulas for inner-shell ionization cross sections, C. J. Powell, *SP460*, pp. 97-104 (Dec. 1976).

Key words: cross sections; electron-probe microanalysis; electrons; inner-shell; ionization.

An evaluation is presented of various formulas that can be used to describe cross sections for inner-shell ionization by electron impact in the electron-probe microanalyzer. Owing to lack of experimental data, most of the discussion pertains to the case of K-shell ionization. For incident energies greater than four times threshold ($U_K > 4$), the Bethe equation can describe adequately the observed cross-sections and recommended values are given for the two Bethe parameters. For ($U_K < 4$), the classical result of Gryzinski or the expressions of Lotz or Fabre should be useful.

NBS Monte Carlo electron trajectory calculation program, R. L. Myklebust, D. E. Newbury, and H. Yakowitz, *SP460*, pp. 105-128 (Dec. 1976).

Key words: electron trajectories; magnetic effects; Monte Carlo calculations; multiple scattering x-ray generation; particle analysis; quantitative x-ray microanalysis; thin films; x-ray emission.

A number of Monte Carlo programs for obtaining information of interest to x-ray microanalysts and scanning electron microscopists have been developed; the outputs from many of these programs are discussed elsewhere in this volume. The purpose of this paper is to present the Monte Carlo program for microanalysis currently in use at the National Bureau of Standards. This program is a considerably extended treatment of the Curgenven-Duncumb formulation. A large number of electron trajectories can be simulated rapidly—about 1200 per minute of central processing unit time—at a reasonable cost. The electron scattering calculation is an approximation to multiple elastic electron scattering in an amorphous solid. Details of other assumptions made in constructing the program, as well as a number of comparisons of calculated and experimental data, are given in the text.

Application of Monte Carlo simulation to electron microprobe analysis of thin films on substrates, D. F. Kyser and K. Murata, *SP460*, pp. 129-138 (Dec. 1976).

Key words: electron probe microanalysis; Monte Carlo electron trajectory calculations; nuclear backscattering analysis; scanning electron microscopy; thin films; x-ray analysis.

A Monte Carlo simulation procedure has been developed for high-energy (1-50 keV) electron beam scattering, energy loss, and x-ray production in targets consisting of thin alloy

films on thick substrates. The method utilizes experimental x-ray intensities referenced to thick standards, and avoids the problems associated with preparation and characterization of thin film standards. The chemical analysis C_t (weight percent) and mass thickness ρt (g/cm²) of the alloy film can be deduced separately; specific examples are given of alloy films Mn_xBi_{1-x} and CO_xPt_{1-x} on SiO_2 substrates. The chemical analysis obtained with the Monte Carlo procedure is correlated with that obtained from nuclear backscattering energy analysis.

Monte Carlo-generated calibration curves of total electron backscatter yield η are presented for the case of Al films on Au substrates and Au films on Al substrates. These curves show a smooth transition of η versus ρt between the asymptotic limits of η(Al) and η(Au). The shape of the curve depends on the electron beam voltage E_0 (keV). Further experimental work is necessary to confirm the accuracy of these calculations for η, and then the method may be useful for a nondestructive, localized thickness measurement of thin films on substrates.

Calculation of type II magnetic contrast in the low-loss image in the scanning electron microscope, O. C. Wells, *SP460,* pp. 139-150 (Dec. 1976).

Key words: contrast calculations; energy filtering; low-loss electron image; magnetic contrast; Monte Carlo electron trajectory calculations; scanning electron microscopy.

The backscattered electrons which are often most useful in the scanning electron microscope (SEM) are those which have lost the least energy. (We have called these the "low-loss" electrons.) The question is whether they can be analyzed by a simple electron scattering model, or whether the Monte Carlo method must be used. Previously, it has been shown that a simple model based jointly on the Bethe energy loss law and a single Rutherford wide-angle scattering event can account for both the angular distribution and the absolute magnitude of the low-loss electron emission from amorphous SiO_2 with oblique incidence with an accuracy of a few percent provided that the energy loss is less than about 1 percent. This simple model has been extended to allow for curvature of the electron trajectories in the specimen, so as to calculate the contribution to Type II magnetic contrast in a suitable specimen caused by those backscattered electrons which have been scattered by a single wide-angle scattering event. Some preliminary theoretical results are given.

A study of type II magnetic domain contrast in the SEM by Monte Carlo electron trajectory simulation, D. E. Newbury, H. Yakowitz, and R. L. Myklebust, *SP460,* pp. 151-164 (Dec. 1976).

Key words: iron-silicon transformer steel; magnetic contrast; magnetic domain images; magnetic domains; Monte Carlo electron trajectory calculations; scanning electron microscope.

Magnetic contrast in the scanning electron microscope occurs by two distinct mechanisms: Type I magnetic contrast arises from the interaction of secondary electrons which have exited the specimen with leakage magnetic fields above the surface and Type II magnetic contrast arises from the interaction of beam electrons with the internal magnetic field. The observed properties of Types I and II magnetic contrast are reviewed. The proposed mechanism of Type II magnetic contrast, that of internal beam-magnetic field interactions, is modeled with the Monte Carlo electron trajectory technique. Details of the modifications to the standard Monte Carlo technique to account for magnetic deflection are given. Monte Carlo results are given for the following cases: contrast as a function of specimen magnetization, tilt, rotation, beam energy and energy fraction. The spatial resolution of domain edges is also considered. Calculated results are compared with experimental values, and the correspondence is excellent.

SP462. **Laser induced damage in optical materials: 1976.** Proceedings of a Symposium Sponsored by: National Bureau of Standards, American Society for Testing and Materials, Office of Naval Research, Energy Research and Development Administration, Defense Advanced Research Project Agency, July 13-15, 1976, NBS Boulder, CO, A. J. Glass and A. H. Guenther, Eds., *Nat. Bur. Stand. (U.S.), Spec. Publ. 462,* 410 pages (Dec. 1976) SD Catalog No. C13.10:462.

Key words: avalanche ionization; infrared windows; laser damage; metal mirrors; optical fabrication; optical materials; thin films.

The Eighth Annual Symposium on Optical Materials for High Power Lasers, the Boulder Damage Symposium, was hosted by the National Bureau of Standards in Boulder, Colorado, from July 13th to 15th. The Symposium was held under the auspices of ASTM Committee F-1, Subcommittee on Laser Standards, with the joint sponsorship of NBS, the Defense Advanced Research Project Agency, the Energy Research and Development Administration, and the Office of Naval Research.

About 160 scientists attended the Symposium, including representatives of the United Kingdom, France, Canada, and Brazil. The Symposium was divided into five half-day sessions, concerning Bulk Material Properties and Thermal Behavior, Mirrors and Surfaces, Thin Film Properties, Thin Film Damage, and Scaling Laws and Fundamental Mechanisms.

As in previous years, the emphasis of the papers presented at the Symposium was directed towards new frontiers and new developments. Particular emphasis was given to new materials for use at 10.6 μm in mirror substrates, windows, and coatings. New techniques in film deposition, and advanced in diamond turning of optics were described. The scaling of damage thresholds with pulse duration, focal area, and wavelength are discussed.

Alexander J. Glass of Lawrence Livermore Laboratory and Arthur H. Guenther of the Air Force Weapons Laboratory were Co-chairpersons of the Symposium. The Ninth Annual Symposium is scheduled for October 4-6, 1977, at the National Bureau of Standards, Boulder, Colorado. *These proceedings include the following papers (indented):*

Thermal distortion thresholds for optical trains handling high pulse powers, H. E. Bennett, *SP462,* pp. 11-24 (Dec. 1976).

Key words: laser windows and mirrors; optical figure; pulsed laser; thermal distortion.

The maximum pulse power level which components in the optical train of a high energy laser can pass is determined by the catastrophic damage threshold for the system. Before that level is reached, however, thermally induced optical distortion may make the beam unfocusable and hence for most practical purposes unusable. The amount of thermally induced optical distortion which may be tolerated depends strongly on the initial optical figures of the various components, and in the case of windows, on their optical homogeneity. Requirements for these parameters in a multicomponent infrared optical train can be surprisingly severe, and are frequently comparable to those commonly used for high quality optics designed for the visible region of the spectrum. Figure requirements for mirrors are more

severe than for windows unless their index of refraction is above about 2.4. Adaptive optics may be used to remove some of the resultant wave front error, but the lower the requirements made by the optical train the more easily the adaptive optics system can correct for wave front distortions arising from the laser medium and from the optical path. A detailed analysis is required to set optimum tolerances for the various components in the optical path of a particular system. Simple relations can be developed, however, which can be used to predict the approximate pulse power handling capability of the optical train for short periods of time in terms of the material parameters of the various components in the system, their optical figures, and in the case of windows, their homogeneity. These relations can be used as figures of merit to select between materials and preliminary calculations for system design.

Electric fields and power dissipation in windows at oblique incidence, J. H. Apfel, *SP462*, pp. 25-28 (Dec. 1976).

Key words: electric fields; laser damage; oblique incidence; standing waves.

Formulas are provided for calculating the strength of the electric fields and the power dissipation due to weak absorption in a window illuminated by a collimated beam at nonnormal incidence. For a glass window the power dissipation per unit volume varies approximately as the cosine of the incident angle.

Analysis of laser-induced thermal stresses in laser windows, . E. Rondeau and D. Ford, *SP462*, pp. 29-35 (Dec. 1976).

Key words: computer analysis; laser induced stresses; stress analysis; thermal analysis; zinc selenide window.

Laser induced damage in the ZnSe output coupler of a 15 kilowatt cw CO_2 coaxial electric discharge laser has been investigated. An analytical technique has been developed for predicting thermal stresses from in depth absorption of laser energy in laser window materials. A two-dimensional transient heat transfer code, APPLE, (Aerotherm Prediction Procedure for Laser Effects) was used to obtain the temperature histories of the irradiated window. The effect of window thickness, transmitted power level, absorptance and exposure time were investigated. The stress distribution in the circular disk was computed from radial and axial temperature distributions obtained from the APPLE code. This analytical technique has been used to determine maximum power levels and exposure times to prevent window damage in laser experiments.

Interferometric measurement of laser heated windows, E. rnal and J. S. Loomis, *SP462*, pp. 36-44 (Dec. 1976).

Key words: interferometry; laser windows; optical materials; thermal distortion.

The optical aberrations in infrared window materials irradiated with a CO_2 laser have been measured at 0.6328 μm. The contributions of anisotropic aberrations due to polarization dependence were examined and found to be small for several materials of interest. Techniques for the semi-automatic digital analysis of our interferometric data will be discussed. The results will be applied to figure-of-merit characterization of window performance and calculation of far-field irradiance degradation.

Model calculations of the thermal profiles in irradiated windows and the resulting optical aberrations will be reviewed. Synthetic interferograms generated from these calculations were used to exhibit many of the experimentally observed features and to test the digital analysis techniques mentioned earlier.

New materials for chemical laser windows, J. A. Harrington, *SP462*, pp. 45-49 (Dec. 1976).

Key words: chemical lasers; infrared materials; laser windows; multiphonon absorption; optical absorption; water repellent coatings.

Many of the more common materials such as the alkaline earth fluorides, ZnSe, and the alkali halides have been studied for use as low loss windows on DF-HF chemical lasers yet there remain others which have received little or no attention at these wavelengths. We have begun to investigate some of these other materials in hopes of finding additional low absorbing materials which show potential as laser windows. Specifically, our measurements of the optical absorption in $LiYF_4$, Yttralox, ZnS, CdTe, KBr, SrF_2, and KRS-5 will be discussed and related to the intrinsic absorption in these hosts. In all cases, the measured absorption has been found to be greater than the intrinsic value. In addition to the absorption measurements on these substances, some recent optical absorption measurements on water repellent coatings on KCl will be discussed.

Studies of absorption in mid IR laser window materials, A. Hordvik, B. Bendow, H. G. Lipson, L. H. Skolnik, and R. N. Brown, *SP462*, pp. 50-57 (Dec. 1976).

Key words: bulk absorption; CO laser; HF laser; infrared laser window materials; multiphonon absorption; surface absorption.

An investigation has been made of the absorption properties of various potential laser window materials in the wavelength ranges of the CO_2, CO, and HF lasers. Various experimental techniques were utilized including emittance spectroscopy, Fourier spectroscopy, laser calorimetry, and a new photoacoustic technique which allowed both bulk and surface absorption to be determined simultaneously. The materials investigated were ZnSe, Al_2O_3, MgO, LiF, MgF_2, CaF_2, SrF_2, and BaF_2. At both the CO and HF laser wavelengths it was found that surface absorption was substantial in most cases and particularly so in the HF laser region. Among the materials tested, sapphire emerged as an excellent candidate for use with the HF laser provided its large surface absorption can be reduced substantially. Preliminary theoretical calculations have been made of the intrinsic absorption in ZnSe to interpret the measurements.

Effect of temperature and stress on the refractive index of window materials, A. Feldman, D. Horowitz, and R. M. Waxler, *SP462*, pp. 58-63 (Dec. 1976).

Key words: BaF_2; CaF_2; fused silica; interferometry; photoelasticity; piezo-optic constants; thermal coefficient of refractive index; thermal expansion coefficient; ZnSe.

Windows subjected to high average power laser radiation experience a rise in temperature due to residual absorption. The temperature distribution, which is nonuniform, will distort the wavefront of the beam. The distortion results both from changes of refractive index with temperature and from changes of refractive index with stress induced by the temperature gradients. We are presently measuring dn/dT and the photoelastic constants of laser window materials at 632.8 nm, 1.15 μm, 3.39 μm, and 10.6 μm. Two new experimental arrangements have been constructed. The first permits measuring dn/dT and thermal expansion from −180 °C to +200 °C. The second is a highly stable and sensitive interferometer for measuring photoelastic constants in the visible, the near infrared, and the near ultraviolet. Thermal expansion data are obtained on CVD ZnSe, CaF_2 and BaF_2

between −100 °C and +120 °C and fitted to a third degree polynomial in temperature. We obtain dn/dT for CVD ZnSe at 632.8 nm over the same temperature range. The piezo-optic constants of fused silica and CVD ZnSe obtained with the new interferometer at 632.8 nm are in excellent agreement with values obtained by other methods.

Refractive index and temperature coefficient of refractive index of hot-forged calcium fluoride, M. J. Dodge, *SP462*, pp. 64-68 (Dec. 1976).

Key words: calcium fluoride; refractive index; temperature coefficient of refractive index.

The refractive index of a sample of hot-forged CaF_2 was measured from 0.25 μm to 8.0 μm by means of the minimum-deviation method on a precision spectrometer. Data were obtained near 21 °C and 34 °C. Each data set was fitted to a three-term Sellmeier-type dispersion equation, which permits interpolation of refractive index as a function of wavelength within a few parts in 10^{-5}. Using the index values obtained at the two temperatures, the change in index with temperature, $\Delta n/\Delta T(°C)^{-1}$ was calculated. The refractive index and $\Delta n/\Delta T(°C)^{-1}$ values obtained for this specimen are compared with data previously published.

Fabrication and properties of laser window materials, R. M. Cannon, H. K. Bowen, A. M. Glaeser, H. J. Mayson, F. A. McClintock, W. M. Sherry, J. B. Vander Sande, and M. F. Yan, *SP462*, pp. 69-81 (Dec. 1976).

Key words: CaF_2; crack coalescence; flaw detection; flaw distribution; forging; grain boundary mobility; subgrains.

In hot forged CaF_2, as in forged alkali halides, fine subgrains develop and the subgrain size varies inversely with the forging stress. Dynamic recrystallization is more of a problem than for KCl or KBr; it results in very coarse grained regions in which the subgrains are poorly developed. In alkali halides aliovalent impurities exert a significant drag on grain boundaries causing large reductions in grain boundary migration rates and significant retardation of recrystallization and grain growth. Theoretical results for the boundary mobility and for the conditions under which a boundary may escape from the segregated impurity cloud are presented.

Theory of the macroscopic fracture behavior resulting from failure by coalescence of subcritical cracks shows the extent of detectable precracking and the effects of biaxial stresses, specimen size, and the distribution of microstrengths. The ultimate strengths do not fit an extreme value distribution even if the microscopic strengths do; this makes statistical design more difficult and may necessitate proof testing or inspection. Flaw strength distribution curves can be determined from acoustic emission measurements during microhardness testing. Crack openings as small as 0.1 μm have been nondestructively detected using scattered light. Better resolution is required for stronger materials for which crack openings as small as 0.01 μm must be detected.

Double-doped alkali halide laser windows, H. Posen, N. Klausutis, J. Bruce, J. A. Adamski, J. R. Weiner, and S. A. Kulin, *SP462*, pp. 82-86 (Dec. 1976).

Key words: double-doped KCl laser windows; grain boundary stability; hot forging; KCl; mechanical strength; microstructure; optical absorption; RbCl; $SrCl_2$.

We have observed grain boundary instability in alloys doped with 1.75 percent RbCl. Theoretical studies have indicated that doping with divalent ions can provide some strengthening, and at the same time provide grain boundary stability. In an attempt to provide both solid-solution strengthening and grain-boundary stability, we have studied a series of double-doped RAP-grown KCl crystals. The primary dopant is fixed at 1.75 mole percent RbCl, while the secondary dopant is varied from 10 ppm to 250 ppm $SrCl_2$. Polycrystalline discs were forged under constant strain rate. The strength, texture, 10.6 μm absorption, and grain-boundary stability were studied as a function of $SrCl_2$ dopant level. Our studies indicate that double doping with a divalent ion enhances grain-boundary stability without degrading other desirable window properties.

Intermediate temperature (0.5 to 0.7 T_{mp} K) forging of calcium fluoride crystals, R. H. Anderson, B. G. Koepke, and E. Bernal, *SP462*, pp. 87-94 (Dec. 1976).

Key words: annealing; fracture energy (γ_c); isostatic forging; kinking; microstructures; recrystallization temperature; veiling.

Crack free forgings have been successfully produced from CaF_2 crystals at temperatures as low as 0.5 T_{mp} (K) using an isostatic forging technique. Forging temperatures and isostatic pressures have ranged from 500° to 750 °C and to 2[illegible] MN/m² respectively. Most forging has been along ⟨111⟩ directions. The resulting microstructures varied from highly deformed structures with barely recognizable subgrains to structures with subgrain sizes of around 10 μm in crystals forged at higher temperatures. Annealing for long times at 720 °C resulted in recrystallization and a large grained polycrystalline structure. Internal cloudiness or "veiling" is observed in all ⟨111⟩ oriented forgings. The extent of the veiling decreases with increasing forging temperature. The fracture energies of several forgings are compared with the fracture energies of single crystals and large grained polycrystalline material.

Forging finished halide optical components, R. H. Anderson, E. Bernal, and R. J. Stokes, *SP462*, pp. 95-99 (Dec. 1976).

Key words: closed die; forging; isostatic; polishing; quartz; shaping.

The forging of completely finished halide optical components to eliminate the necessity of shaping and polishing is being evaluated. The forging operation is being done isostatically using a closed die technique. Quartz die faces are being used to produce the desired surface shape and finish. A synthetic oil is being used as the lubricant while the forging is performed at 275 °C.

To produce the finished component, two forging operations are being used. The first forging is necessary to produce uniform strain distribution. This pressing is then preshaped by water polishing before the final minor shaping operation.

These, as forged surfaces, appear superior to mechanically prepared surfaces for the deposition of the required protective and optical coating of thallium iodide.

Optical performance results obtained with these lenses will be compared with those obtained with conventional polished halide and glass lenses.

Vapor deposition and mechanical properties of CdTe, H. Tuller, K. Uematsu, J. B. Vander Sande, E. L. Hall, and H. K. Bowen, *SP462*, pp. 100-118 (Dec. 1976).

Key words: cadmium telluride; growth kinetics; mechanical properties; microstructure; stoichiometry; transmission electron microscopy; vapor deposition.

The vapor deposition of CdTe from elemental cadmium

and tellurium sources was studied as a function of the Cd/Te ratio, the supersaturation, and the substrate temperature. A multisubstrate arrangement was designed to enable simultaneous acquisition of growth data on six CdTe windows under conditions where substrate temperature and radial positioning remained the only variables. Polycrystalline blanks 4 $cm^2 \times 1$ mm thick were grown at rates of .02 – .10 mm/h with the growth rate exhibiting sensitivity to all of the above parameters. The affects of varying P_{Cd}/P_{Te_2} ratios during growth, as well as post growth annealing, on surface microstructure, grain size and void density, as observed under SEM and IR microscopy, will be presented.

Shear stress-shear strain results have been obtained from single crystal CdTe deformed in compression at 300 °C. The defect microstructures associated with this deformation schedule have been observed by transmission electron microscopy. The macroscopic mechanical behavior will be discussed in terms of the dislocation interactions observed for the various deformation states.

Absorbing tellurium inclusions in polycrystalline cadmium luride: Estimates for extrinsic damage thresholds, H. S. nnett and C. D. Cantrell, *SP462*, pp. 119-125 (Dec. 1976).

Key words: cadmium telluride; elastic compliance tensor; elastic moduli; extrinsic damage thresholds; high-power lasers; infrared materials; tensile stress.

Cubic cadmium telluride is a promising infrared material for highly transparent windows. However, one problem encountered in high-power laser systems is thermal extrinsic damage to the optical elements which arise from absorbing inclusions. Absorbing inclusions are impurities with physical and optical properties which differ substantially from those of the host material. Such inclusions may absorb an appreciable amount of the incident radiation and thereby may undergo thermal expansion. This produces major stresses within the host. In this paper, we give estimates of the maximum tensile stress as a function of inclusion size, laser pulse width, and laser power for polycrystalline Te spheres in polycrystalline CdTe. Our computations suggest that the heating of 0.1 μm to 10 μm aggregates of Te in CdTe when subjected to power densities of about 100 MW/cm^2 and pulse widths of about 200 ns may produce stresses comparable to or greater than the breaking strength of the CdTe host.

Hot-pressed $CdCr_2S_4$ for Faraday effect isolation at 10.6 μm: eliminary damage tests, S. D. Jacobs and K. J. Teegarden, *P462*, pp. 126-135 (Dec. 1976).

Key words: $CdCr_2S_4$; chalcogenide spinel; Faraday effect; ferromagnetic semiconductor; hot-pressed; infrared transmission; laser induced damage; optical isolation.

The ferromagnetic spinel, $CdCr_2S_4$ is considered an attractive candidate for future use in target back reflection isolation of high power infrared lasers for fusion investigations. Used with liquid nitrogen refrigerant in a Faraday rotator configuration, this material demonstrates isolation in excess of 30 dB and an insertion loss (due to material attenuation) of 30 percent in saturating magnetic fields of 3500 Oe. Minimal homogeneity requirements for dc magnetic field biasing and the scalability of the hot-pressing process make $CdCr_2S_4$ suitable for large aperture applications. Single crystal growth and hot-pressing procedures are currently being optimized to reduce extrinsic attenuation at 10.6 μm.

The threshold for laser induced damage in $CdCr_2S_4$ ($n_{10.6} = 2.84$) is of fundamental importance to the proposed application. Preliminary measurements have been made using a 50 ns, TEA CO_2 laser with a multimode output of 20 joules. The results indicate that this material has a damage threshold in excess of 2 J/cm^2.

Pulsed laser induced damage at the DF laser wavelength, M. Bass, K. M. Leung, C. Tang, and M. J. Soileau, *SP462*, pp. 136-144 (Dec. 1976).

Key words: alkali-halides; alkaline-earth fluorides; bulk damage; focal spot diameter; inclusion damage; interference ripples; pulsed DF laser damage; sapphire; scattering; waveform distortion.

A pulsed TE DF laser has been used to study the damage phenomenon in materials which are transparent to DF laser light (3.5 – 4.1 μm). We measured the bulk damage threshold in several alkaline-earth fluorides, alkali-halides, and sapphire. The peak on axis intensity which damaged CaF_2 and sapphire was 25 GW/cm^2. Surface damage occurred at intensities less than 1/10 that required for bulk damage. This was attributed to poor surface finish quality and points out the need for improvements in finishing optics for use with DF lasers.

Naval Weapons Center diamond turned optics facility, D. L. Decker and R. E. Cram, *SP462*, pp. 145-148 (Dec. 1976).

Key words: diamond single point turning; interferometric control; laser damage threshold; optical absorption; optical components; optical scattering.

The generation of optical surfaces by diamond single point turning or milling is of much current interest. This fabrication method can be cost effective and can readily produce very unconventional surfaces and components, allowing radically new system designs. In addition, this fabrication method can reliably produce optical components with superior characteristics including very low scatter, near intrinsic absorption and laser damage threshold. This paper will briefly describe the requirements and existing machines for diamond single point machining of high quality optics, and materials known to be amenable to this fabrication method. The characteristics of a new machine at NWC, which includes an air bearing spindle and carriage ways and closed loop interferometer control will also be discussed. The emphasis of the NWC effort is to explore selected areas of machine technology and to further explore the capabilities of diamond turned components.

10.6 μm pulsed laser damage studies of diamond turned KCl window surfaces, M. J. Soileau, J. M. Bennett, J. O. Porteus, W. Faith, J. Jernigan, and T. T. Saito, *SP462*, pp. 149-157 (Dec. 1976).

Key words: diamond turning; KCl laser windows; laser damage; 10.6 μm laser.

Laser damage measurements at 10.6 μm are presented for diamond turned surfaces of polycrystalline KCl. The two types of windows tested were hot-forged RbCl- and EuCl-doped KCl. Surface damage thresholds of the two materials range from 1.8 to 2.4 GW/cm^2. The optical properties of these specimens were measured after diamond turning and compared to chemically etched surfaces on the same specimens. RMS roughness, infrared scattering, and absorption at 10.6 μm were measured. The influence of the machining grooves on the character of the laser damage on the surface is discussed. The regularity of the surface defects produced by the diamond turning process offers a unique opportunity to study the effects of surface defects on the laser damage threshold of optical surfaces.

Surface, optical and laser damage characteristics of diamond-turned metal mirrors, D. L. Decker, M. J. Soileau, J. O. Porteus, and J. M. Bennett, *SP462*, pp. 158-164 (Dec. 1976).

Key words: Auger analysis; diamond-turned metal mirrors; laser damage; light scattering; optical absorption; surface roughness.

Diamond turning, in addition to its attractive manufacturing advantages, can produce superior optical components. Low scattered light, low absorption, and high damage threshold can be reliably realized with present technology. This paper intercompares the surface and optical characteristics of a large number of diamond-turned metal mirrors, including bare, electroplated, and sputtered substrates. Many diamond-turned specimens display near intrinsic pulsed laser damage threshold values, often accompanied by slip banding. This phenomenon has been previously observed only on atomically clean, well ordered single crystal surfaces of aluminum. In contrast, however, some electroplated specimens fail catastrophically by delamination. Regardless of sample type, most sites fail by melting initiated by localized absorbing centers.

Character of pulsed laser damage to Al at 10.6 μm inferred from single-crystal targets in vacuum, J. O. Porteus, M. J. Soileau, and C. W. Fountain, *SP462*, pp. 165-180 (Dec. 1976).

Key words: laser-induced stress; plastic deformation; single-crystal aluminum; slip bands; vaporization.

Pulsed laser-induced stress can produce permanent damage to metal surfaces, even in the absence of melting. Possible causes of such damage in Al are differential expansion resulting from thermal gradients and compression resulting from vaporization. By using single-crystal targets in which plastic deformation can be observed in the form of slip bands, one may obtain information on the direction, magnitude, and thus on the origin of stress. Targets having (111), (001), and (110) surface plane orientations were prepared and tested under oxide-free, ultrahigh vacuum conditions, using well-characterized 100 ns, 10.6 μm focused laser pulses. Vapor particle emission was monitored to provide an indication of vaporization pressure. At energy densities ≥ 37 J/cm^2 the results indicate the dominance of evaporative compression. At energy densities near and below the threshold for melting (14.2 J/cm^2) the interpretation of the observed slip banding is less clear, apparently due to the combined effects of thermal and evaporative stresses.

Laser-induced damage of mirror and window materials at 10.6 μm, R. Gibbs and R. M. Wood, *SP462*, pp. 181-188 (Dec. 1976).

Key words: dielectric coatings; infrared laser windows; laser heating of metal surfaces; laser mirrors; pulsed CO_2 laser damage; surface damage; 10.6 μm absorption; 10.6 μm optical components.

Pulsed laser-induced damage thresholds (CO_2 TEA laser, 60 ns FWHH) and 10.6 μm absorption measurements have been made on a wide variety of mirror and window materials. The effects due to different methods of substrate preparation and coating of metal mirrors have been studied, and as a result, mirrors of higher damage threshold have been manufactured. Front surface damage thresholds of uncoated windows have been measured and correlated with microscopically visible surface features. Improvement has been achieved by ion-beam etching of single-crystal materials. The damage threshold of dielectric coatings, both reflecting and antireflecting, has been found to be limited by microscopically visible coating defects.

Absorptance of dielectric enhanced mirrors at 5.3 μm, P. Kraatz, J. R. Buckmelter, and S. J. Holmes, *SP462*, pp. 189-194 (Dec. 1976).

Key words: absorptance; CO laser calorimetry; CO laser mirrors; dielectric-enhanced mirrors; infrared laser mirrors metal mirrors; reflectance.

The absorptance of a variety of dielectric-enhanced mirrors has been measured in the 5.3 μm region using CO laser calorimetry. The samples comprise nineteen designs fabricated from ten dielectric material combinations deposited on thirteen basic mirror types (i.e., four substrate materials with a total of six metallic coating combinations). Thirty-two samples were fabricated by six vendors without duplications of any complete mirror design among any two (or more) vendors.

Results are grouped according to dielectric material combinations and design. Effects of substrate material selection and metallic coatings (if any) are discussed. The precision (i.e., standard deviation) of all absorptance measurements is presented. Accuracy, relative to (1-R) obtained from standard reflectometer measurements, is evaluated for selected mirrors.

Optical properties of mirrors prepared by ultraclean dc sputter deposition, P. A. Temple, D. K. Burge, and J. M. Bennett, *SP462*, pp. 195-202 (Dec. 1976).

Key words: aluminum; copper; flash desorption spectroscopy; gold; reflectance; silver; sputter deposition.

Sputter deposition is a method for producing mirror surfaces. However, the sputtering gas is generally incorporated in the metal film. This investigation was undertaken to determine the amount of gas trapped and the effect this gas had on film optical properties. Thin film mirrors of aluminum, silver, copper, and gold were prepared by dc sputter deposition under ultraclean conditions using argon or xenon as the sputtering gas. The sputtering gas entrapment was measured by a flash desorption technique. Film reflectance was correlated with preparation conditions and gas entrapment. In general, the film reflectance was reduced by the presence of sputtering gas. The gas trapped was a function of the metal being sputtered, the sputtering gas type, and the sputtering gas pressure. For example, the gas content of silver films could be varied over nearly two orders of magnitude. In some cases, films with reflectances as high as the best UHV evaporated films were prepared.

Materials for high-power window and mirror coatings and multilayer-dielectric reflectors, M. Sparks, *SP462*, pp. 203-21 (Dec. 1976).

Key words: attenuated total reflection spectroscopy; dielectric coatings; infrared lasers; laser damage; thin films.

Antireflection coatings and reflectors having lower values of absorptance than are presently available are needed for high-power, and even some low-power, applications. Intrinsic values of absorptance of antireflection coatings, multilayer-dielectric reflectors, and metallic-reflection-enhancing coatings are orders of magnitude lower than current experimental values A_{exp}. A major factor limiting the values A_{exp} is that a given coating material usually has orders magnitude greater absorption when deposited as a film than when grown as a bulk crystal. The most likely source of the extra film absorptance A_f is contamination of the film. Numerous contaminants include water, HCO_3, ClO_3, NO_3, OH^-, and CN^-. Contamination can occur before or during deposition, upon exposure to the atmosphere (where absorption by porous films and surface adsorption are impo

tant), or during use or storage. At 10.6 μm only two molecular layers of water or a packing density of 99.95 percent are formally required to give $A_f = 10^{-4}$, which is a typical desired value. High-packing-density films should be vacuum vapor deposited using ultraclean deposition conditions including thorough baking of the entire system, high-purity single-crystal starting materials, special care in evaporation, state-of-the-art substrate preparation, and ultrahigh vacuum. Spectroscopic and calorimetric measurements of $A_f(\omega)$ on very thick films and on normal-thickness films, both deposited on attenuated-total-reflection plates, should be made. Material-selection guidelines, including a *bulk* absorption coefficient less than 0.5 cm^{-1} and a value of the index of refraction in the required range, are developed and used to select the following 10.6 μm candidate materials: ThF_4, NaF, BaF_2, SrF_2, NaCl, KCl, $KGaF_4$, As_2S_3, As_2Se_3, ZnS, ZnSe, and TlI. Distinguishing absorption on the coating surface from that in the bulk of the coatings by utilizing the nearly zero electric field on the surface of certain coatings is proposed. Inclusion damage is expected at ~ 1-10 J/cm² for nanosecond pulses or ~ 10 to several hundred J/cm² for microsecond pulses. Intrinsic damage is expected by heating at ~ 100 J/cm² for a 10 μs pulse and $A_f = 10^{-3}$, or by such nonlinear processes as electron-avalanche breakdown at ~ 10 J/cm² (i.e., I ≅ 10 GW per cm²) for a 10 ns pulse. Strongly absorbing 1-μm-radius inclusions spaced 175 μm apart in the coating give rise to absorptance $A_f \cong 10^{-4}$. Thermally induced stresses in a 2 mm-diameter detached film segment may be sufficient to cause additional detachment and a runaway process.

Alternate materials for infrared window coatings, A. D. Baer, T. M. Donovan, A. K. Green, and G. Turner, *SP462*, pp. 214-220 (Dec. 1976).

Key words: alkali halides; antireflectance coating; chalcogenide glasses; infrared optical properties; laser damage; optical absorption; optical scattering; thin-film coating.

The results from studies of a number of new materials (NaF, SrF_2 and As_2Se_3) to be used in antireflectance coatings for KCl and NaCl windows are reported. The preparation and measured properties of thin films of these materials are reported. The properties studied include absorption at 10.6 μm, scattering, structure, index of refraction, and damage threshold. NaF is a promising material in that it has a relatively low absorption and high damage threshold and can be used as a single-layer antireflectance coating on NaCl. The properties of NaF films are good enough that this material can be used as a component of 10.6 μm coatings. SrF_2 films are higher absorbing, but less easily damaged than BaF_2 films. As_2Se_3 films are more easily damaged than As_2S_3 films.

Design of three-layer antireflectance coatings, A. D. Baer, *SP462*, pp. 221-229 (Dec. 1976).

Key words: absorptance; antireflectance coating; bandwidth; coating design; multilayer coating.

Design constraints are less stringent for three-layer coatings than for two-layer coatings. Mathematical relationships which govern the design of three-layer antireflectance coatings are presented. These new relationships are analogous to those governing the design of two-layer coatings; however, a continuous range of solutions exists. Three-layer solutions are represented by closed curves in coating-thickness space, while two-layer solutions are represented by two discrete points. Armed with a knowledge of the performance of similar designs with similar materials, one can select the three-layer solution with lowest absorptance (within 10%). Three-layer coatings offer greater design flexibility than two-layer coatings not only because of the wider-range of solutions, but also because of a wider choice of viable materials. Three-layer antireflectance coatings can be formed entirely of low-index materials (BaF_2, NaF), or with the low index material next to the window (As_2S_3, NaF).

Characteristics of plasma polymerized ethane for laser window coating, T. A. Reis, H. Hiratsuka, A. T. Bell, and M. Shen, *SP462*, pp. 230-238 (Dec. 1976).

Key words: laser window coating; plasma polymerized.

Thin film coatings were produced by passing ethane through a radiofrequency glow discharge in a tubular plasma polymerization reactor. Infrared absorption characteristics of the plasma polymerized ethane (PPE) depends on the reactor conditions. Absorptions are large for C-H stretching (3.5 μm) and bending (7.0 μm) frequency regions. However, outside of these regions the absorptions are low. Under appropriate polymerization conditions, the absorption coefficient at 10.6 μm for PPE film on polished, finished KCl crystal is 4-7 cm^{-1}. The refractive index for PPE is 1.51 (at sodium D line), which is higher than that of KCl. Thus the use of multilayer coating for good antireflection is indicated. Moisture resistance was tested by exposing the coated crystals at room temperature and 84 percent relative humidity for 100 hours.

Epitaxy and optical scattering in TlI films, R. A. Skogman, *SP462*, pp. 239-245 (Dec. 1976).

Key words: biaxial birefringence; epitaxial microstructure; optical scattering.

Thallium iodide has been identified as a protective high index coating material for potassium chloride laser windows. TlI has a high refractive index and an optical absorption of less than 1 cm^{-1} at 10.6 μm. The protective quality of TlI lies in its insolubility and remarkable adhesion to potassium chloride. This adhesion is due, in part, to the epitaxial growth of TlI and KCl. TlI microstructures resulting from different epitaxial growth habits are responsible for the optical scattering observed in films grown on certain KCl orientations.

We have found that the alignment of the TlI b_0 axis parallel to the KCl ⟨110⟩ direction nearest the substrate surface determines the epitaxial growth habit. On the precise KCl (100) orientation, for example, *two* KCl ⟨110⟩ directions lie in the surface. This causes the TlI to nucleate in *two* orientations rotated 90° from one another. This unusual microstructure results in scattering by the diffraction of light passing from one biaxially birefringent orientation to another.

This model has been demonstrated for all KCl orientations and is well supported by x-ray data and polarized light microscopy. A practical solution to this problem has been found which routinely yields visibly clear TlI coatings.

Thin-film coating evaluation by attenuated total reflection, R. T. Holm and E. D. Palik, *SP462*, pp. 246-252 (Dec. 1976).

Key words: absorption; antireflection coatings; attenuated total reflection; laser windows; spectroscopic.

Attenuated total reflection (ATR) is a particularly attractive technique for the determination of absorption constants of thin-film coatings because a wide spectral range can be studied in a relatively simple way. Calculations of ATR spectra have been made for typical thin-film laser-window

coatings, e.g., ZnSe on BaF_2 and ThF_4 on ZnSe. With the aid of such calculations, it is possible to establish the optimum ATR trapezoid geometry, angle of incidence, and film thickness for particular film-substrate configurations to maximize the sensitivity of the experiment to the absorption constant. ATR has potential applications in thin-film characterization for large-window coatings, as examination of an ATR sample coated at the same time would enable rapid quantitative evaluation of resulting coatings.

ZnSe sputtered coatings, D. A. Walsh and J. A. Detrio, *SP462*, pp. 253-263 (Dec. 1976).

Key words: absorption damage levels; coatings; CVD; hot pressed; sputtered.

The sputter deposition of ZnSe for laser window coating preparation has been studied using substrates of ZnSe and KCl. Sputtering targets made from CVD ZnSe and commercially hot pressed material were also compared. Self films of ZnSe and ZnSe were studied for absorption versus thickness using films of $\lambda/4$, $3\lambda/4$, and $5\lambda/4$ at 10.6 μm. Calorimetric absorption measurements showed the HP target material produced coatings with 3 to 6 times greater absorption. Auger analysis indicated the presence of sulfur in the HP films, but none in films made with the CVD target. Both types of coatings appeared to be nonstoichiometric. Film and substrate inhomogeneity prevented reliable measurements of the film absorption coefficient. ZnSe on KCl coatings were investigated with Auger Spectroscopy in order to distinguish between target material effects and the influence of surface preparation methods. As-polished material showed Al and oxygen present at the interface which indicate a residue of polishing compound. The residue was readily removed by etching in concentrated HCl. Damage measurements were also made on the ZnSe coatings.

Laser damage studies of low index coating materials at 10.6 μm, M. J. Soileau, A. D. Baer, J. O. Porteus, J. L. Hernigan, W. N. Faith, T. M. Donovan, and A. K. Green, *SP462*, pp. 264-278 (Dec. 1976).

Key words: coatings; laser damage; laser windows; 10.6 μm lasers.

The 10.6 μm laser damage thresholds were measured for a variety of promising low index coating materials. Coatings deposited on KCl and NaCl windows were studied. Measurements on NaF, BaF_2, and SrF_2 indicate that all these materials have thresholds in excess of 1 GW/cm² when properly deposited. A comparison of the bulk and thin film threshold of these materials will be given. Our results indicate that NaF is an attractive alternative to ThF_4 since it has reasonably low absorption, a high damage threshold, and can be used as a single layer antireflection coating on NaCl. The primary mechanism of failure in the coatings tested was found to be coating delamination associated with defects on the substrate surfaces.

The use of rare earth fluorides as 10.6 μm antireflective coatings, A. Golubovic, J. Fitzgerald, I. Berman, J. Bruce, R. Bradbury, J. J. Comer, W. S. Ewing, and H. G. Lipson, *SP462*, pp. 27 -278 (Dec. 1976).

Key words: laser antireflective coatings; materials purification requirements; pulsed laser damage; rare earth fluorides; zinc selenide coatings.

The rare earth fluorides have been evaluated as possible antireflective laser window coatings at 10.6 μm. Emphasis was placed on SmF_3, EuF_3, and GdF_3 as a single layer coating for ZnSe and as the low index material in a 2-layer design with ZnSe on KCl substrates. The chemistry, structure and texture of the coatings were examined by several techniques including electron and optical microscopy, x-ray diffraction, Auger spectroscopy, and optical spectroscopy. Pulsed laser damage studies at 10.6 μm were performed to evaluate the relative merits of these coatings. As expected, the damage threshold for the single layer fluoride coatings as ZnSe were found to exceed the threshold of the 2-layer designs on KCl substrates.

Performance of $Ge_{0.45}Se_{0.55}/As_2S_3$ antireflection coatings at 3.8, 5.3, and 10.6 μm, J. F. Lewis and M. C. Ohmer, *SP462*, pp. 279-282 (Dec. 1976).

Key words: absorption; antireflection coatings; germanium selenide; infrared laser windows.

Transparent vitreous films of Ge_xSe_{1-x} have been grown by conventional evaporation techniques whose refractive index can be varied from 2.5 to 3.1 by varying x from .35 to .5. For x = .45 it is possible to construct a two-layer double-quarter wave AR coating where $Ge_{.45}Se_{.55}$ is the layer nearest the substrate and As_2S_3 is the outer layer. In a cooperative program, AR coatings of this type were synthesized at the Materials Research Laboratories, Victoria, Australia, and evaluated at the Air Force Material Laboratory. AR coatings were deposited on Eu^{++} doped KCl (10.6 μm), BaF_2 (5.3 μm), and CaF_2 (3.8 μm). The coatings were characterized with regard to absorption, transmission, and bandwidth. For the KCl sample, the cw CO_2 damage threshold was determined. The absorption per surface for all wavelengths was less than .1 percent. Absorption bands at the shorter wavelengths were not visible in the spectrophotometer data.

AR-coated KCl damage at 10.6 μm, J. A. Detrio, R. D. Petty, M. C. Ohmer, and O. F. Swenson, *SP462*, pp. 283-291 (Dec. 1976).

Key words: alkali halides; antireflection coatings; coatings; KCl; laser damage.

Antireflection coatings on KCl windows for high power CO_2 lasers have been studied using focused radiation to establish relative damage thresholds. Single layer coatings composed of TlI, multilayer designs employing TlI and either KCl or ThF_4 were capable of withstanding 9 second irradiation at an average power density of nearly 130 kW cm^{-2}. Two definitions of the onset of mechanical damage were used; physical degradation including thermally induced fracture, and the first appearance of permanent residual strain as observed in a plane polariscope. Nomarski microscopic observations were also utilized to search for subtle signs of damage. Data were taken to detect any "conditioning" effects due to below-threshold irradiation. Conditioning was found to be negligible in all coatings studied except possibly one. No special handling precautions were taken and therefore these values represent the inclusion of ordinary laboratory environmental degradation. Correlations between damage levels and factors such as absorption were investigated.

Spectral dependence of damage resistance of refractory oxide optical coatings, B. E. Newnam and D. H. Gill, *SP462*, pp. 292-300 (Dec. 1976).

Key words: damage thresholds; electron avalanche; picosecond pulses; refractory oxides; standing-wave field; thin films; two-photon absorption.

The laser damage thresholds of three refractory oxide

material coatings (TiO_2, ZrO_2, and HfO_2) and SiO_2 were measured at three wavelengths (355, 532, and 1064 nm). For each wavelength, quarter-wave thick films were deposited on fused silica substrates by three manufacturers using electron-gun evaporation. Samples were irradiated with the primary, doubled and tripled frequency of a mode-locked Nd:YAG laser with pulse duration 20-30 ps. An increase of the threshold electric field from 1064 to 532 nm was measured, which was consistent with that predicted for electron-avalanche breakdown. Reduced thresholds at 355 nm indicated dominance of two-photon absorption.

The role of electric field strength in laser damage of dielectric ultilayers, J. H. Apfel, J. S. Matteucci, B. E. Newnam, and). H. Gill, *SP462*, pp. 301-309 (Dec. 1976).

Key words: dielectric films; electric fields; laser damage; optical coatings; standing-waves.

The intensity of the local electric field within a multilayer illuminated by a laser beam is determined by the vector addition of forward and reverse flowing waves as a result of interference. The profile of the electric field intensity will therefore depend upon the multilayer design and can have a peak value which is more or less than the peak field of the incident beam. We have examined four multilayer designs, each composed of approximately equal numbers of high and low index films arranged so that the electric field profiles are significantly different. Laser damage thresholds for these coatings were compared with calculated electric field strength profiles.

For electron-gun evaporated titania/silica coatings damaged by 30 picosecond pulses of 1.064 μm radiation the damage threshold is dictated by electric field intensity in the titania layers.

Preparation techniques and hydroxyl concentration vs. surface damage threshold, R. A. House, J. R. Bettis, and A. H. Guenther, *SP462*, pp. 310-314 (Dec. 1976).

Key words: damage threshold; etching; flame polishing; fused silica; hydroxyl; ion polishing; polishing; roughness; surface damage; thin films; threshold.

A previous study on pulsed laser-induced damage on fused silica and other optical materials indicated that the damage threshold E (in V/cm) depended upon the RMS surface roughness σ (in A) as follows: $E\sqrt{\sigma} \sim$ const. Application of this relationship to previously measured thresholds affords a measure of the efficacies of various surface preparation techniques in improving surface damage thresholds, allowing a quantitative comparison. We have, in addition, observed an apparent correlation between thin film damage threshold and hydroxyl concentration in fused silica substrates. Depending on the particular film materials, the results imply that hydroxyl ions on the surface of silica substrates can be either beneficial or deleterious.

Laser induced damage to thin films immersed in liquids, A. Balbin-Villaverde and L. G. DeShazer, *SP462*, pp. 315-330 Dec. 1976).

Key words: high power ruby laser damage; multilayer reflectors; single layer coatings; spark detection; thin films immersed in liquids.

A high power ruby laser system, operating in a single longitudinal and transverse mode was used to measure the damage threshold of a series of quarter-wave and half-wave single coatings, as well as for multilayer reflectors and antireflection "vee" coatings, immersed in different liquids: water, carbon disulfide, nitrobenzene, ethanol, methanol, acetone, and diiodomethane. Coatings of TiO_2, MgF_2, SiO_2, ZrO_2, and ZnS on substrates of glass were studied. Liquids were chosen covering a wide range of their physical properties. A correlation is intended between the damage threshold of the coatings and liquid properties. It is found that the damage threshold for all the films increases steadily with the low frequency dielectric constant of the liquids. For multilayer reflectors is also observed a clear dependence of the damage threshold on the liquid index of refraction, through the modification of the electric field inside the films.

Dielectric coatings on metal substrates, S. S. Glaros, P. Baker, and D. Milam, *SP462*, pp. 331-337 (Dec. 1976).

Key words: laser damage; laser fusion; metal mirrors; reflecting optics.

Large aperture, beryllium substrate based mirrors have been used to focus high intensity pulsed laser beams. Finished surfaces have high reflectivity, low wavefront distortion and high laser damage thresholds. This paper describes the development of a series of metallic coatings, surface finishing techniques and dielectric overcoatings to meet specified performance requirements. Beryllium substrates were coated with copper, diamond machined to within 5 microinches to final contour, nickel plated and abrasively figured to final contour. Bond strengths for several bonding processes will be presented. Dielectric overcoatings were deposited on finished multimetallic substrates to increase both reflectivity and the damage thresholds. Coatings were deposited using both high and low temperature processes which induce varying stresses in the finished coating substrate system. Data will be presented to show the evolution of wavefront distortion, reflectivity, and damage thresholds throughout the many steps involved in fabrication.

Spot size and pulse duration dependence of laser-induced damage, J. R. Bettis, R. A. House, and A. H. Guenther, *SP462*, pp. 338-345 (Dec. 1976).

Key words: frequency dependence; laser damage; spot size dependence; time dependence.

The threshold electric field for laser-induced damage in transparent dielectrics is shown to follow an inverse relation with the fourth root of the pulse duration. Preliminary analytical studies suggest the process involves the free-free plasma heating rate. The relationship is demonstrated for pulse durations ranging from a few picoseconds to several tens of nanoseconds. Furthermore, from considerations of total energy deposition, it is proposed that the threshold electric field follows an inverse relation with the square root of the damaging spot size. The results are compared to measured values with acceptable agreement.

Re-examination of laser induced breakdown in the alkali halides at 10.6 μm, C. C. Tang, K. M. Leung, and M. Bass, *SP462*, pp. 346-349 (Dec. 1976).

Key words: alkali halide crystals; laser induced damage; RAP grown materials.

Since the 10.6 μm bulk laser damage thresholds of alkali halides have been shown to depend on the experimental procedures used, we have remeasured the damage flux for these materials. Multiple shot per site thresholds were found to be higher than single shot per site thresholds for samples containing a large density of defects. By irradiating with two different spot sizes and observing an increase in damage threshold with decreasing spot size, a correlation between

damage thresholds and the distribution of defects was determined. The single shot per site bulk breakdown electric field for NaCl using a 59 μm spot diameter was 1.8 MV/cm. Measurements made on conventional and RAP grown samples showed that both types of material preparation techniques are not yet able to produce samples with reproducible damage thresholds. Some, but not all, RAP grown samples are harder to damage than conventionally prepared materials.

Can a model which describes gas breakdown also describe laser damage to the bulk and surfaces of solid dielectrics, D. Milam, *SP462*, pp. 350-356 (Dec. 1976).

Key words: absorption; avalanche ionization; damage morphology; damage statistics; distribution of damage times; photoionization.

By assuming that laser-induced breakdown in highly transparent solids is a three-step process consisting of preionization, ionization growth, and absorption, it is possible to explain "explosive" threshold damage, typical surface damage morphology, the presence or absence of damage statistics, and the distribution of breakdown times. Special constraints on the preionization stage necessary to explain these phenomena are discussed.

Laser damage to semiconductor materials from 10.6 μm CW CO_2 laser radiation, S. K. Gulati and W. W. Grannemann, *SP462*, pp. 357-364 (Dec. 1976).

Key words: carrier mobility; damping rates; laser damage of semiconductors; parametric plasma instability; photon induced excitation.

Damage thresholds for Si, Ge, GaAs, GaAsP, and GaP have been found experimentally. All the damage thresholds are of the order of KW/cm^2 for an irradiation time of 0.15 to 0.18 second. The damaged devices of Si and Ge show 30 to 50 percent decreases in carrier mobility at lower tempera tures, thereby showing lattice damage. It is found that th experimental damage thresholds, surface and lattice damag can all be explained by applying the theory of parametric in stability of the type formulated by DuBois and Goldman The same theory is also applied to explain CW CO_2 damag thresholds for KCl windows as experimentally observed b Loomis and Huguly.

Phototransport damage of optical materials, S. M. Wong an D. L. Olson, *SP462*, pp. 365-370 (Dec. 1976).

Key words: absorption; electrotransport; ionic segregation laser; momentum transfer; phototransport; scattering vacancies.

Described as well-established electrotranspo phenomena which may serve as analogies for studies c laser-induced damage in optical materials throug phototransport. Phototransport or photomigration relates t the segregation of ionic species or in vacancies in the optic materials caused by a competitive momentum transfer fro the scattered photons to the specific ionic species of the o tical material. Such microstructural changes in the materi are expected to cause severe increases in localized absor tion and enhance laser-induced damage.

Resonant defect enhancement of the laser electric field, P. A Temple and M. J. Soileau, *SP462*, pp. 371-378 (Dec. 1976).

Key words: damage theory; laser damage; 10.6 μm laser.

This paper describes a physical model for laser damage i duced by surface defects. The model predicts that: (a) polarizable defect will give rise to an electric field which c interfere with the laser field, (b) the interference pattern w be fixed in space along the direction of the laser bea polarization and with a spacing equal to the wavelength the laser beam in the material, and (c) there is a strong defe size effect causing a significant increase in the field streng when the defect size is an odd number of half wavelengt Experimental evidence supporting this model is presente

3.10. APPLIED MATHEMATICS SERIES

Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

MS59. **Tables relating to Mathieu functions, Characteristic values, coefficients, and joining factors,** NBS Appl. Math. Series 59 (Aug. 1, 1967).

Key words: Characteristic values; coefficients; joining factors; Mathieu's equation.

This second edition of "Tables Relating to Mathieu unctions" (Columbia University Press, New York, 1951) corporates the article "Table of Characteristic Values of athieu's Equation for Large Values of the Parameter" by ertrude Blanch and Ida Rhodes, Journal of the Washington cademy of Sciences, Volume 45, No. 6, 166-196, June 1955, t makes no essential changes in tables or introductory aterial. However, a number of misprints in the first edition ve been corrected and the bibliography updated. (A reissue, th additions, of Columbia University Press 13).

MS60. **Matrix representations of groups,** M. Newman, Nat. Bur. Stand. (U.S.), Appl. Math. Series 60, 82 pages (July 1968).

Key words: Algebraic numbers; groups; matrices; representations.

The theory of group representations is presented from the atrix standpoint. Many special representations are worked out detail, and there are appendices on the elements of the theory f algebraic numbers.

MS61. **Lectures on modular forms,** J. Lehner, Nat. Bur. Stand. (U.S.), Appl. Math. Series 61, 77 pages (Dec. 1969).

Key words: Automorphism; finite field; genus; Hecke operator; Klein's invariant; linear transformation; modular form; Riemann surface.

This book is an expository account of the theory of modular rms and its application to number theory and analysis. The first apter defines modular forms and develops their most impor- nt properties. The second and third chapters introduce the ecke modular forms. A Hecke form f is a simultaneous eigen- nction of a family of linear operators T_p, where p runs over the ositive primes. The eigenvalue corresponding to T_p is the pth ourier coefficient a(p) of f. The Fourier coefficients of f are ultiplicative, i.e., a(mn) = a(m) a(n) when m and n have no com- on divisors. The intimate connection of these results to the eory of certain zeta-functions is indicated in a note to Chapter . The fourth chapter is devoted to the automorphisms of a com- act Riemann surface. It is shown what groups of linear-frac- onal transformations with coefficients in a finite field can be the roup of automorphisms of a compact Riemann surface. In the ast two chapters congruences and other arithmetic properties re developed for the Fourier coefficients of Klein's absolute odular invariant. Analogies with the Hecke theory as well as ith the Ramanujan congruences for the partition function are iscussed.

AMS62. **Cyclic designs,** J. A. John, F. W. Wolock, H. A. David, J. M. Cameron, and J. A. Speckman, Nat. Bur. Stand. (U.S.), Appl. Math. Ser. 62, 79 pages (Apr. 1972).

Key words: Analysis of variance; cyclic designs; design of experiments; designs for calibration; incomplete block designs.

Cyclic designs are incomplete block designs based on cyclic development of an initial block or blocks. Their flexibility, ease in conduct of the experiment and natural grouping for elimination of heterogeneity make them worthy of attention in their own right even though their analysis does not possess the ease of computation of the more common completely balanced or partially balanced incomplete block designs with two associate classes. Methods for construction and analysis of the designs are given along with a numerical example. Applications of the designs are discussed and an appendix on their use in calibration is given.

AMS63. **Tables of two-associate-class partially balanced designs,** W. H. Clatworthy, J. M. Cameron, and J. A. Speckman, Nat. Bur. Stand. (U.S.), Appl. Math. Ser. 63, 327 pages (May 1973) $3.45, SD Catalog No. C13.32:63.

Key words: Analysis of PBIB designs; experiment designs; finite fields; finite geometries; finite projective planes; incidence matrices; incomplete block designs, partially balanced; mathematics; partially balanced incomplete block designs; PBIB designs; statistics; tables of PBIB designs.

This book is a revised and vastly expanded version of the monograph of R. C. Bose, W. H. Clatworthy, and S. S. Shrikhande, *Tables of Partially Balanced Designs with Two Associate Classes,* Tech. Bull. No. 107 of the North Carolina Agricultural Experiment Station, Raleigh, N.C., 1954.

Approximately 950 combinatorially distinct designs are given, which represents a doubling of the number of parametric specifications for designs of the original publication. The introduction includes special instructions to aid analysis using hand calculations and a section on the general least squares approach for use when the analysis is to be done on an electronic computer.

For those interested in the construction of the designs, information is provided on methods of construction and extensive references, including original sources for the designs, are given. A tabulation of known information about uniqueness, resolvability, and the nature of the corresponding dual and complementary designs is also included for each design.

3.11. NATIONAL STANDARD REFERENCE DATA SERIES

Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS. Program under the authority of National Standard Data Act (Public Law 90-396).

NSRDS-NBS3, Section 2. **Selected tables of atomic spectra; atomic energy levels and multiplet tables; Si I**, C. E. Moore, NBS Natl. Std. Ref. Data Series 3, Section 2 (Nov. 30, 1967).

Key words: Atomic energy levels; atomic spectra Si I; first spectrum; multiplet table; silicon; spectrum, Si I; wavelengths, Si I.

The present publication is the second Section of a series being prepared in response to the increasing demand for a current revision of two sets of tables containing data on atomic spectra as derived from analyses of optical spectra.

Both the atomic energy levels and the multiplet table are included in the same publication, as parts A and B, respectively. The Sections are being prepared at irregular intervals for these spectra whose analyses are essentially complete. A flexible paging system permits the arrangement of the various Sections by atomic number regardless of the order in which the spectra are published in this series. Section 1 included three spectra of silicon, Z=14: Si II, Si III, Si IV. The present Section contains similar data for Si I. The form of presentation is described in detail in the text to Section 1, and need not be repeated here.

NSRDS-NBS3, Section 3. **Selected tables of atomic spectra. A. Atomic energy levels-second edition, B. Multiplet tables, NIV, CIII, CIV, CV, CVI, data derived from the analyses of optical spectra,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 3, Sec. 3, 71 pages (Nov. 1970).

Key words: Atomic energy levels, carbon spectra; atomic spectra of carbon; carbon spectra; multiplet tables, carbon spectra; spectra, carbon; wavelengths, carbon spectra.

The present publication is the third Section of a series being prepared in response to the persistent need for a current revision of two sets of tables containing data on atomic spectra as derived from analyses of optical spectra. As in the first two Sections, Part A contains the atomic energy levels and Part B the multiplet tables: All six spectra of carbon, CI through CVI are included. The form of presentation is described in detail in the text to Section 1, and need not be repeated here.

NSRDS-NBS3, Section 4. **Selected tables of atomic spectra. A. Atomic energy levels-second edition, B. Multiplet tables, NIV, NV, NVI, NVII, data derived from the analyses of optical spectra,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 3, Sec. 4, 46 pages (Aug. 1971).

Key words: Atomic energy levels, NIV-NVII; multiplet tables, NIV-NVII; nitrogen spectra, NIV-NVII; spectra, NIV-NVII; wavelengths, nitrogen spectra NIV-NVII.

The present publication is the fourth Section of a series being prepared in response to the persistent need for a current revision of two sets of tables containing data on atomic spectra as derived from analyses of optical spectra. As in the previous Sections, Part A contains the atomic energy levels and Part B the multiplet tables. Four spectra of nitrogen, NIV, NV, NVI and NVII, are included. The form of presentation is described in detail in the test to Section 1.

NSRDS-NBS3, Section 5. **Selected tables of atomic spectra. A: Atomic energy levels—Second edition. B: Multiplet tables. N I, N II, N III,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 3, Sec. 5, 67 pages (May 1975) SD Catalog No. 13.48:3/Sec.5.

Key words: atomic energy levels, N I, N II, N III; multiplet tables, N I, N II, N III; nitrogen spectra, N I, N II, N III; spectra, N I, N II, N III; wavelengths, nitrogen spectra N I, N II, N III.

The present publication is the fifth Section of a series being prepared in response to the persistent need for a current revision of two sets of tables containing data on atomic spectra as derived from analyses of optical spectra. As in the previous sections, Part A contains the atomic energy levels and Part B the multiplet tables. The first three spectra of nitrogen, N I, N II and N III are included. The form of presentation is described in detail in the text of Section 1.

NSRDS-NBS3. Section 6. **Selected tables of atomic spectra: A Atomic energy levels—second edition; B. Multiplet tables, HI D, T (Data derived from the analyses of optical spectra),** C. E Moore and E. O. Hulburt, Nat. Stand. Ref. Data Ser., Nat Bur. Stand. (U.S.), 3, Sec. 6, 36 pages (Sept. 1972).

Key words: Atomic energy levels, HI, D, T; hydroge spectra, HI, D, T; multiplet tables, HI, D, T; spectra HI, D T; wavelengths, hydrogen spectra HI, D, T.

The present publication is the sixth Section of a series bein prepared in response to the persistent need for a current revisio of two sets of tables containing data on atomic spectra as derive from analyses of optical spectra. As in the previous section Part A contains the atomic energy levels and Part B the multiple tables. The spectra of hydrogen and of the isotopes deuteriun and tritium are included. The form of presentation is describe in detail in the text to Section 1.

NSRDS-NBS3, Section 7. **Selected tables of atomic spectra. A Atomic energy levels—Second edition. B: Multiplet tables. O** C. E. Moore, *Nat. Stand. Ref. Data Ser., Nat. Bur. Stand (U.S.), 3, Sec. 7,* 30 pages (Apr. 1976) SD Catalog No C13.48:3/Sec. 7.

Key words: atomic energy levels, O I; atomic spectra, O multiplet table, O I; oxygen, first spectrum; spectrum O wavelengths, O I.

The present publication is the seventh Section of a series bein prepared in response to the need for a current revision of tw sets of the author's tables containing data on atomic spectra a derived from analyses of optical spectra. As in the previous Se tions, Part A contains the atomic energy levels and Part B th multiplet tables. Section 7 presents this material for the fir spectrum of oxygen, O I. The form of presentation is describe in detail in the text to Section 1.

NSRDS-NBS5. **The band spectrum of carbon monoxide,** P. Krupenie, NBS Natl. Std. Ref. Data Series 5 (July 8, 1966).

Key words: Carbon monoxide; spectrum; review.

This is an exhaustive review of the literature and a critic compilation of the observed and predicted spectroscopic data CO, CO^+, and CO^{2+} in the gas phase.

NSRDS-6, Superseded by National Standard Reference Data Series 39.

NSRDS-NBS7. **High temperature properties and decomposition of inorganic salts. Part I. Sulfates,** K. H. Stern and E. L. Weise, NBS Natl. Std. Ref. Data Series 7 (Oct. 1, 1966).

Key words: Sulfates; thermodynamic functions; decomposition pressures.

The literature dealing with the high-temperature behavior of organic sulfates has been critically reviewed. Free energy nctions of reactants and products of the decomposition actions were calculated and have been tabulated from 298 °K o to as high a temperature as possible. Free energy functions, quilibrium constants of reactions, and partial pressures of aseous components were tabulated. Auxiliary data on phase ansitions, densities, and kinetics of chemical decomposition ave also been included.

NSRDS-NBS8. **Thermal conductivity of selected materials,** R. W. Powell, C. Y. Ho, and P. E. Liley, NBS Natl. Std. Ref. Data Series 8 (Nov. 25, 1966).

Key words: Gases; liquids; metals; solids; thermal conductivity.

The data presented in this publication consists of the critical valuation and analysis of the available thermal conductivity ta on eleven metals and nine nonmetals for the solid state, on ven fluids for both the liquid and gaseous states and on two for e liquid state only. The materials studied were selected imarily for their potential applicability as reference standards because of their technical importance. The temperature range r which values are given often exceeds that for which these lues are known with a high degree of certainty.

NSRDS-NBS9. **Tables of bimolecular gas reactions,** A. F. Trotman-Dickenson and G. S. Milne, NBS Natl. Std. Ref. Data Series 9 (Oct. 27, 1967).

Key words: Activation energies; Arrhenius equation; bimolecular: chemical kinetics; data; gas; rate constants; reactions; tables.

This survey covers the kinetics of bimolecular and rmolecular gas reactions that do not involve atoms or olecules in electronically excited states. Bimolecular reactions e here defined as reactions in which two molecules are volved as reactants, that yield two or more molecules as oducts. Those reactions in which two molecules combine to rm one molecule are most usefully considered as the reverse of nimolecular reactions which will be dealt with in another rvey. Reactions of oxygen and nitrogen atoms have been mitted as they will also form the subject of another survey.

The literature from 1954 to December 31, 1965 has been khaustively searched and it is hoped that for this period nothing as been omitted that should have been included.

The survey of earlier work has been based on one of the riters' books on "Gas Kinetics" which covered the literature to 954. Use of the book for over ten years has revealed few missions and these have been included in these tables. Data for e period January to August 1966 has been included where ossible.

NSRDS-NBS10. **Selected values of electric dipole moments for molecules in the gas phase,** R. D. Nelson, Jr., D. R. Lide, Jr., and A. A. Maryott, NBS Natl. Std. Ref. Data Series 10 (Sept. 1, 1967).

Key words: Dielectric constant; electric dipole moments; gas phase; microwave; microwave absorption; molecular beam; permittivity; refractive index; spectroscopy.

This table revises, brings up to date, and extends the coverage on numerical values for dipole moments which was included in NBS Circular 537, Tables of Dielectric Constants and Electric Dipole Moments of Substances in the Gaseous State, prepared by Maryott and Buckley in 1953. A recommended value with an estimate of accuracy is presented for more than five hundred organic and inorganic compounds. Extensive comments are given on the definition of dipole moment and principal methods of dipole moment measurement, as well as an exposition of the criteria employed in selecting the tabulated data. (Supersedes the data on dipole moments included in NBS Circ. 537).

NSRDS-11, Superseded by National Standard Reference Data Series 39.

NSRDS-NBS12. **Tables for the rigid asymmetric rotor: transformation coefficients from symmetric to asymmetric bases and expectation values of P_z^2, P_z^4, and P_z^6,** R. H. Schwendeman, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 12, 102 pages (June 1968).

Key words: Angular momentum; asymmetric rotor; eigenfunction; microwave spectra; rotational spectrum; transformation coefficients.

Tables of computed quantities associated with the rigid asymmetric rotor are presented. The first group of tables gives transformation coefficients from symmetric to asymmetric rotor bases. These coefficients permit the eigenfunctions of the asymmetric rotor to be written in terms of symmetric-rotor eigenfunctions. In Part II the angular-momentum expectation values (P_z^2), (P_z^4), and P_z^6 are tabulated. In both sets of tables values are given at intervals of 0.1 in the asymmetry parameter κ and for $J \leqq 15$. The tabulated quantities find use in the analysis of microwave rotational spectra and the rotational fine structure in vibrational and electronic band spectra.

NSRDS-NBS13. **Hydrogenation of ethylene on metallic catalysts,** J. Horiuti and K. Miyahara, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 13, 66 pages (June 1968).

Key words: Critical data; ethylene; hydrogenation; metallic catalysts; reaction mechanisms; reaction rates.

Reaction rate data for the catalyzed hydrogenation of ethylene, primarily in the presence of unsupported metallic catalysts, are critically reviewed. Reaction mechanisms are discussed in detail, and a statistical mechanical treatment of the reaction is given, according to the generalized theory of reaction starting from the well-known procedure of Glasstone, Laidler, and Eyring. Data for single-element catalysts and alloys are included and interpreted, as are data illustrating differences due to the physical form of the catalyst (film, foil, wire, powder, and some supported systems). Problems are discussed concerning reproducibility of experimental results over repeated runs, and as a function of catalyst pretreatment. The data is analyzed in 29 graphs and 29 tables, some of which are very extensive. The bibliography includes 141 references.

NSRDS-NBS14. **X-ray wavelengths and X-ray atomic energy levels,** NBS Natl. Std. Ref. Data Series 14 (Sept. 25, 1967).

Key words: Absorption; atomic; data compilation; emission; energy levels; x-ray wavelength.

X-ray wavelengths, J. A. Bearden:

Inconsistencies in accepted values (in x units) of x-ray reference lines have recently been demonstrated, although all are supposedly based on "good" calcite crystals. Factors supporting the selection of the W $K\alpha_1$ line as *the X-Ray Wavelength*

Standard are critically discussed. A review is given of the experimental measurements which are used to establish the wavelength of this line on an absolute angstrom basis. Its value is λ W $K\alpha_1$=(0.2090100±5 ppm) Å. This may be used to define a new unit, denoted by Å*, such that the W $K\alpha_1$ wavelength is exactly 0.2090100 Å*; hence 1Å=1Å±5ppm. The wavelengths of the Ag $K\alpha_1$, Mo $K\alpha_1$, Cu $K\alpha_1$, and the Cr $K\alpha_2$ have been established as secondary standards with probable error of approximately one part per million. Sixty-one additional x-ray lines have been used as reference values in a comprehensive review and reevaluation of more than 2700 emission and absorption wavelengths. The recommended wavelength values are listed in Å* units together with probable errors; corresponding energies are given in keV. A second table lists the wavelengths in numerical order, and likewise includes their energies in keV.

Reevaluation of X-ray atomic energy levels, J. A. Bearden and A. F. Burr:

All of the x-ray emission wavelengths have recently been reevaluated and placed on a consistent Å* scale. For most elements these data give a highly overdetermined set of equations for energy level differences, which have been solved by least-squares adjustment for each case. This procedure makes "best" use of all x-ray wavelength data, and also permits calculation of the probable error for each energy difference. Photoelectron measurements of absolute energy levels are more precise than x-ray absorption edge data. These have been used to establish the absolute scale for eighty-one elements and, in many cases, to provide additional energy level difference data. The x-ray absorption wavelengths were used for eight elements and ionization measurements for two; the remaining five were interpolated by a Moseley diagram involving the output values of energy levels from adjacent elements. Probable errors are listed on an absolute energy basis. In the original source of the present data, a table of energy levels in Rydberg units is given. Difference tables in volts, Rydbergs, and milli-Å* wavelength units, with the respective probable errors, are also included there.

NSRDS-NBS15. **Molten salts: Volume 1. Electrical conductance, density, and viscosity data,** G. J. Janz, F. W. Dampier, G. R. Lakshminarayanan, P. K. Lorenz, and R. P. T. Tomkins, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 15, 145 pages (Oct. 1968).

Key words: Data compilation; density; electrical conductance; molten salts; standard reference data; viscosity.

Data on the electrical conductance, density and viscosity of single-salt melts were compiled from a comprehensive search of the literature up to December 1966 and a critical assessment made of the compiled data. Recommended values were determined and are presented as functions of temperature in the form of equations and tables.

The results for some 174 compounds as single-salt melts are reported; no attempt was made in the present effort to embrace the results for molten salt mixtures. Data are presented for fluorides, chlorides, bromides, iodides, carbonates, nitrites, nitrates, oxides, sulfides, sulfates, and a miscellaneous group.

NSRDS-NBS16, Part 2. **Thermal conductivity of selected materials,** C. Y. Ho, R. W. Powell, and P. E. Liley, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 16, Part 2, 154 pages (Feb 1968).

Key words: Critical evaluation; gases; graphites; metalli elements; metals; recommended values; standard referenc data; thermal conductivity.

The work presented in this report comprises the critic evaluation, analysis, and synthesis of the available thermal co ductivity data and the generation of recommended values f twelve metallic elements, mainly for the solid state, for a range graphites, and for three fluids in the gaseous state. These are ca mium, chromium, lead, magnesium, molybdenum, nickel, niob um, tantalum, tin, titanium, zinc, zirconium, Acheson graphit ATJ graphite, pyrolytic graphite, 875S graphite, 890S graphit acetone, ammonia, and methane. For each of the materia recommended values are given over a wide range of temperatur

NSRDS-17, Superseded by National Standard Reference Data Series 39

NSRDS-NBS18. **Critical analysis of the heat-capacity data of th literature and evaluation of thermodynamic properties c copper, silver, and gold from 0 to 300 °K,** G. T. Furukawa, W G. Shaba, and M. L. Reilly, Nat. Stand. Ref. Data Ser., Na Bur. Stand. (U.S.), 18, 53 pages (Apr. 1968).

Key words: Calorimetry; copper; Debye theta (θ); ele tronic coefficient of heat capacity; enthalpy; entropy; Gibl energy; gold; heat capacity; silver; temperature scales; the modynamic properties.

The literature sources of heat-capacity data on copper, silve and gold between 0 and 300 °K have been compiled and the da critically analyzed. Tables of heat capacity (C_p), enthalpy (H $H_0°$), entropy ($S°$), Gibbs energy ($G-H_0°$), enthalpy function ($-H_0°)/(T)$, and Gibbs energy function $(G-H_0°)/(T)$ have be obtained from the analyses. The literature values of the he capacity, the electronic coefficient of heat capacity (γ), and t 0 °K limiting Debye characteristic temperature ($\theta_D(0)$) are co pared with the selected values. The sources of the data are tab lated chronologically along with the temperature range of me surements, purity of sample, and the pertinent experimen procedures used. A bibliography of the references is listed. brief appraisal of low-temperature calorimetry is given.

NSRDS-NBS19. **Thermodynamic properties of ammonia as ideal gas,** L. Haar, Nat. Stand. Ref. Data Ser., Nat. Bur. Stan (U.S.), 19, 13 pages (Aug. 1968).

Key words: Ammonia; ideal gas; thermodynamic functio

Thermodynamic functions for ammonia as an ideal gas at o atmosphere pressure have been evaluated. The contribution the highly anharmonic out-of-plane vibrational mode, includi its large coupling with rotation and its coupling with the oth vibrational modes, is considered in detail. Tables of $C_P°/R$, ($-E_0°)/RT$, $(E_0°-G°)/RT$, and $S°/R$ have been calculated closely spaced intervals from 50 to 5000 °K within an overall u certainty of less than 0.1 percent at 1000 °K. (Reprinted from t Journal of Research of the NBS—A. Physics and Chemist Vol. 72A, No. 2, March-April 1968).

NSRDS-NBS20. **Gas phase reaction kinetics of neutral oxyg species,** H. S. Johnston, Nat. Stand. Ref. Data Ser., Nat. B Stand. (U.S.), 20, 54 pages (Sept. 1968).

Key words: Chemical kinetics; dissociation; isoto exchange; oxygen atom; oxygen molecule; ozone; reco bination; review.

The available data for reactions among neutral oxygen species, ygen atoms, oxygen molecules and ozone, have been viewed. Selected data have been reanalyzed and used to tablish values for the rates of these reactions:

$$O_2 + M \rightarrow O + O + M \quad -\ (M = O_2, Ar)$$

$$O + O + M \rightarrow O_2 + M \quad -\ (M = O_2)$$

$$O_3 + M \rightarrow O + O_2 + M \quad -\ (M = O_2, O_3, He, Ar, N_2, CO_2)$$

$$O + O_2 + M \rightarrow O_3 + M \quad -\ (M = O_2, O_3, He, Ar, N_2, CO_2)$$

$$O + O_3 \rightarrow O_2 + O_2$$

$$O + O_2 \rightarrow O + O_2 \text{ (isotopic exchange)}$$

SRDS-NBS21. **Kinetic data on gas phase unimolecular reactions,** S. W. Benson, H. E. O'Neal, Nat. Bur. Stand. (U.S.), Nat. Stand. Ref. Data Series 21, 645 pages. (Feb. 1970).

Key words: Arrhenius parameters; chemical kinetics; critical review data; gas phase; mechanisms; molecular reactions; rate constants; reaction rates.

Available rate data on thermally induced, unimolecular, homoneous gas phase reactions of molecules and free radicals have en reviewed and critically evaluated. Introductory discussion given of theory and assumptions used in compiling the selected ta. Mechanisms of reaction are discussed. The major portion 37 out of 617 pages) of the work presents selected data, with erences, in the form of data sheets (one to two pages per olecule). Preferred values are indicated and discussed.

SRDS-NBS22. **Atomic transition probabilities. Volume II. Sodium through calcium,** W. L. Wiese, M. W. Smith, and B. M. Miles, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 22, 306 pages (Oct. 1969).

Key words: Allowed and forbidden transitions; aluminum; argon; calcium; chlorine; magnesium; oscillator strengths; phosphorus; potassium; silicon; sodium; sulfur; transition probabilities.

Atomic transition probabilities for about 5,000 spectral lines the second ten elements, based on all available literature urces, are critically compiled. The data are presented in parate tables for each element and stage of ionization. For ch ion the transitions are arranged according to multiplets, supermultiplets, transition arrays, and increasing quantum numers. Allowed and forbidden transitions are listed separately. or each line the transition probability for spontaneous emison, the absorption oscillator strength, and the line strength are ven along with the spectroscopic designation, the wavelength, e statistical weights, and the energy levels of the upper and wer states. In addition, the estimated accuracy and the source e indicated. In short introductions, which precede the tables r each ion, the main justifications for the choice of the adopted ata and for the accuracy rating are discussed. A general inoduction contains a detailed discussion of the critical factors ntering into each major experimental and theoretical method. It so includes a general critical assessment of the widely used oulomb approximation, and a number of illustrative examples r the exploitation of regularities of systematic trends among scillator strengths.

SRDS-NBS23. **Partial Grotrian diagrams of astrophysical interest,** C. E. Moore and P. W. Merrill, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 23, 70 pages (June 1968).

Key words: Atomic spectra; Grotrian diagrams; partial Grotrian diagrams.

This publication is a reprint of Appendix A of the book by Paul W. Merrill entitled, "Lines of the Chemical Elements in Astronomical Spectra" (Carnegie Inst. Wash. Publ. 610, 1956). It contains partial Grotrian Diagrams of selected spectra of astrophysical interest, which give wavelengths, multiplet numbers and key letters for the transitions shown. The diagrams are accompanied by tabular keys in which the key letters indicate related lines in spectra similar in structure to those illustrated in the diagrams. There are 39 diagrams of spectra between hydrogen and nickel and tabular keys for 90 spectra between lithium and rhenium.

NSRDS-NBS24. **Theoretical mean activity coefficients of strong electrolytes in aqueous solutions from 0 to 100 °C,** W. J. Hamer, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 24, 276 pages (Dec. 1968).

Key words: Activity coefficients; electrolytes; interionic attraction expressions.

In determining the activity coefficients of electrolytes in aqueous solutions from the freezing point to the boiling point of the solvent, various equations have been used in the treatment of the data. This paper gives values for activity coefficients of electrolytes of various valence types from 0 to 100 °C, and for ionic strengths from zero to 0.1 molal or 0.1 molar, as calculated by seven different equations based on the theory of interionic attraction. These equations are those of Debye and Hückel, Güntelberg, Davies, Scatchard, and Bjerrum, and what may be termed an extended Güntelberg equation and an extended Scatchard equation.

NSRDS-NBS25. **Electron impact excitation of atoms,** B. L. Moiseiwitsch and S. J. Smith, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 25, 120 pages (Aug. 1968).

Key words: Atom; electron; excitation; experimental; helium; hydrogen; impact; review; theoretical.

The experimental and theoretical literature about the electron impact excitation of atoms is reviewed. Theoretical methods ranging from the Bethe and Born approximations to the close coupling approximations are discussed and intercompared. Where possible, on theoretical grounds or through intercomparison, the reliability of the various methods is discussed.

A general critique of the optical method of measuring excitation functions is given, with the objective of promoting higher quality future experimental work. A critical study of existing experimental work leads to the conclusion that most workers have ignored important physical and instrumental effects, and it may be presumed that the data in the literature is subject to many unrecognized systematic errors. The literature on hydrogen and helium is discussed critically. The literature on the alkalis, heavy rare gases, mercury, cadmium and zinc is surveyed but the quality of the literature does not support critical review beyond some general comments about the physics of these atoms.

NSRDS-NBS26. **Ionization potentials, appearance potentials, and heats of formation of gaseous positive ions,** J. L. Franklin, J. G. Dillard, H. M. Rosenstock, J. T. Herron, K. Draxl, and F. H. Field, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 26, 289 pages (June 1969).

Key words: Appearance potential; compilation; data; heat of formation; ionization potential; ions; positive ions.

This is a compilation of ionization and appearance potentials of positive ions published from 1955 through June 1966. The compilation lists the ion formed, the parent species from which it was formed, the other products of the process, the threshold energy for the formation of this ion, and the method by which this data was obtained.

Where feasible, the heat of formation at 298 K of the positive ion has been computed for each entry using auxiliary thermochemical data. From these computed values "best" values have been chosen.

NSRDS-NBS27. **Thermodynamic properties of argon from the triple point to 300 K at pressures to 1000 atmospheres,** A. L. Gosman, R. D. McCarty, and J. G. Hust, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 27, 151 pages (Mar. 1969).

Key words: Argon; compressibility factor; enthalpy; entropy; equation of state; internal energy; Joule-Thomson coefficient; P-V-T; specific heat; vapor pressure; virial coefficient.

Tabular values of density, internal energy, enthalpy, and entropy of liquid and gaseous argon are presented for temperatures from 83.8 to 300 K at pressures of 0.01 to 1000 atmospheres. Diagrams of specific heats, compressibility factor, and entropy are included. The properties presented are calculated from an equation of state which was fitted to experimental P-ρ-T data from the world literature. Extensive comparisons were made between the equation of state and the experimental data, and deviation plots are presented. The second virial coefficient and Joule-Thomson inversion curve were also calculated and comparisons made with values from other sources. A vapor pressure equation which covers the range from the triple point to the critical point is also given.

NSRDS-NBS28. **Molten salts: Volume 2. Section 1. Electrochemistry of molten salts: Gibbs free energies and excess free energies from equilibrium-type cells,** G. J. Janz and Chr. G. M. Dijkhuis. **Section 2. Surface tension data,** G. J. Janz, G. R. Lakshminarayanan, R. P. T. Tomkins, and J. Wong, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 28, 116 pages (Aug. 1969).

Key words: Critically evaluated data; equilibrium electrochemical cells; excess entropies; excess Gibbs free energies; Gibbs free energies; molten salt mixtures; molten salts; surface tension; thermodynamics of molten salts.

This book consists of two sections as follows:

Section 1. The critical evaluation of excess free energies of binary molten salt mixtures with a common ion from equilibrium-type electrochemical cells is described in this report. For this purpose calculations using the original emf data were systematically undertaken to establish comparisons of free energy values of various workers that would be significant. The reversibility of electrodes is investigated by comparing the electromotive force of cells with a single molten salt as liquid electrolyte with thermochemical data.

Section 2. Data on the surface tensions of single salt melts have been systematically collected and evaluated. Results are given for 106 inorganic compounds over a range of temperatures where available.

NSRDS-NBS29. **Photon cross sections, attenuation coefficients, and energy absorption coefficients from 10 keV to 100 GeV,** J. H. Hubbell, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 29, 85 pages (Aug. 1969).

Key words: Attenuation coefficient; Compton scattering; cross section; energy absorption coefficient; gamma rays; pair production; photoelectric absorption; photons; x-rays.

This report updates and extends previous NBS tabulations. Section 1 contains the information of most immediate practical use: (a) a tabulation of the attenuation coefficient for 23 elements ($_1$H to $_{92}$U) between 10 keV and 100 GeV and (b) a tabulation of the energy absorption coefficient for air, water, and 18 elements between 10 keV and 10 MeV, and for air, water, and 7 elements up to 100 MeV. Section 2 contains detailed information on the predominant processes (photoelectric absorption, Compton scattering and pair production) and a brief discussion of other processes which combine to give the attenuation coefficient. Theoretical and experimental data are reviewed, and auxiliary tables and approximation formulas are given. Section 3 contains tabulations of cross sections for the predominant processes between 10 keV and 100 GeV for 23 elements and for 13 compounds and mixtures.

NSRDS-NBS30. **High temperature properties and decomposition of inorganic salts, Part 2. Carbonates,** H. H. Stern, and E. L. Weise, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 30, 32 pages (Dec. 1969).

Key words: Carbonates; thermal decomposition; thermodynamic functions.

The literature dealing with the high-temperature behavior of inorganic carbonates has been critically reviewed. Free energy functions of reactants and products of the decomposition reactions were calculated and have been tabulated from 298 °K up to as high a temperature as possible. Free energy functions and equilibrium constants of reactions were tabulated. Auxiliary data on phase transitions, densities, and kinetics of thermal decomposition have also been included. The literature of the endothermic decomposition kinetics of solids, as it applies to carbonates, has been reviewed.

NSRDS-NBS31. **Bond dissociation energies in simple molecules,** B. deB. Darwent, Nat. Bur. Stand. (U.S.), Nat. Stand. Ref. Data Series 31, 52 pages (January 1970).

Key words: Bond dissociation energy; gaseous state; inorganic simple compounds; recommended value; zero vibrational state of the ground electronic state.

Bond dissociation energy values (kcal/mol) and (kJ/mol) for simple compounds are tabulated from a literature review covering the years 1962-1966 inclusively. Some selected values which appeared in the years 1956-1962 are also included. Organic compounds are excluded except those containing one carbon atom. The groups $>$CO and $-$CN are not considered to be organic.

The values are quoted usually at 0 K or 298 K and refer to the gaseous state. They represent the energy required to break a bond at the specified temperature with all substances in the zero vibrational state of the ground electronic state. The experimental method for the energy value listed is given and referenced in the table. A value recommended by the author is listed as the final value for each reaction.

NSRDS-NBS32. **Phase behavior in binary and multicomponent systems at elevated pressures: *n*-pentane and methane-*n*-pentane,** V. M. Berry and B. H. Sage, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 32, 73 pages (June 1970).

Key words: Evaluated data; liquid-vapor equilibria; methane-*n*-pentane system; *n*-pentane; thermodynamics.

This paper, which is concerned with the critical evaluation of data on the phase behavior of binary systems, consists of three parts. In the first part the rationale of the evaluation process used is discussed, in the second the behavior of *n*-pentane, and in the third the behavior of the system methane-*n*-pentane.

The properties of *n*-pentane considered are the critical constants and the vapor pressures and densities of the saturated coexistent phases as functions of temperature. For the methane-*n*-pentane system the compositions and densities of the coexisting phases are given as functions of temperature and total pressure. Data for the unique states of the two-component sys-

re also presented.

Discussions are given of the reliability of the selected values nd of the differences between the selected values and various neasured values.

NSRDS-NBS33. **Electrolytic conductance and the conductances of the halogen acids in water,** W. J. Hamer and H. J. DeWane, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 33, 37 pages (May 1970).

Key words: Conductances of HF, HCl, HBr, and HI; electrolytic conductance; theories of electrolytic conductance.

Definitions, symbols, general principles, and general laws related to the electrolytic conductance of aqueous solutions are presented. The general laws considered are Coulomb's law for charged bodies, Poisson's equation relating the electrostatic potential to charge distribution, and the Stokes and Oseen laws for the velocity of a sphere in a fluid medium. The relations between electrical resistance, electrical conductance, specific resistance, specific conductance, and equivalent conductance are set forth. Theoretical expressions for the equivalent conductance as derived by Debye, Onsager, and Fuoss are given in general form and in a somewhat more detailed fashion in an appendix. The general methods of treating the equivalent conductances of onophores and ionogens, especially in regard to the determination of the limiting equivalent conductance, the degree of ionic association, and the degree of ionic dissociation are discussed. Data on the equivalent conductances of the halogen acids, hydrofluoric, hydrochloric, hydrobromic, and hydriodic acids in water are given for a wide range of concentration and temperature.

NSRDS-NBS34. **Ionization potentials and ionization limits derived from the analyses of optical spectra,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 34, 22 pages (Sept. 1970).

Key words: Atomic spectra, ground terms; ground terms, atomic spectra; ionization limits; ionization potentials.

A current table of ionization potentials expressed in electron volts and a detailed table giving the limits from which they have been derived are presented. For each spectrum the ground term is given, with the limit as the ground state. The energy levels of terms of the lowest configuration determined from ground state zero, are also included for selected spectra. The literature references used for each spectrum are indicated by number and listed in a bibliography with some 200 entries.

The latest recommended conversion factor (cm^{-1} to eV) 0.000123981 corresponding to 1 eV = 8065.73 cm^{-1} has been used throughout.

NSRDS-NBS35. Volume I. **Atomic energy levels as derived from the analyses of optical spectra, ^{1}H to ^{23}V,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 35/V.I, 359 pages (Dec. 1971).

Key words: Energy levels; H-V.

This series of three volumes is a critical compilation of atomic energy levels prepared at the National Bureau of Standards from the analyses of optical spectra. Volume I contains data on the spectra of hydrogen, deuterium, tritium, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, argon, potassium, calcium, scandium, titanium, and vanadium (^{1}H to ^{23}V). Volume II covers the spectra of chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, arsenic, selenium, bromine, krypton, rubidium, strontium, yttrium, zirconium, and niobium (^{24}Cr to ^{41}Nb). Volume III includes the spectra of molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium, tin, antimony, tellurium, iodine, xenon, cesium, barium, lanthanum; hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold, mercury, thallium, lead, bismuth, polonium, radon, radium, and actinium (^{42}Mo to ^{57}La; ^{72}Hf to ^{89}Ac). This is a reprint of NBS Circular 467, Volume I.

NSRDS-NBS35. Volume II. **Atomic energy levels as derived from the analyses of optical spectra, ^{24}Cr to ^{41}Nb,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 35/V.II, 259 pages (Dec. 1971).

Key words: Cr-Nb; energy levels.

This series of three volumes is a critical compilation of atomic energy levels prepared at the National Bureau of Standards from the analyses of optical spectra. Volume I contains data on the spectra of hydrogen, deuterium, tritium, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, argon, potassium, calcium, scandium, titanium, and vanadium (^{1}H to ^{23}V). Volume II covers the spectra of chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, arsenic, selenium, bromine, krypton, rubidium, strontium, yttrium, zirconium, and niobium (^{24}Cr to ^{41}Nb). Volume III includes the spectra of molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium, tin, antimony, tellurium, iodine, xenon, cesium, barium, lanthanum; hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold, mercury, thallium, lead, bismuth, polonium, radon, radium, and actinium (^{42}Mo to ^{57}La; ^{72}Hf to ^{89}Ac). This is a reprint of NBS Circular 467, Volume II.

NSRDS-NBS35. Volume III. **Atomic energy levels as derived from the analyses of optical spectra, ^{42}Mo to ^{57}La, ^{72}Hf to ^{89}Ac,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 35/V.III, 282 pages (Dec. 1971).

Key words: Energy levels; Hf-Ac; Mo-La.

This series of three volumes is a critical compilation of atomic energy levels prepared at the National Bureau of Standards from the analyses of optical spectra. Volume I contains data on the spectra of hydrogen, deuterium, tritium, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, argon, potassium, calcium, scandium, titanium, and vanadium (^{1}H to ^{23}V). Volume II covers the spectra of chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, arsenic, selenium, bromine, krypton, rubidium, strontium, yttrium, zirconium, and niobium (^{24}Cr to ^{41}Nb). Volume III includes the spectra of molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium, tin, antimony, tellurium, iodine, xenon, cesium, barium, lanthanum; hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold, mercury, thallium, lead, bismuth, polonium, radon, radium, and actinium (^{42}Mo to ^{57}La, ^{72}Hf to ^{89}Ac). This is a reprint of NBS Circular 467, Volume III.

NSRDS-NBS36. **Critical micelle concentrations of aqueous surfactant systems,** P. Mukerjee and K. J. Mysels, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 36, 227 pages (Feb. 1971).

Key words: Association colloid; bibliography; CMC; colloid; colloidal electrolyte; critical concentration; critical micelle concentration; detergent; hydrophobic bonding; Krafft point; long chain compounds; micelle; paraffin chain salts; selected values; soap; solubilization; standard values; surface active agents; surface chemistry; surface tension; surfactant.

Critical micelle concentrations (CMC's), have been collected, organized and evaluated. The literature has been scanned for numerical values from 1926 up to and including 1966. In addition, over 800 values, hitherto available only in graphical form or implied in experimental data, have been extracted from the publications and are included. Close to 5,000 entries, based on 333 references, dealing with 720 compounds are tabulated in the main tables. Whenever available, the temperature, any additives present, the method of determination and the literature source are given for each CMC value and an indication of the apparent quality of the preparation and method used are included. A shorter table gives selected values which are believed to be particularly reliable, including highly accurate ones. Among these, concordant values from at least two independent laboratories are emphasized.

Included in the Introduction is a general discussion of the importance and significance of CMC values and of methods for their determination, as well as a summary of the procedures used in the collection, evaluation and presentation of these values in the present work. Extensive indexes are provided.

NSRDS-NBS37. **JANAF thermochemical tables, second edition,** D. R. Stull and H. Prophet, Project Directors, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 37, 1141 pages (June 1971).

Key words: Evaluated data; thermal functions; thermodynamic properties of materials; thermodynamics.

This is the second edition of the JANAF Thermochemical Tables. It contains thermodynamic properties for some 1099 chemical species. The following properties are tabulated as functions of temperatures: C_p°, S°, $(F^\circ\text{-}H_{298}^\circ)/T$, $H^\circ\text{-}H_{298}^\circ$, ΔH_f° and Log Kp. Superseding PB168-370 and Addenda 1, 2, and 3.

NSRDS-NBS38. **Critical review of ultraviolet photoabsorption cross sections for molecules of astrophysical and aeronomic interest,** R. D. Hudson, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 38, 106 pages (Aug. 1971).

Key words: Aeronomic; astrophysical; partial; photoabsorption cross sections; photodissociation; photoexcitation; photoionization; photon-scattering; total; ultraviolet cross sections.

This paper is devoted to a critical review of photoabsorption cross sections for molecules of aeronomic and astrophysical interest at wavelengths less than 3000 A. A discussion of the relative merits of various experimental techniques is given along with possible systematic and random errors that may be associated with them. The problems in data analysis associated with finite spectral bandwidths are reviewed, with special emphasis on the interpretation of published absorption cross sections. This review does not contain a complete set of cross-section-versus-wavelength values for each molecule; the prepared figures are used to compare the results of several determinations or to point out where difficulties of interpretation might arise. However, references to all papers believed to contain the more reliable data are given.

NSRDS-NBS39. **Tables of molecular vibrational frequencies, consolidated Volume I,** T. Shimanouchi, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 39, 164 pages (June 1972).

Key words: Fundamental frequencies; infrared spectra; polyatomic molecules; Raman spectra; vibrational frequencies.

The compilations of fundamental vibrational frequencies of molecules previously published as NSRDS-NBS6, NSRDS-NBS11, and NSRDS-NBS17 have been revised and extended to 52 additional molecules. This consolidated volume includes data on a total of 223 molecules. Selected values of the fundamental vibrational frequencies are given for each molecule, together with observed infrared and Raman spectral data and citations to the original literature. The selection of vibrational fundamentals has been based on careful studies of the spectral data and comprehensive normal-coordinate analyses. An estimate of the accuracy of the selected values is included. The tables provide a convenient source of information for those who require vibrational energy levels and related properties in molecular spectroscopy, thermodynamics, analytical chemistry, and other fields of physics and chemistry.

NSRDS-NBS40. **A multiplet table of astrophysical interest, (Revised Edition), Part I—Table of multiplets and Part II—Finding list of all lines in the table of multiplets,** C. E. Moore, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 40, 253 pages (Feb. 1972).

Key words: Atomic spectra, multiplet table; finding list, atomic spectra; multiplet table; spectra, atomic.

Pending the completion of a current edition, the 1945 Multiplet Table is being reprinted here to meet continuing demands. The leading lines in 196 atomic spectra of 85 chemical elements are listed in related groups called multiplets. Estimated intensities, excitation potentials and multiplet designations are given for the individual lines, and each multiplet is assigned a number. An extensive bibliography covers the source material used for the compilation.

The Table is presented in two parts: Part I includes the multiplets, with the spectra of each element being given in order of increasing ionization, and the elements in order of increasing atomic number. Part II is a Finding List in which all the lines in Part I are entered in order of increasing wavelength, with their multiplet numbers.

The range of the Table is from 2951 Å to 13164 Å. A supplementary table of "Forbidden Lines" extends from 2972 Å to 12645 Å. Reprint of NBS Technical Note 36 (PB151395).

NSRDS-NBS41. **Crystal structure transformations in binary halides,** C. N. R. Rao and M. Natarajan, Nat. Stand Ref. Data Ser., Nat. Bur. Stand. (U.S.), 41, 53 pages (July 1972).

Key words: Binary halides; crystal structure transforma tion; electronic data; phase transformation; spectroscopi data; thermodynamic data; x-ray diffraction data.

A critical survey of the data describing crystal structure trans formations in binary halides is compiled. Data on thermodynam ic, crystallographic, spectroscopic and electronic properties ar given for each transformation. Experimental techniques used t obtain the data are named and comments on the data are ir cluded in the tables. The literature is surveyed up to 197(References have been selected on the basis of their pertinence t the data which are cited and do not represent all the availabl literature.

NSRDS-NBS42. **Selected specific rates of reactions of the so vated electron in alcohols,** E. Watson, Jr., and S. Roy, N Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 42, 22 pag (Aug. 1972).

Key words: Alcohols; chemical kinetics; data compilatio radiation chemistry; rates; solvated electron.

Solvated electrons are generated in alcohols by radiolysi photolysis, reaction with sodium, etc. Rates of reactions of e with solvent and solute molecules, ions, and transients, in a cohol solutions, have been compiled. Arrhenius parameters a tabulated for some reactions.

NSRDS-NBS43. **Selected specific rates of reactions of transients from water in aqueous solution. 1. Hydrated electron,** M. Anbar, M. Bambenek, and A. B. Ross, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 43, 67 pages (May 1973) 90 cents, SD Catalog No. C13.48:43.

Key words: Aqueous solution; chemical kinetics; data compilation; hydrated electron; radiation chemistry; rates.

Rates of reactions of hydrated electrons with over 700 different organic and inorganic molecules, ions, and transients have been tabulated. Most of the data are derived from pulse radiolysis of aqueous solutions; results from photolysis and from steady-state radiolysis by competition kinetics are also included.

NSRDS-NBS43. Supplement. **Selected specific rates of reactions of transients from water in aqueous solution. Hydrated electron, supplemental data.** A. B. Ross, Nat. Stand. Ref. Data. Ser., Nat. Bur. Stand. (U.S.), 43, Suppl., 43 pages (June 1975) SD Catalog No. C13.48:43, Suppl.

Key words: aqueous solution; chemical kinetics; data compilation; hydrated electron; radiation chemistry; rates.

A compilation of rates of reactions of hydrated electrons with other transients and with organic and inorganic solutes in aqueous solution appeared in NSRDS-NBS43, and covered the literature up to early 1971. This supplement includes additional rates which have been published through July 1973.

NSRDS-NBS45. **Radiation chemistry of nitrous oxide gas. Primary processes, elementary reactions, and yields,** G. R. A. Johnson, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 45, 27 pages (Dec. 1973) 60 cents, SD Catalog No. C13.48:45.

Key words: Chemical kinetics; data compilation; dosimetry; G; gas; nitrous oxide; radiation chemistry; rates; review.

Data on the radiation yields from nitrous oxide gas, and the effects of variables, including dose-rate, total dose, pressure, temperature, applied fields and scavengers are reviewed and tabulated. The use of N_2O as a gas-phase, chemical dosimeter is discussed. Primary processes in irradiated N_2O are discussed and elementary reactions, relevant to the system, are listed.

NSRDS-NBS46. **Reactivity of the hydroxyl radical in aqueous solutions,** L. M. Dorfman, G. E. Adams, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 46, 72 pages (June 1973) 90 cents, SD Catalog No. C13.48:46.

Key words: Abstraction reactions; addition reactions; aqueous solution; biological molecules; electron transfer reactions; hydroxyl radical; oxide radical ion; radical reactions; rate constants; reference data.

The reaction rate data of the hydroxyl radical in aqueous solution are compiled and evaluated in this critical review. The values are reported in a series of tables covering additon, hydrogen abstraction, inorganic electron transfer and radical reactions. Rate constants for the hydroxyl radical with biological molecules are included. In addition, the rate constant data for the oxide radical ion are given. Physical properties are listed and the experimental methods employed in OH radical chemistry are reviewed. An analysis involving rate constant data comparisons is made.

NSRDS-NBS47. **Tables of collision integrals and second virial coefficients for the (m,6,8) intermolecular potential function,** M. Klein, H. J. M. Hanley, F. J. Smith, and P. Holland, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 47, 157 pages (June 1974) SD Catalog No. C13.48:47.

Key words: collision integrals; diffusion; potential; thermal conductivity; thermal diffusion; transport properties; viscosity.

Tables of collision integrals and second virial coefficients are presented for the (m,6,8) potential function. Ten values of the repulsive exponent m are included which range in unit steps from $m=9$ through $m=18$. Approximately 6 values of the parameter, γ, associated with the inverse eighth power term, are included for each value of m. These tables are equivalent, therefore, to tables for 60 three-parameter (m,6) potential functions. Comparisons of our results for $m=12$ and $\gamma=0$ (corresponding to the (12,6) function) have been made with other calculations. Based on these comparisons, the accuracy of the present calculation appears to be at least two or three parts in 10,000 depending on the temperature. A table is included which contains the Boyle temperature, the Boyle volume, and the ratio of the intermolecular separation at the potential minimum to the separation at the zero of the potential.

NSRDS-NBS48. **Radiation chemistry of ethanol: A review of data on yields, reaction rate parameters, and spectral properties of transients,** G. R. Freeman, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 48, 43 pages (Feb. 1974) SD Catalog No. C13.48:48.

Key words: chemical kinetics; data compilation; ethanol; G; radiation chemistry; rates; review; spectra.

The yields (G) for products and intermediates formed by irradiation of ethanol, in the solid, liquid and gaseous state, have been compiled and reviewed. Rates of reactions of transient ions and radicals and spectroscopic parameters, including optical and esr spectra, are also included.

NSRDS-NBS49. **Transition metal oxides. Crystal chemistry, phase transition and related aspects,** C. N. R. Rao and G. V. Subba Rao, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 49, 138 pages (June 1974) SD Catalog No. C13.48:49.

Key words: critical data, transition metal oxides; crystal structure transformations; electronic properties; magnetic properties; phase equilibria; phase transitions.

A survey is made of the data describing the thermodynamics of phase equilibria, crystal chemistry and phase transformations of binary oxides of $3d$, $4d$, and $5d$ transition metals. Changes in electrical, magnetic, and other properties which accompany phase transitions are discussed. Nearly complete coverage of the literature is provided up to 1973.

NSRDS-NBS 50. **Resonances in electron impact on atoms and diatomic molecules,** G. J. Schulz, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 50, 118 pages (Oct. 1973) $1.35, SD Catalog No. C13.48:50.

Key words: Atoms; compound states; cross-sections; diatomic molecules; electron impact; energy levels; resonances; temporary negative ions.

Two reviews are presented on the energies, configuration and other properties of resonances in electron impact on atoms and diatomic molecules. Included are discussions of the experimental methods which are useful for studying resonances and of the results obtained by various investigations. Much of the information is presented in the form of tables and energy level diagrams.

NSRDS-NBS51. **Selected specific rates of reactions of transients from water in aqueous solution. II. hydrogen atom,** M. Anbar, Farhataziz, and A. B. Ross, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 51, 56 pages (May 1975) SD Catalog No. C13.48:51.

Key words: aqueous solution; chemical kinetics; data compilation; hydrogen atom; radiation chemistry; rates.

Rates of reactions of hydrogen atoms (from radiolysis of water and other sources) with organic and inorganic molecules, ions, and transients in aqueous solution have been tabulated. Directly measured rates obtained by kinetic spectroscopy or conductimetric methods, and relative rates determined by competition kinetics are included.

NSRDS-NBS52. **Electronic absorption and internal and external vibrational data of atomic and molecular ions doped in alkali halide crystals,** S. C. Jain, A. V. R. Warrier, and S. K. Agarwal, Nat. Stand. Ref. Data. Ser., Nat. Bur. Stand. (U.S.), 52, 59 pages (July 1974) SD Catalog No. C13.48:52.

Key words: atomic ions; doped alkali halide crystals; external vibrational modes; internal vibrational modes; molecular ions.

Spectral data for more than 70 atomic and molecular ions doped in alkali halide crystals are tabulated. The tables include electronic absorption data, listings of internal vibrational frequencies of doped complex ions, and tabulations of the frequencies of external modes. The data that appear in the tables were selected on the basis of the consistency among different authors, the types of instruments, and the temperature of measurement. In addition to the data, the tables include the spectroscopic assignments given by the authors in the references cited.

NSRDS-NBS53. **Crystal structure transformations in inorganic nitrites, nitrates, and carbonates,** C. N. R. Rao, B. Prakash, and M. Natarajan, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 53, 54 pages (May 1975) SD Catalog No. C13.48:53.

Key words: carbonates; crystal structure transformation; nitrates; nitrites; phase transformation; x-ray diffraction data.

A critical survey of the data describing crystal structure transformations in inorganic nitrites, nitrates, and carbonates is compiled. Data on crystallographic, thermodynamic, spectroscopic, electrical, dielectric, and other properties are given for each solid. Experimental techniques used to obtain the data are given and comments on the data are included in the tables. The literature is surveyed up to June 1973. References have been selected on the basis of their pertinence to the data cited.

NSRDS-NBS54. **The radiolysis of methanol: product yields, rate constants, and spectroscopic parameters of intermediates,** J. H. Baxendale and P. Wardman, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 54, 26 pages (Apr. 1975) SD Catalog No. C13.48:54.

Key words: chemical kinetics; data compilation; methanol; radiation chemistry; rates; review.

Product yields and primary yields in the radiolysis of methanol in the solid, liquid and vapor phase have been compiled and reviewed. Preferred values for G of the major products in the vapor and liquid states are listed. Rates of reactions of solvated and trapped electrons and other transient ions and radicals, and optical absorption and esr parameters for e_s^-, e_t^-, $\dot{C}H_2OH$ and $CH_3O\cdot$ are also included.

NSRDS-NBS55. **Property index to NSRDS data compilations, 1964-1972,** D. R. Lide, Jr., G. B. Sherwood, C. H. Douglass, Jr., and H. M. Weisman, Nat. Stand. Ref. Data. Ser., Nat. Bur. Stand. (U.S.), 55, 15 pages (June 1975) SD Catalog No. C13.48:55.

Key words: cumulative property index; data compilations; National Standard Reference Data System.

A property index to data contained in publications of the National Standard Reference Data System during the period 1964-1972 is presented. Data compilations published in the NSRDS-NBS series, other publication series of the National Bureau of Standards, scientific journals, and books of commercial publishers are included. When used with the cumulative property index published annually since 1972 in the *Journal of Physical and Chemical Reference Data*, this index serves as an entry to the complete output of the NSRDS program.

NSRDS-NBS56. **Crystal structure transformations in inorganic sulfates, phosphates, perchlorates, and chromates,** C. N. R. Rao and B. Prakash, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 56, 38 pages (Nov. 1975) SD Catalog No. C13.48:56.

Key words: chromates: crystal structure; crystal structure transformations; perchlorates; phase transformations; phosphates; sulfates; thermodynamic data; x-ray diffraction data.

Literature dealing with crystal structure transformations of simple inorganic sulfates, phosphates, perchlorates and chromates has been critically reviewed. Data on thermodynamic, crystallographic, spectroscopic, dielectric and other properties are given. Experimental techniques employed to obtain the data are indicated and comments on the data are made wherever necessary. All pertinent references to the published literature (up to 1974) are listed.

NSRDS-NBS57. **Yields of free ions formed in liquids by radiation,** A. O. Allen, *Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 57,* 25 pages (Apr. 1976) SD Catalog No. C13.48:57.

Key words: electrons; free ions; ion yields; liquid; nonpolar systems; radiation chemistry; radiation physics.

Free ions are those produced by ionizing radiation which escape initial recombination. Yields of free-ion pairs are tabulated for liquid alkanes, alkenes, alkynes, dienes and aromatic hydrocarbons, and other nonpolar and polar compounds, including alcohols, ethers, esters, halides, amines, nitriles, etc. Total ion yields for a few liquids are compared with gas phase ion yields. Theoretical treatments of these data are discussed.

NSRDS-NBS58. **Drift mobilities and conduction band energies of excess electrons in dielectric liquids,** A. O. Allen, *Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 58,* 23 pages (May 1976) SD Catalog No. C13.48:58.

Key words: conduction band; drift mobility; energy levels; excess electrons; hydrocarbons; ion mobility; liquids; mobility; quasifree electrons; solvated electrons.

The properties of electrons in liquids which are covered in this review include drift mobilities and the energy level (V_0) at the base of the conduction band. Tables are given of zero-field electron mobilities for several liquefied diatomic and inert gases, a number of aliphatic and aromatic hydrocarbons, and polar solvents. V_0 values are given for liquid helium and argon, a number of hydrocarbons, tetramethylsilane, and tetramethyltin. Theories attempting to explain these results are described in a qualitative way.

3.12. BUILDING SCIENCE SERIES

Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

BSS0. **Building research at the National Bureau of Standards,** P. R. Achenbach, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 0, 59 pages (Oct. 1970).

Key words: Building materials; building performance; building research; building systems; building technology; history.

The history of building research and technology at the National Bureau of Standards is as long as the history of the institution itself. The participation of the Bureau in the application of science and engineering to building materials and components played an early and important role in the development of steel and reinforced concrete as structural materials; in the understanding of physics and chemistry of cement, lime and gypsum; in the evaluation of the fire properties of building components; in safe plumbing practices; in laboratory evaluation of the effects of weather on deterioration of building materials; and in measurement of the heat and sound transmission properties of building materials and constructions. The central and continuing objectives of the building research program are shown to be the development of new technical information and new measurement methods for building materials, components, and systems, and the application of this knowledge to the specifications for Federal procurement, to the national standards of the building industry, and to the building code structure of the nation. The Bureau has served as a major technical resource in three large-scale national efforts to accelerate the construction of economical and effective buildings for housing and commercial purposes. One of these efforts is currently in progress and is characterized by an emphasis on the design of buildings to meet the performance requirements of the user rather than through the specification of the properties of the materials used.

BSS1. **Performance of buildings—concept and measurement.** Proceedings of the 1st conference in a series of Conferences on Man and His Shelter held at the National Bureau of Standards, Gaithersburg, Md., September 23-25, 1968. W. W. Walton and B. C. Cadoff, Editors, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 1, 132 pages (Jan. 1970).

Key words: Building systems; performance of buildings; standards; test methods; urban planning; user needs.

The Conference entitled "Performance of Buildings—Concept and Measurement" was held at the National Bureau of Standards, Gaithersburg, Md. on September 23-25, 1968. This was the first in a planned series of conferences on "Man and His Shelter." The purpose of these conferences is to bring together those people from various disciplines who may contribute to improving the quality of man's shelter. At the present conference, papers were presented by nineteen authors representing govern-

BSS7. **Organic coatings. Properties, selection, and use,** A. G. Roberts, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 7, 202 pages (Feb. 1968).

Key words: Application; coatings; coating systems; corrosion-inhibiting; Federal specifications; fire-retardant; lacquer; latex; multicolor; organic coatings; paint; pigments; polymers; properties; resins; selection; substrates; surface preparation; varnish; water-thinned.

This publication was prepared to fill the need for a comprehensive, unifying treatise in the field of organic coatings. Besides presenting practical information on the properties, selection, and use of organic coatings (and certain inorganic coatings), it provides basic principles in a number of important areas such as polymer structure, coatings formulation, pigment function, use of thinners, coating system compatibility, and theory of corrosion. Each chapter deals with a major area of the coatings field, including types of coatings, properties of synthetic resins, selection of coating systems, storage and safety, application methods, and surface preparation and pretreatment. There is also a consolidating chapter with illustrative examples of solutions to typical coatings problems. Interrelationships among the various areas of information are indicated through appropriate cross-referencing in the text. Specific references to Federal, Military, and other specifications are given where pertinent, and an entire chapter is devoted to a quick guide and summary of Federal specifications for organic coating materials. Finally, a selected bibliography and a comprehensive index are provided. While written primarily to meet the informational needs of the engineer, architect, maintenance superintendent, and responsible coatings procurement officer, the treatise is sufficiently broad in scope to serve as a general manual, a concise text, or a convenient reference source in the field of organic coatings.

BSS8. **Interrelations between cement and concrete properties, Part 3. Compressive strengths of portland cement test mortars and steam-cured mortars,** (Contains section 7 and section 8.) R. L. Blaine, H. T. Arni, and M. R. DeFore, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 8, Part 3, 101 pages (Apr. 1968).

Section 7. **Compressive strength of test mortars.**

Key words: Chemical composition; fineness; heat of hydration; strength gain of portland cements; trace elements.

The relationships between cement characteristics and compressive strength of 1:2.75 (cement to graded Ottawa sand) mortars of standard consistency at ages of 24 hours to 10 years, and made with 199 cements of different types, were studied by fitting multivariable regression equations with the aid of a digital computer. The dominant variables associated with the differences of compressive strength, strength gain, and strength ratios were different at the various test ages, and after different curing conditions. The additional use of certain trace elements with commonly determined independent variables resulted in a significantly better fit between the equations and the observed data. Interactions between the fineness values and other independent variables were noted. Certain parallelisms and differences were noted with respect to variables associated with compressive strength differences at various ages and the heat of hydration of the cements at these ages.

Section 8. **Compressive strength of steam-cured portland cement mortars.**

Key words: Accelerated curing of cements; autoclave curing of portland cement mortars; chemical composition; compressive strength of portland cement; compressive strength of steam-cured cements; mortars; steam curing of portland cement mortars; trace elements.

The relationships between the chemical and physical characteristics of 161 portland cements and the compressive strengths of 2-inch mortar cubes made from those cements after both low- and high-pressure steam, as well as moist-air curing, were studied by computing multivariable regression equations with the aid of a digital computer, and determining which of the independent variables appeared to have a significant relationship to the compressive-strength values. An increase in C_3A, SO_3, and K_2O each appeared associated with higher compressive strengths with the low-pressure-steam-cured specimens but not with 28-day strengths of the 23 °C moist-air-cured specimens. Increases of C_3A, C_3S, C_2S, SO_3 and fineness were all associated with

higher strength values when autoclave curing was started after 5 hours, but when started after 24 hours, variations of neither C_3A nor C_3S appear to have any effect. The use of certain of the trace elements in the equations together with commonly determined variables resulted in a reduction in variance although the coefficients of the individual trace elements were, in most instances, not highly significant.

BSS9. **Thermal-shock resistance for built-up membranes,** W. C. Cullen and T. H. Boone, NBS Bldg. Sci. Series 9 (Aug. 21, 1967).

Section 1. Progress in the development of a thermal-shock resistance factor for bituminous built-up roofing membranes.

Key words: Development; roofing membrane; strength properties; thermally induced forces; thermal-shock resistance factor.

The resistance of bituminous built-up roofing membranes to thermally induced forces is considered in terms of their strength properties such as breaking load in tension, modulus of elongation and apparent linear thermal expansion coefficient. The development of a Thermal-Shock Resistance Factor is described and values are given for three bituminous built-up membranes at temperatures of -30 °F (-34.4 °C), 0 °F (-17.8 °C), 30 °F (-1.1 °C) and 73 °F (22.8 °C). The apparent relation between the values obtained in the laboratory and the observed performance of roofing membranes in service is considered. The utilization of the Thermal-Shock Resistance Factor in the reduction of potential failures of bituminous built-up roofing membranes in service from thermally induced forces is also discussed.

Section 2. Thermal-shock resistance for bituminous built-up roofing membranes--Its relation to service life.

Key words: Bituminous-built-up roofing; roofing membrane; service life; thermal-shock resistance factor; tension splitting.

The assignment of a service life to a bituminous built-up roofing system is frequently difficult because of the many variables involved. A knowledge of these variables, and of their effect on the performance of the total building system, will greatly assist in the selection of a roofing assembly and the assignment of a service life to such an assembly.

Some of the factors such as breaking load in tension, modulus of elongation, and apparent linear thermal expansion coefficient of roofing membranes of different composition are given for both laboratory-prepared and field-obtained samples. Membranes of 2, 3, and 4-plies of felt are included. The relations of some engineering properties of a roofing membrane to performance in sevice as expressed by a Thermal-Shock Resistance Factor are also given. Ways and means to reduce potential failures of bituminous built-up roofing membranes resulting from thermally induced forces are discussed.

BSS10. **Field burnout tests of apartment dwelling units,** D. Gross, NBS Bldg. Sci. Series 10 (Sept. 29, 1967).

Key words: Apartment dwelling; burnout test; fire load; fire performance; flame penetration; potential heat; structural load.

Results are reported of three burnout tests in an experimental test building, using a wood crib fuel load of 6 lb/ft², representing combustible contents, and a structural design load of 40 lb/ft² applied to the floor or roof above the test room. Measurements were made of temperature, radiation, smoke, gas composition, and structural deflection. A discussion of the fire performance of materials and methods of construction, and conclusions with regard to specific fireprotective objectives are presented.

BSS11. **Fire resistance of steel deck floor assemblies,** H. Shoub and S. H. Ingberg, NBS Bldg. Sci. Series 12 (Dec. 1967).

Key words: Burnout tests; fire endurance; fire severity; floor tests; steel plate floors.

Tests were conducted to determine the resistance to fire of welded steel plate and beam floor assemblies with various conditions of floor covering on the plates, and ceiling protections beneath the beams. The trials included fire exposures from the burnout of combustible materials ranging from 10 to 40 lb/ft² on the floor surface as well as standard fire endurance tests in which the ceiling of the structure was exposed to fire.

The results of the tests indicated that the use of steel floor structures was practical from considerations of fire safety. For the test conditions established, fire exposure on top of the floor did not heat the structural steel supporting members sufficiently to cause load failure or collapse, and did not produce untenable conditions in the room below. In tests involving fire exposure to the underside of floors, the fire endurance times, based solely on heat transmission criteria, ranged from 1 hr 24 min to over 4 hr. Temperature levels attained by the structural members and deflection of the floor assemblies are also reported.

BSS12. **Performance of square-edged orifices and orifice-target combinations as air mixers,** T. K. Faison, Jr., J. C. Davis, and P. R. Achenbach, NBS Bldg. Sci. Series 12 (Nov. 24, 1967).

Key words: Diameter ratio; mixing effectiveness; square-edged orifice; temperature measurement; temperature pattern.

A study was made at the National Bureau of Standards to determine the effectiveness of the square-edged orifice, or the orifice in combination with a target (circular baffle), for mixing an air stream which was initially nonuniform with respect to temperature. By achieving uniformity of temperature at all points within the cross section of an air stream, instrumentation for measurement might be simplified and a more representative temperature value obtained. Orifices having throat diameters of 8, 12, and 16 in were evaluated in a 24-in circular test duct to determine mixing effectiveness under selected test conditions of temperature distribution and flow rate. Targets of 8, 12, and 16 in in diameter in combination with a 12-in orifice were also investigated under similar conditions.

Graphic material is presented which illustrates how the orifice and orifice-target combinations perform as mixing devices under selected conditions. Results indicate that the 8-in (0.33 diam ratio) orifice effectively diminished the nonuniformity of temperature but only at a high pressure drop across the orifice and that a distance of 4.5 duct diameters was required for mixing.

BSS13. **Shrinkage and creep in prestressed concrete,** P. H. Petersen and D. Watstein, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 13 (Mar. 22, 1968).

Key words: Creep; loss of prestress; prestressed concrete; relaxation; shrinkage; variable prestress.

The loss of prestress resulting from creep and shrinkage in concrete was investigated for concrete specimens made with Type I portland cement and with Type III portland cement. The primary variables in this study were: (1) Relative humidity at which the concrete was maintained while under observation. (2) Age of the concrete at the time it was prestressed. (3) Ratio of prestress to strength; variation of this parameter required that the ratio of reinforcement be a variable. (4) Mass ratio factor defined as the ratio of the cross-section area of concrete specimen to its surface area per unit length.

Forty-nine sets of specimens were fabricated and tested; each et consisted of a prestressed specimen and an otherwise identi- al companion specimen without reinforcement.

The length changes with time were observed at intervals up to n age of 500 days. These observations were made for concretes ubjected to different levels of prestress, and for concretes restressed at different ages. Length changes in nonreinforced ompanion specimens were also obtained. Thus this study is oncerned with elastic deformation occurring at time of stress ransfer, shrinkage or swelling, and creep.

SS14. **Experimental determination of eccentricity of floor loads applied to a bearing wall,** D. Watstein and P. V. Johnson, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 14 (June 1968).

Key words: Bearing pads; bearing walls; brick masonry; design of bearing walls; eccentricity of applied loads.

The eccentricity of the loads applied to a specially calibrated ompressive strut simulating a brick bearing wall was experi- entally determined for a variety of bearing materials and condi- ons of contact. In one series of tests, an I-beam was bedded in gh strength gypsum plaster, bonded and unbonded. For the un- onded plaster bed the eccentricity ratio increased with the ap- lied load to a maximum value of about 0.42, while for the onded plaster bearing this ratio decreased to an average value f about 0.24 at the maximum load.

In the second series of tests the eccentricity was observed for n I-beam supported on neoprene rubber pads, capped and un- apped, of different thicknesses, and of different bearing length. n general the eccentricity ratio increased slightly with the ap- lied load. Lack of intimate contact between the I-beam and the ubber pad 1/8 in thick resulted in an eccentricity ratio of about .40, or nearly the same as for unbonded plaster bearing. Intima- y of contact produced by plaster capping resulted in a marked eduction in the eccentricity ratio to about 0.29; the confinement f the bearing length of the rubber pad to one-half of that used in revious tests and placing it at the extreme end of the beam, rther reduced the eccentricity ratio to about 0.18, and to 0.13 r a rubber pad 0.25 in thick.

SS15. **Interrelations between cement and concrete properties, Part 4. Shrinkage of neat portland cement pastes and concretes,** (Contains section 9 and section 10.) R. L. Blaine, H. T. Arni, and D. N. Evans, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 15, Part 4, 79 pages (Mar. 1969).

ection 9. **Shrinkage of hardened portland cement pastes,** R. L. Blaine, H. T. Arni, and D. N. Evans.

Key words: Chemical composition of portland cements; cracking of portland cements; cracking resistance of cements; portland cement; shrinkage of portland cements; trace elements.

The relationship between cement properties and drying hrinkage of partially hydrated neat cement pastes of normal onsistency made of a large number of portland cements of dif- erent types and composition were studied by fitting multivaria- le regression equations with the aid of a digital computer. The me of cracking of annular specimens restrained from shrinking y a steel core varied from 0.1 to more than 40 hours. The prin- ipal variables which appeared to have the greatest effect were he fineness and K_2O and C_4AF contents of the cements. The ineness and K_2O contents of the cements appeared to have the reatest effect on the nonrestrained shrinkage of prisms at the me of cracking of the annular specimens. The shrinkage of neat ement bars after 1, 6, 27 days, and 6 months in laboratory air iffered greatly with different cements. The principal variables ppeared to be the C_3A, SO_3, and C_3A/SO_3 ratios. Other com- only determined variables were associated with each of the above test values. The trace elements, other than Na_2O and K_2O, were not generally associated with the shrinkage or cracking characteristics.

Section 10. **Shrinkage and expansion of concrete,** R. L. Blaine and H. T. Arni.

Key words: Cement composition; expansion-shrinkage ratios; portland cement concrete; shrinkage of concrete; trace elements.

The relationship between the cement characteristics and the drying shrinkages of concretes made of a large number of cements of different types and compositions, as well as the subsequent expansions when the concretes were rewetted, were studied by fitting multivariable regression equations with the aid of a digital computer. Specimens $6 \times 8 \times 16$ inches, were made using 5.5 bags of cement (nominal) per cubic yard with a water/cement ratio of 0.635, as well as with a slump of 5 ± 1 inches. Increases in C_3A, C_4AF, fineness of the cement, and air content of the concrete were associated with increases in both shrinkage on drying and expansion on rewetting of the concretes. Increases in Na_2O, SO_3, and ignition loss of the cements were associated with decreases in the shrinkage values of the concretes. None of the individual trace elements, except possibly Rb and SrO, were associated to a highly significant degree with shrinkage or expansion characteristics of the concretes. The use of trace elements in equations with other more commonly determined variables resulted in a significant reduction in variance. There was no relationship between the shrinkage of concrete specimens moist cured 14 days and then dried in laboratory air for eight weeks, and the shrinkage of neat cements, moist cured only 24 hours and then dried in laboratory air. Higher values for dynamic Young's modulus of elasticity of the concretes were associated with lower shrinkage and expansion values.

BSS16. **Techniques for the survey and evaluation of live floor loads and fire loads in modern office buildings,** J. O. Bryson and D. Gross, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 16, 32 pages (Dec. 1968).

Key words: Fire loads; live floor loads; loads survey techniques; occupancy loads.

The procedures and techniques developed for measuring and evaluating the live floor loads and fire loads in modern office buildings are summarized. The main features of a computer program for analyzing the data are outlined. This program provides a tabulation of the data, some statistical properties, and selected graphical relationships between the measured loads and the characteristics and usage of the structure. A rationale is developed which is intended to achieve the ultimate goal—easier and less expensive means of surveying live loads in buildings and their combustible content.

Two office buildings have been surveyed in a pilot evaluation of the survey techniques—the National Bureau of Standards Administration Building in Gaithersburg, Maryland, and the U. S. Civil Service Commission in downtown Washington, D.C. Typical results are presented to illustrate the computer output.

BSS17. **Causes of variation in chemical analyses and physical tests of portland cement,** B. L. Bean and J. R. Dise, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 17, 34 pages (Mar. 1969).

Key words: Chemical analyses; physical tests; portland cement.

Variations in testing that could lead to the rejection of a material fully conforming to specification requirements, or the acceptance of a material with undesirable chemical or physical properties, are apparent in the results reported by laboratories participating in comparative tests of portland cements. Many of the causes for variation in chemical analyses and physical test results are listed in this discussion, and remedies for some of the

more frequently encountered deficiencies in apparatus and methods are suggested. Particular consideration is given to problems which do not seem to have been covered in sufficient detail in previous discussions of cement testing procedures. Literature references are given for additional information. (Supersedes NBS Monograph 28.)

BSS18. **Smoke and gases produced by burning aircraft interior materials,** D. Gross, J. J. Loftus, T. G. Lee, and V. E. Gray, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 18, 29 pages (Feb. 1969).

Key words: Aircraft materials; combustion products; fire tests; interior finish; smoke; toxic gases.

Measurements are reported of the smoke produced during both flaming and smoldering exposures on 141 aircraft interior materials. Smoke is reported in terms of specific optical density, a dimensionless attenuation coefficent which defines the photometric obscuration produced by a quantity of smoke accumulated from a specimen of given thickness and unit surface area within a chamber of unit volume. A very wide range in the maximum specific optical density was observed. For the majority of materials, more smoke was produced during the flaming exposure test. However, certain materials produced significantly more smoke in the absence of open flaming.

During the smoke chamber tests, indications of the maximum concentrations of CO, HCl, HCN, and other selected potentially toxic combustion products were obtained using commercial colorimetric detector tubes. A study was made of the operation, accuracy, and limitations of the detector tubes used. Measurements of the concentrations of HCl were also made using specific ion electrode techniques.

Qualitative identification of the major components of the original test materials was accomplished primarily by infrared absorption spectrophotometry.

BSS19. **A study of the variables involved in the saturating of roofing felts,** S. H. Greenfeld, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 19, 18 pages (June 1969).

Key words: Absorption; asphalts; felts; moisture; roofing; saturation.

The degree of saturation of a No. 27 felt with a typical roll saturant and a No. 55 felt with roll, mixed, and shingle saturants varied with saturation time and pressure, saturant temperature and viscosity, felt conditions, and press roll pressure and clearance. Optimum temperature and viscosity ranges were determined for each asphalt-felt combination. Both pressure and vacuum increased the completeness of saturation under optimum conditions, but frequently shortened the working temperature range in which optimum saturation could be produced.

Rate and degree of moisture and liquid water absorption decreased with increasing saturation. Air permeability decreased with increasing saturation. The consequences of some of these findings are discussed.

BSS20. **Durability of insulating glass.** Proceedings of a seminar held at the National Bureau of Standards, Gaithersburg, Md., November 14-15, 1968, H. E. Robinson, Editor, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 20, 84 pages (Feb. 1970).

Key words: Accelerated laboratory tests; double-glazed window units; factory-sealed insulating glass units; field performance tests, correlation with laboratory tests; sealant performance; standardized testing; test methods.

A two-day seminar on the Durability of Insulating Glass was attended by some 130 persons on November 14 and 15, 1968. The seminar was held at the Gaithersburg, Maryland, facilities of the National Bureau of Standards and featured fourteen speakers who participated in panel discussions or delivered individual papers. Numerous agencies interested in design, manufacture, specification, purchase, installation or maintenance of windows were represented at the seminar.

Among the topics considered in the panel discussions were: (1) The need for reliability and durability of insulating glass; (2) manufacturers' test methods; (3) proposals for future action. The Canadian experience with an accelerated test method and acceptance program was presented and discussed, as were the Norwegian accelerated test methods and their correlation with field experience. A review of current practices leading to new test methods and standards was also presented, and a "round robin" program that would compare various test methods now employed in the industry was proposed. Affirmative interest in participating in the proposed round robin was expressed by about a score of manufacturers present at the seminar. *These proceedings include the following papers (indented):*

BSS21. **Algorithms for psychrometric calculations (skeleton tables for the thermodynamic properties of moist air),** T. Kusuda, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 21, 53 pages (Jan. 1970).

Key words: Computer algorithm; psychrometrics; saturated and unsaturated moist air; thermodynamic properties.

Computer algorithms to obtain thermodynamic properties of saturated and unsaturated moist air are presented in this paper. The saturated moist air properties are calculated by the methodology developed by J. A. Goff and S. Gratch for their ASHRAE tables (1967 Book of Fundamentals, The American Society of Heating, Refrigerating and Air Conditioning Engineers). Sample calculations were performed using a computer program based upon the algorithms presented herein and the results are attached.

BSS22. **Investigation of performance characteristics for sanitary plumbing fixtures,** P. R. Achenbach, Project Director Coordinator, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 22, 72 pages (Jan. 1970).

Key Words: Abrasion resistance; chemical resistance; cigarette-burn resistance; cleanability and soilability; concentrated static-load capacity; performance characteristics; performance level; sanitary plumbing fixtures; scratch resistance; stain resistance; surface-impact resistance; test methods.

This report gives findings and recommendations developed during an investigation of performance characteristics for sanitary plumbing fixtures, conducted at the request of the Building Research Advisory Board of the National Academy of Sciences—National Research Council. The report describes the test methods that are recommended for the evaluation of 16 performance characteristics, and the nature of further work required to complete the development of four or five additional test procedures.

The suitability of various existing test methods for evaluating the functional and performance characteristics of sanitary plumbing fixtures was investigated in the laboratory. In addition, new or modified tests for certain characteristics were developed. The laboratory work was performed only on bathtubs and flat specimens provided by industry through appropriate arrangements with the Building Research Advisory Board. Field inspection trips were made to provide the NBS project staff with up-to-date information on certain manufacturing processes and on installation and use problems. The complexities involved in the selection of valid performance levels are discussed, as well as the elements of judgment involved. A format that might be used in specifying performance is suggested for each test procedure, and the rationale underlying each suggested format is given.

SS23. **Hail resistance of roofing products,** S. H. Greenfeld, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 23, 11 pages (Aug. 1969).

Key words: Asphalt shingles; built-up roofing; hail; roofing; shingles; storm damage.

A test was developed for evaluating the hail resistance of ofings, in which synthetic hailstones (ice spheres) of various zes were shot at roof assemblies at their free-fall terminal locities. Indentations, granule loss and roofing fracture were bserved. The following conclusions have been made from these sults: (a) All roofing materials have some resistance to hail mage, but as the size of the hail increases, a level of impact ergy is reached at which damage occurs. This level lies in the nge of 1 1/2 to 2 inch (3.8–5.1 cm) hailstones for most epared roofings. (b) Because of the ways in which prepared ofings are applied, most products have areas of different vulrability. (c) The solidly supported areas of roofing tend to be e most resistant to hail damage. (d) Heavier shingles tend to be ore hail-resistant than Type 235 shingles. (e) Weathering tends lower the hail resistance of asphalt shingles. (f) Built-up roofs dense substrates tend to resist hail better than those on soft bstrates. (g) Built-up roofs made with inorganic felts tend to be ore hail resistant than those made with organic felts. (h) Coarse gregrate surfacing tends to increase the hail resistance of roofg.

SS24. **Natural weathering of mineral stabilized asphalt coatings on organic felt,** S. H. Greenfeld, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 24, 17 pages (Oct. 1969).

Key words: Additive; asphalt; durability; felt; stabilizer; weathering.

Sixteen years of outdoor weathering of laboratory-prepared nooth-surface and mineral-surfaced, felt-base roofing ecimens has provided information on the effects of mineral adives on the durability of coating-grade roofing asphalts. Six ely divided mineral additives (blue black slate, clay, dolomite, ash, mica and silica) were evaluated at concentrations up to percent in California, Mid-Continent and Venezuela asphalts. e mineral-surfaced specimens are all performing satisfactorily, d show only minor degrees of degradation. Of the smooth-surced specimens, the Mid-Continent asphalt performed the best d the California asphalt the poorest. The mica and blue black te increased the durabilities of all three asphalts at all concenations and two coating thicknesses. Fly ash, clay, dolomite and ica were beneficial in some combinations, but had little effect others. In general, these early results from outdoor exposure d to corroborate the results obtained on these coatings exsed in weatherometers.

SS25. **Structural performance evaluation of a building system,** E. O. Pfrang and F. Y. Yokel, Nat. Bur. Stand. (U.S.), Bldg. Sci. Series 25, 127 pages (Nov. 1969).

Key words: Building systems; low-income housing; performance criteria; performance testing.

A full-scale, first-story portion of a building system was tested the laboratory in such a manner as to simulate the structural havior of a three-story building under both service and potenl ultimate loading conditions. Additional tests were performed the system components to provide behavioral data needed for e evaluation of the system.

Performance criteria for the evaluation of the structural safety d adequacy of certain building systems were developed. This port presents the results of the physical tests performed in the aluation of the safety and structural adequacy of one such stem, and discusses their significance. The report also presents ta concerning the complex interaction between components hich takes place in the building system.

The primary conclusions reached were: (1) The system, as erected in the laboratory, satisfied the performance criteria which were set for its evaluation with a substantial margin. As a system, it exhibited strength and stiffness in excess of service and ultimate load requirements. (2) The walls of the system behaved as an integral part of the structure. They provided most of the stiffness of the system with respect to lateral loads, and provided a significant portion of the stiffness against vertical loads.

BSS26. **Radiation errors in air ducts under nonisothermal conditions using thermocouples, thermistors, and a resistance thermometer,** J. C. Davis, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 26, 14 pages (Nov. 1969).

Key words: Conduction error; radiation error; resistance thermometer; temperature measurement; thermistor; thermocouple.

Studies were made to determine the radiation error in temperature measurements made with thermocouples, thermistors, and a resistance thermometer in moving air at velocities ranging from 300 to 1300 fpm when the temperature of the duct wall surrounding the air stream was from 0 to 50 °F higher than that of the air in the center of the duct. To eliminate all but the variable under study, conduction errors were minimized to a point where they were almost nonexistent by using Chromel P-constantan thermocouple wire and by employing other techniques. Radiation effects were studied when the probe housing the three types of temperature sensors was unshielded and again when it was shielded. The studies showed that when the sensors were unshielded and the temperature difference between the duct wall and the air was 50 °F (28 K, approximately), the error in the sensors was about 3.8 °F (2.1 K) for an air velocity of 300 fpm (1.5 m/s) and 1.0 °F (0.6 K) for an air velocity of 1300 fpm (6.6 m/s). When the sensors were shielded, the error was about 0.2 °F (0.1 K) for 300 and 500 fpm velocities and the same duct wall air-temperature difference. Tests were not performed at 1300 fpm with the sensors shielded because theory indicated that radiation error would be negligible at this velocity. Under the test conditions that prevail in the testing of air conditioners and heat pumps in laboratories, it should be possible to reduce the error in temperature measurement of the moving air to about 0.2 °F (0.1 K) by a suitable combination of air mixers, duct insulation, radiation shields, and calibration techniques.

BSS27. **Performance of louvered devices as air mixers,** T. K. Faison, Jr., J. C. Davis, and P. R. Achenbach, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 27, 22 pages (Mar. 1970).

Key words: Effectiveness; forced mixing; mixing device; pressure drop; temperature; uniformity.

As part of a study of evaluating methods for reducing thermal gradients within the cross section of an air stream, three louvered mixing devices were investigated. Each of these devices was found to be capable of reducing the cross-sectional nonuniformity of air temperature to a few percent of the entering value. The three devices covered in this report contain combinations of louvers (directing vanes) and baffles as mixing elements. Two of the devices were designed at the National Bureau of Standards; the third was a modification of a previous design. The three mixers (the louvered strip, the concentric louvers, and the louvered-baffle) required 4.75, 3.8, and 3.0 duct diameters, respectively, to reach a mixing effectiveness level of 97 percent. The mixing effectiveness of the louvered strip and concentric louver models was independent of the approach velocity, whereas the effectiveness of the louver-baffle model was somewhat dependent on the approach velocity. The pressure drops accompanying air flow through the mixers, expressed as multiples of the velocity head of the entering air, were approximately 7, 5, and 38 for the lou-

vered strip, concentric louver, and louver-baffle mixers, respectively.

BSS28. **Exploratory studies of early strength development in portland cement pastes and mortars,** R. L. Blaine and L. A. Tomes, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 28, 14 pages (July 1970).

Key words: Cement; cement mortar; cement paste; early strength; false set; hardening of cement; hydration; shear resistance; theory of cement hardening; time of set; vane-shear apparatus.

A modified vane-shear apparatus was used to measure the shear resistance of neat cement pastes of normal consistency and 1:2.75 (cement to sand) mortars of standard consistency, and to measure the increase in shear resistance with time as the cements hardened. The hardening process appeared to occur in three stages. The rate of increase of shear resistance as well as the duration of the different phases differed with the different cements. The results were analyzed in terms of the various theories proposed to explain the hardening of cements.

BSS29. **1964 exposure test of porcelain enamels on aluminum—three year inspection,** M. A. Baker, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 29, 13 pages (April 1970).

Key words: Color; gloss; porcelain enamel on aluminum; weather resistance.

An exposure test of porcelain enamels on aluminum was initiated by the National Bureau of Standards and the Porcelain Enamel Institute in 1964. The enamels were returned from the exposure sites to the laboratory at NBS to be measured for changes in gloss and color after exposures of six months, one year, and three years. Changes were found to be greatest at Kure Beach and least at Montreal and Los Angeles, with moderate changes occurring at Washington and New York.

Although the boiling citric acid test is used as an acceptance test for these enamels, the correlation with color change, particularly at Kure Beach, was not as good as expected. A cupric chloride test was developed which shows an improvement in this correlation.

BSS30. Wind loads on buildings and structures. Proceedings of a Technical Meeting held at the National Bureau of Standards, Gaithersburg, Maryland, January 27-28, 1969, R. D. Marshall, Editor, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 30, 169 pages (Nov. 1970).

Key words: Aerodynamic forces; atmospheric boundary layer; structural design; turbulence; wind effects; wind loads.

A technical meeting concerning wind loads on buildings and structures was held at the Gaithersburg Facility of the National Bureau of Standards on January 27 and 28, 1969. The meeting, jointly sponsored by the Building Research Division of the National Bureau of Standards and the Environmental Data Service of the Environmental Science Services Administration, was intended to promote the exchange of information between research workers and practicing engineers engaged in this important area of technology.

Thirteen papers covering four themes were presented. These themes were as follows: engineering problems in the design of structures to resist wind loads; atmospheric considerations; experimental and theoretical determination of aerodynamic forces; and recent advances in design procedures and current deficiencies. Presentations were followed by a panel discussion which included a summary of each theme. The last session of the meeting was devoted to open discussion.

Design and construction for what wind loads and why, L. C. Maugh, *BSS30,* pp. 5-8 (Nov. 1970).

Key words: Buildings; design criteria; dynamics; gust factors; smoke stacks; structural failure; wind loads.

This paper is primarily concerned with the design of various structures for wind forces from the viewpoint of the average structural engineer. The subject matter focuses attention upon three important types of structural problems whose solutions are still so uncertain as to require considerably more study and research. These problems are:

1. Wind action upon structural frameworks during construction with emphasis upon the relatively large number of partial or complete failures.

2. The behavior of completed structures of relatively high frequencies when subjected to wind loads. An important factor here is the amount and characteristics of motion in high-rise buildings that will be accepted by the occupants.

3. Some dynamic problems associated with wind forces acting upon structures of low frequencies such as tall chimneys and guyed towers.

The above problems are discussed from the need fo better design criteria and specifications as well as mor exact mathematical analysis and more refined wind mea surements. The importance of the latter factor is recognize but the many empirical factors in structural design are als considered in this paper.

Design wind loads for building wall elements, W. F. Koppes *BSS30,* pp. 9-18 (Nov. 1970).

Key words: Buildings; fluctuating pressure; gust factors walls; wind damage; wind loads.

It is principally the structural engineer who has been con cerned with wind forces acting on buildings, because it is hi responsibility to design the structure to resist their overa effect. Recently, however, the importance of localized win loads acting on the surfaces of buildings has also bee receiving much attention. These local loads affect wa design, and are a matter of concern to both the architect an the manufacturer of wall parts.

The important differences between overall and local win loads include magnitude of intensity, character, period c duration, significance in relation to building size and shape and importance in respect to potential property loss Complete destruction of buildings by wind action is rare, bu local failures are not uncommon and, on the whole, are mor costly.

Because gust and shape factors are highly unpredictable increasing reliance is being placed on wind tunnel tests an measurements on actual buildings. Both confirm that nega tive pressures usually exceed positive pressures on parts o wall areas. Few building codes in this country recogniz this, in specifying design wind loads for walls, though code in some other countries do. The importance of terrain cond tions is not reflected, either, in code provisions.

Failures of windows and other wall elements due to win loads occur rather frequently, but relatively few of them ar documented. Several interesting examples of such failure can, however, be cited.

Another important aspect of local wind effects is the fur neling often experienced near the base of tall buildings Notable examples of this phenomenon have been observed and research studies directed at their causes have produce significant findings.

Codes and standards cannot be expected to provide guidance for designers in respect to unique local wind effects, but they should provide information as to loads which wall surfaces of typical buildings will likely experience. The only standard currently providing this kind of data is the Tentative Standard for Design Wind Loads on Walls of Rectangular Buildings, published by the National Association of Architectural Metal Manufacturers. The background, purpose and features of this Standard are noteworthy, and it is serving a useful purpose.

A review of current investigations of local wind loads, both by wind tunnel tests and field measurements, indicates that certain common assumptions regarding their intensity and distribution on building surfaces should be reexamined. Further information regarding the nature of these loads is urgently needed by, and should be more promptly disseminated to, the designers and producers of building wall systems.

Guidelines in selecting wind measuring instruments and their ocations for wind loading studies, G. C. Gill, *BSS30,* p. 21 Nov. 1970).

Key words: Anemometers; instrumentation; tower interference; transducers; wind vanes; wind loads.

The different types of wind speed sensors (cup, propeller, pressure tube, pressure sphere, hot wire, and sonic) will be discussed in relation to their suitability for wind loading studies. For very sound reasons the rotational types of anemometers (cup and propeller) have become the standard wind speed sensors used in North America today. Pressure type wind speed sensors will be considered but they have inherent weaknesses as anemometers. In view of the versatility of the rotational anemometers and in view of all weather records and charts being based on observations with these instruments it appears advisable for wind loading studies to measure wind speed with these conventional anemometers.

Wind vanes of different types (flat plate, splayed vane, and aerodynamic cross section) will be discussed and the transducers to be used with them. Very light vanes of the flat plate type are recommended.

The dynamic response and fidelity of recording of both anemometers and wind vanes will be discussed.

The wind-shadow effect of towers on the wind sensors mounted thereon, and the orientation of the sensors will be discussed. For good exposure the sensors should be mounted one to two tower widths out from the tower, and, either into the prevailing wind, or, into the wind direction of maximum concern. The height and location of towers relative to the building or structure under study will be discussed.

The adequacy of existing meteorological data for evaluating ructural problems, I. A. Singer and M. E. Smith, *BSS30,* pp. 3-25 (Nov. 1970).

Key words: Climatology; meteorology; spatial correlation; turbulence; wind observations; wind profiles.

Available meteorological data are usually unsuitable for application to structural problems for a variety of reasons. The most obvious deficiency involves instrument location in the three-dimensional sense. Most meteorological observations have been obtained at low elevation in open country, and they therefore do not reveal the wind structure at the typical heights of modern urban buildings. Furthermore, few of the data have been processed to reflect the turbulent structure of the flow. More subtle problems are involved with the failure of any current programs to define the horizontal structure of turbulence, although a small number of appropriate studies have been made in the vertical. Very important also is the lack of data taken under extreme meteorological conditions, such as thunderstorms and hurricanes. These deficiencies derive in part from the difference in objectives that have led to existing meteorological programs and those that would suit the structural engineer, but they are also associated with the failure of the latter to define his requirements. An experimental program that may fill some of the gaps is outlined for discussion and criticism.

The characteristics of atmospheric turbulence as related to wind loads on tall structures, G. H. Fichtl, J. W. Kaufman, and W. W. Vaughan, *BSS30,* pp. 27-41 (Nov. 1970).

Key words: Atmospheric boundary layer; gust factors; peak values; power spectra; turbulence; wind profiles.

An engineering boundary layer wind model based upon data collected at the NASA 150-meter meteorological power facility at the Kennedy Space Center, Florida is discussed. A statistical power-law peak wind profile is used to extrapolate peak wind statistics valid at the 10-meter to other levels. The relationship between the instantaneous extreme wind profile and the peak wind profile for various periods of exposure up to ten minutes is examined. The gust factor profile, which depends on the peak wind speed, height, and averaging time, is applied to the peak wind profile to obtain a mean wind profile. A spectral model of the longitudinal and lateral components of turbulence for the neutral boundary layer (high wind speeds) is presented.

Fluctuating moments on tall buildings produced by wind loading, J. E. Cermak, W. Z. Sadeh, and G. Hsi, *BSS30,* pp. 45-59 (Nov. 1970).

Key words: Boundary layer; buildings; instrumentation; overturning moments; pressure fluctuations; wind loads; wind tunnel modeling.

Wind loading on a 1:384 scale model of a building 666 ft high was studied experimentally in a thick-boundary-layer wind tunnel. Measurements of mean velocity and turbulence intensity upstream of the model building verified that the wind tunnel flow was an adequate simulation of atmospheric-surface-layer flow over an urban area.

Mean pressure distributions and local pressure fluctuations were measured for a variety of upstream roughness conditions and wind directions. Use of a high frequency response pressure-measuring system permitted rms and peak values of the local pressure fluctuations to be determined at numerous points on the building surface.

Emphasis was placed on direct measurement of mean and fluctuating overturning moments by means of a strain-gage dynamometer. A stiff model, $U/Dn < 1$, was used to obtain moments due to wind action alone. Peak values of the moment fluctuations were found to have a magnitude of $\pm 34\%$ of the mean moment. Root-mean-square values of the moment fluctuations were also determined in an effort to relate the moment fluctuations to the measured pressure fluctuations.

Experience with wind pressure measurements on a full-scale building, W. A. Dalgliesh, *BSS30,* pp. 61-71 (Nov. 1970).

Key words: Buildings; full-scale tests; power spectra; pressure fluctuations; wind loads; wind tunnel modeling.

Wind pressure measurements made over a 4-year period on a 34-story building in downtown Montreal were used to obtain data for checking and improving wind tunnel techniques of modeling flow characteristics of wind and aerodynamic behavior of buildings. It had been hoped that the measurements could be applied directly to certain

problems of design such as evaluation of peak suction load over small wall areas. The small number of pressures recorded, however, combined with limitations of field measurements made direct application of the data extremely difficult.

The major problems involved in making field measurements and in comparing them with wind tunnel measurements were found to be:

(*a*) difficulty of establishing a static reference pressure and its relation to the static pressure in the wind tunnel;

(*b*) inadequacy of wind velocity information, which in this case consisted of one anemometer and wind vane located 1,500 ft southwest of the building;

(*c*) lack of stationarity and homogeneity of the velocity field as compared with the wind tunnel situation.

Comparisons with model measurements are made on the basis of mean pressures, rms pressures, power spectra, and the correlation between selected pairs of pressures measured at various points on the building. Examples have been found of excellent agreement in almost all respects, but for some wind directions the comparisons gave unsatisfactory correlation. The lack of agreement is attributed mainly to differences between indicated and actual on-site wind direction, but this cannot be shown conclusively because of incomplete wind information.

The total cost of the project over the 4-year period was of the order of $100,000. A greater expenditure would have been advisable, primarily for instrumentation to permit a better definition of the wind velocity around the building. Measurements are now under way on a 600-ft office building using a much more sophisticated data acquisition system by means of which it should be possible to acquire the desired information more efficiently and in a shorter period of time.

Influence of architectural features on the static wind loading of buildings, H. J. Leutheusser, *BSS30,* pp. 73-86 (Nov. 1970).

Key words: Architectural features; buildings; mullions; parapets; roof projections; static pressures; wind effects; wind tunnel modeling.

The paper deals with the exploration, by model tests, of the effects of roof parapets and roof projections onto the roof wind-loading, and of wall mullions (or ribs) onto the wall wind-loading, of bluff building forms. Results are presented which suggest that parapets are effective in equalizing the pressure distribution over the roof surface while slightly reducing the uplift force. Roof projections, on the other hand, have the opposite effects. The presence of wall mullions causes sawtooth like deviations from the peripheral wall pressure-distribution for the no-rib case. The deviations are particularly significant in regions of attached flow and tend to become more pronounced with an increase in rib spacing.

The unsteady surface pressure around circular cylinders in two-dimensional flow, W. E. Simon, *BSS30,* pp. 87-91 (Nov. 1970).

Key words: Circular cylinders; power spectra; pressure fluctuations; subcritical flow; supercritical flow; transcritical flow; turbulence.

The unsteady surface pressure around circular cylinders in two-dimensional flow has been measured in the subcritical, supercritical, and transcritical flow regions. A representation of the crosspower spectral density has been developed which is a reasonable representation of the data and which applies to all three regions. The most important result is the essential similarity of the subcritical and transcritical regions.

On the reliability of gust loading factors, B. J. Vickery *BSS30,* pp. 93-104 (Nov. 1970).

Key words: Buildings; dynamics; gust factor; mode shape probability theory; wind loads.

The accuracy of the simplified gust factor approach to the determination of wind loads is examined. An expression for the gust factor is derived which treats the scale of turbulence, mode shape of vibration, and parameters defining the vertical and crosswind cospectra as variables. The method formulated in this paper differs from previous methods primarily in the size reduction factor and in the form of the spectrum of velocity fluctuations. Predicted values of gust factors are compared with those observed on eight different aeroelastic models tested in a boundary layer wind tunnel. The gust factor relates only to overall loads in the mean wind direction. Where basic data are well defined, the ratio of expected peak values of wind-induced stress or deflection to their average values can be predicted to an accuracy of typically 5 percent to 10 percent.

The treatment of wind in the design of very tall buildings, L. E. Robertson and P. W. Chen, *BSS30,* pp. 107-114 (Nov. 1970).

Key words: Aeroelasticity; buildings; dynamics; statistical analysis; structural engineering; wind loads; wind tunnel modeling.

This paper describes briefly some highlights of a study of the wind effects for the design of the United States Steel Office Building in Pittsburgh, Pennsylvania. Three types of models were used in a boundary layer wind tunnel to obtain data of the wind effects on the building. The wind tunnel results are combined with Weather Bureau data to obtain statistical estimates of the design parameters. These parameters include the envelopes of maximum deflections, the contours of maximum and minimum wind pressures on the exterior walls, and the expected number of cycles of oscillation per year which exceeds specific values of acceleration and of deflection.

Dynamic response of tall flexible structures to wind loading J. Vellozzi and E. Cohen, *BSS30,* pp. 115-128 (Nov. 1970).

Key words: Aeroelasticity; buildings; circular cylinders; gust factors; masts; structural engineering; towers; vortex shedding; wind loads.

The purpose of this paper is to present and discuss methods of calculating the dynamic response of tall, flexible structures, such as towers, stacks and masts, to wind loading. The paper is presented in two parts; the first part deals with the dynamic response of cylindrical structures to vortex shedding and the second part deals with dynamic response to gust loading.

Some deficiencies in current methods of analysis, R. W. Clough, Chairman, *BSS30,* pp. 129-131 (Nov. 1970).

Key words: Buildings; climatology; seismic loads; structural engineering: vibrations; wind loads.

Deficiencies in methods of analysis for structures subjected to wind forces are considered. Areas of similarity between wind and seismic forces and their treatment by current building codes are discussed. Deficiencies include neglect of the dynamic nature of the wind problem, a lack of basic information, and an inadequate definition of acceptable levels of risk.

Combining a wind tunnel analysis with a three-dimensional analytic building analysis, G. C. Hart, *BSS30,* pp. 145-147 (Nov. 1970).

Key words: Buildings; dynamics; gust loads; matrix analysis; mode shape; probability theory; wind loads.

A three-dimensional oriented stiffness representation of a high-rise building is described. Statistical quantities obtained from aeroelastic models in a boundary layer wind tunnel are combined with the three-dimensional analytical building model to obtain a probabilistic description of the building's response. The response is expressed in terms of the mean and covariance of floor displacements and stresses in the structural members. The procedure is intended to provide a more realistic combination of the aerodynamic and structural behavior of a high-rise building.

The engineering interpretation of Weather Bureau records for wind loading on structures, S. C. Hollister, *BSS30,* pp. 151-164 (Nov. 1970).

Key words: Buildings; climatology; extreme value theory; gust factors; structural engineering; wind loads; wind profile.

This paper utilizes the records of the fastest mile as published by the United States Weather Bureau from data obtained at their airport stations, to develop wind loadings on engineering structures. It analyzes gusts and shows how gust loadings should be dealt with in structural design. Roughness of terrain and extent of cover in rural and urban localities are systemized for engineering purposes. Occurrence of extreme winds, as studied by the Weather Bureau, is extended to a stage where a practical code may be written. Finally, designing for a given structural life and for a desired level of risk is discussed.

BSS31. **Flexural behavior of prestressed concrete composite Tee-beams,** J. O. Bryson and E. F. Carpenter, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 31, 14 pages (July 1970).

Key words: Composite concrete construction; prestressed concrete beams; Tee-beams.

Prestressed Tee-beams constructed by the split-beam method were tested to failure in flexure to study the behavior and ultimate strength of these beams and to compare their flexural characteristics with those of prestressed beams of conventional construction. The compressive portion of the cross section of the split-beam is cast after the web of the beam has been formed and prestressed. The variables in the study included the precentage of prestressing steel, strength of concrete in the compressive element of the composite split-beams, manner of prestressing and web reinforcement.

Results showed that the composite split-beams behaved similarly to the monolithically constructed beams on the basis of flexural response and ultimate load. The strength of the concrete for the compressive element can be reduced within limits from that required for the prestressed element without sacrificing ultimate load capacity. The required percentage of reinforcing steel is less for the split-beam compared with conventional beams.

BSS32. **Precoordination—basis for industrialized building.** Proceedings of a conference held at Gaithersburg, Md., September 24-26, 1969, R. W. Smith, Jr., Editor, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 32, 136 pages (Jan. 1971).

Key words: Building; components; precoordination; standards.

The Conference entitled "Precoordination—Basis for Industrialized Building" was held at the National Bureau of Standards, Gaithersburg, Md., on September 24-26, 1969. The Conference was sponsored by the American National Standards Institute's Committee A62, Precoordination of Building Components and Systems, to explore the standards required to establish a basis for an industrywide system of building using interchangeable components. Coordinated components, conforming to these standards, will be compatible and interchangeable in both dimension and function and thereby offer unlimited opportunities for product and material selection as well as design flexibility.

BSS33. **Compressive strength of slender concrete masonry walls,** F. Y. Yokel, R. G. Mathey, and R. D. Dikkers, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 33, 32 pages (Dec. 1970).

Key words: Buckling; compressive strength; concrete block walls; elastic stability; flexural strength; masonry walls; reinforced concrete masonry walls; slenderness effect; structural stability.

Sixty reinforced and unreinforced concrete masonry walls of different slenderness ratios were tested to failure under vertical loads applied axially and at various eccentricities. Prism specimens, made of similar masonry units and mortars, were also tested under the same loading conditions. Analysis of test results indicates that wall strength can be conservatively predicted by evaluating cross-sectional wall capacity on the basis of prism strength and reducing the capacity for slenderness effects by evaluating the added moments attributable to wall deflection. Test results were also compared with allowable loads computed in accordance with the current NCMA standard.

BSS34. **Strength of masonry walls under compressive and transverse loads,** F. Y. Yokel, R. G. Mathey, and R. D. Dikkers, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 34, 74 pages (Mar. 1971).

Key words: Brick; cavity walls; composite walls; compressive strength; concrete block; flexural strength; masonry; mortar; slenderness effects; standards; structural stability; walls.

Ninety walls of 10 different types of masonry construction were tested under various combinations of vertical and transverse load. It is shown that the effect of vertical load and wall slenderness on transverse strength can be predicted by rational analysis. The analysis is based on established theory which has been extended to account for the properties of masonry. Similar methods of rational analysis have been adopted for the design of steel structures and are presently being considered for reinforced concrete structures.

BSS35. **Interrelations between cement and concrete properties, Part 5. Freezing-and-thawing durability, saturation, water loss and absorption, dynamic modulus,** R. L. Blaine and H. T. Arni, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 35, 129 pages (Nov. 1971).

Key words: Absorption; autogenous healing; durability factor; dynamic modulus of elasticity; saturation coefficient.

The concretes described in earlier parts of this series were subjected to laboratory freezing and thawing tests, and measurements were made of the weight loss, dynamic modulus, durability factor, and number of cycles required to reach 40 percent reduction in dynamic modulus. Companion specimens were subjected to drying and subsequent soaking in the laboratory and to dynamic modulus tests at various ages and moisture conditions. The effect on these properties of a large number of variables connected with chemical and physical properties of the cements and with properties of the concretes was studied by multivariable regression techniques. Air content of the concretes and degree of saturation generally had the greatest effect on the measurements. In general, minor constituents and trace elements did not show significant relationships with the measured properties, but there was evidence that some of the variables, such as alkali content, water cement ratio, slump, and possibly setting time might have influenced durability through an effect on the air-void system. Specimens stored in the fog room after the freezing-and-thawing tests generally regained most or all of their original

dynamic modulus. There were significant differences between cements with respect to regain of dynamic modulus (autogenous healing), with the non-air-entrained cements gaining more than the air-entraining cements, on the average.

BSS36. **Interrelations between cement and concrete properties, Part 6. Compilation of data from laboratory studies,** J. R. Clifton and R. G. Mathey, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 36, 118 pages (Aug. 1971).

Key words: Cement; chemical composition; concrete; durability; material properties; physical properties.

Data are presented on the properties of Portland cements, mortars and concretes from a long term study reported principally by Blaine and Arni.

These data are from laboratory studies and cover a wide range of cements and concretes. A total of 199 different cements were included in the study.

BSS37. **The effect of moisture on the heat transfer performance of insulated flat-roof constructions,** F. J. Powell and H. E. Robinson, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 37, 81 pages (Oct. 1971).

Key words: Flat roofs; heat transfer; moisture transfer; thermal insulation.

A solution to the problem of unwanted moisture in the thermal insulation of flat roofs was found during a recently completed laboratory investigation of the effects of moisture on heat transfer through these constructions. The objective of the research was to ascertain how much the insulating performance of conventional constructions, having insulation over concrete decks, was affected by moisture. This is presented as Part I. Also, the objective was to investigate properties of materials, their arrangement and dimensions which would yield a construction having an adequate degree of self-drying ability, combined with low winter moisture regain rate. This is presented as Part II. The results show that the best insulating and moisture performance was obtained by utilizing the heat of the summer sun on the roof to vaporize and transfer to the room beneath any free moisture contained within the construction. Roof specimens made from moderately vapor-permeable materials without conventional vapor barriers were, in winter, able to accommodate the small quantity of slowly accumulated condensation without dripping or severe loss of insulating value. During the nine-year investigation, the performance characteristics of 73 insulated roof deck specimens were obtained and two new methods of measurement were developed. Criteria for the design of self-drying insulated flat roofs were developed and limits of the parameters containing the main variables that affect performance were suggested.

This paper presents complete results of the research which was sponsored jointly by the National Bureau of Standards, the Army, the Navy, and the Air Force.

BSS38. **1939 exposure test of porcelain enamels on steel 30-year inspection,** M. A. Baker, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 38, 9 pages (Aug. 1971).

Key words: Acid resistance; color; gloss; porcelain enamel; weather resistance.

The weather resistance of 192 porcelain enameled panels representing 14 enamel types was evaluated after being exposed for 30 years at Washington, D.C. A direct correlation was found between the acid resistance and weather resistance of the enamels tested. The porcelain enamel protected the base metal from corrosion if the initial coverage was complete.

Similar evaluations and findings were made on 58 panels representing 13 enamel types that were added to this test in 1947.

BSS39. **Use of computers for environmental engineering related to buildings.** Proceedings of a Symposium sponsored by the National Bureau of Standards, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., and the Automated Procedures for Engineering Consultants, Inc., held at the National Bureau of Standards, Gaithersburg, Md., Nov. 30-Dec. 2, 1970, T. Kusuda, Editor, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 39, 826 pages (Sept. 1971).

Key words: Building heat transfer analysis; energy usage; environmental engineering; heating and air conditioning; use of computers.

This proceedings of the First Symposium on the Use of Computers for Environmental Engineering Related to Buildings contains all of the technical papers and invited addresses presented at the symposium, which was held November 30-December 2, 1970, at the National Bureau of Standards.

The fifty-nine papers deal with the application of the computer to such environmental engineering problems as building heat transfer calculations, heating and cooling load calculations, system simulations, energy usage analyses, computer graphics, air and smoke movement inside buildings, and weather data analyses for load and energy usage calculations.

BSS40. **Engineering aspects of the 1971 San Fernando earthquake,** H. S. Lew, E. V. Leyendecker, and R. D. Dikkers, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 40, 419 pages (Dec. 1971).

Key words: Bridge; building; codes; dams; earthquake damage; earthquakes; foundation geology; highways; hospital; housing; mobile home; seismic; standards; structural engineering.

Immediately following the San Fernando, California earthquake (February 9, 1971), a four-man team from the Building Research Division of the National Bureau of Standards' Institute for Applied Technology, surveyed the damage to buildings and other structures. This report is based primarily on the data gathered during the survey but includes some data provided by other agencies and individuals. Based on study of these data and observations made during the survey, recommendations are made pertaining to the improvement of building and other structural design and construction practices.

BSS41. **Performance of a single-stack DWV system utilizing low-angle stack-branch confluence and bottom shunt venting,** R. S. Wyly and G. C. Sherlin, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 41, 24 pages (Apr. 1972).

Key words: Criteria for plumbing; hydraulic test loads; performance of plumbing; single stack plumbing.

Among the more important criteria for hydraulic and pneumatic performance of sanitary drain-waste-vent systems are (1) maintenance of water seals in fixture traps, (2) limitation of pneumatic pressures, (3) limitation of hydrostatic and hydrodynamic pressures, and (4) limitation of cross-flow between horizontal branches or trap arms.

Recent tests of a single-stack drainage system proposed for a high-rise apartment project in Fairfax County, Virginia have produced the following findings with respect to these performance criteria: (1) test loads (total discharge rates) ranging up to magnitudes greater than predicted loads yielded reasonable average trap-seal retention; (2) the use of trap-seal retention as a measure of performance appears to be more meaningful than the traditional pneumatic-pressure measure; (3) fitting geometry and branch arrangement can be more critical in single-stack systems than in conventional vented systems, and (4) present procedures for selecting test loads, for making tests, and for reporting and interpreting measured values need improvement and standardization.

BSS42. **Design loads for inserts embedded in concrete,** T. W. Reichard, E. F. Carpenter, and E. V. Leyendecker, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 42, 28 pages (May 1972).

Key words: Anchors; concrete slabs; design loads; fatigue; inserts; pull-out loads; sustained load.

Detailed test procedures are presented for a research program on cast-in-place inserts embedded in reinforced concrete. Three types of inserts, two of malleable iron and one of ductile steel, capable of receiving a 3/4 inch threaded rod were tested. Other variables included concrete aggregate type, concrete strength, reinforcement cover and spacing, angular loading, flexural cracking, sustained load and fatigue loading.

It was found that the pull-out load for an insert could be approximated by a linear function of the concrete unit weight and square root of the compressive strength in a statically loaded reinforced concrete slab. The effect of other variables is related to the insert pull-out loads in these slabs. Design recommendations are presented.

BSS43. **Paper honeycomb sandwich panels as lightweight structural components,** T. W. Reichard, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 43, 7 pages (Apr. 1972).

Key words: Adhesives; paper honeycomb; sandwich facings; sandwich panels.

This paper presents a resume of current practice in the U.S. with regard to the use of sandwich panels in single-story buildings. A description and the properties of typical paper honeycomb cores are given. Some of the factors which are considered in choosing sandwich facings and adhesives are given.

BSS44. **Full scale test on a two-story house subjected to lateral load,** F. Y. Yokel, G. Hsi, and N. F. Somes, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 44, 26 pages (Nov. 1972) 50 cents, SD Catalog No. C13.29/2:44.

Key words: Building damping; drift; dynamics; earthquake; frequency; housing; lateral resistance; racking; stiffness; structural deflections; vibration; wind load; wood frame construction.

Tests were carried out on a house to determine its deflection characteristics under lateral loads. The house is a two-story building of conventional wood-frame construction. Two series of tests were conducted. The first of these was to determine the stiffness of the house when subjected to a simulation of wind loading. The second was to determine the dynamic response of the house to a single impulse load.

The report presents the results of these tests from which the following primary conclusions were derived:

1. The measured second-story drift of the building under the test load was considerably less than the drift permitted for medium- and high-rise buildings by present design criteria for most areas of the United States.

2. Only a small portion of the distortion of the exterior walls was transmitted to the interior gypsum board.

3. The upper ceiling diaphragm experienced significant in-plane deformation. On the other hand, the floor/ceiling diaphragm at the lower ceiling level tended to act as a rigid diaphragm and to translate as a rigid body when the building was subjected to lateral load.

4. The natural frequency of the structure was approximately 9 Hz and damping averaged approximately 6 percent of critical damping varying from 4 to 9 percent.

BSS45. **Dynamic thermal performance of an experimental masonry building,** B. A. Peavy, F. J. Powell, and D. M. Burch, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 45, 103 pages (July 1973) $1.25, SD Catalog No. C13.29/2:45.

Key words: Building heat transfer; computer programs; dynamic thermal performance; heat flow analysis; heating and cooling loads; temperature predictions; thermal analysis; thermal behavior; transient heat flows.

Measurements of the dynamic heat transfer in an experimental masonry building were made in a large environmental chamber to explore the validity of a computer program developed at NBS, labeled NBSLD, for computing heating and cooling loads, and indoor air temperatures. This study was jointly supported by the National Bureau of Standards and the Department of Housing and Urban Development, and is a part of a broader research program being supported by both agencies to improve performance test procedures and criteria for housing.

The experimental structure was a one-room house 20 ft long 20 ft wide, and 10 ft high with walls of solid concrete blocks and a flat roof made of reinforced precast concrete slabs. During the tests changes were made in fenestration, the amount and location of insulation, and the indoor mass; and the building was exposed to a diurnal temperature cycle.

It was found that the combination of mass in the masonry walls and roof, and insulation placed on the outside of the masonry was very effective in reducing and controlling the variation of indoor air temperature. The NBSLD computer program realistically predicted the heat storage effects, and maximum heating loads during these tests. For five heating tests, the greatest difference between computed maximum heating load and measured values was 8 percent and the average difference was 4.3 percent. It was shown that steady-state methods of heating load calculation could result in oversizing heating equipment by 30 percent or more for this particular building and imposed exterior conditions if the lowest outdoor temperature was selected as the design temperature.

BSS46. **Building practices for disaster mitigation.** Proceedings of a workshop sponsored by The National Science Foundation, Research Applied to National Needs Program, and The National Bureau of Standards, held at the National Bureau of Standards, Boulder, Colo., Aug. 28-Sept. 1, 1972, R. Wright, S. Kramer, and C. Culver, Editors, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 46, 483 pages (Feb. 1973) $5.30, SD Catalog No. C13.29/2:46.

Key words: Building; earthquakes; hazards; land use; structural engineering; wind effects.

The national workshop on building practices for disaster mitigation was concerned with earthquakes, extreme winds, and similar dynamic hazards. These proceedings present recommendations derived at the workshop and addressed to policy makers in government and industry, as well as practitioners in engineering, architecture, land use planning, and the earth and meteorological sciences. The recommendations evaluate current building practices, define opportunities for improving current practice from documented research findings, and recommend research to fill gaps in knowledge. Recommendations are made for implementation of improved practices at professional and policy levels. The objectives include avoidance of human suffering, reduction of property loss, and maintenance of vital function in buildings under conditions threatening disaster. Fifteen review articles were prepared by experts in the professions and research disciplines to define the state-of-the-art in disaster mitigation and to guide discussions at the workshop. These articles are included in the proceedings as follows:

Workshop recommendations, *BSS46*, pp. 7–39 (Feb. 1973).

Values and costs, H. Kunreuther, *BSS46*, pp. 41-62 (Feb. 1973).

Approaches to implementation, P. E. Baseler, *BSS46*, pp. 63-81 (Feb. 1973).

Earthquake hazards for buildings, N. C. Donovan, *BSS46*, pp. 82-111 (Feb. 1973).

The problem of seismic zoning, S. T. Algermissen, *BSS46*, pp. 112-125 (Feb. 1973).

Wind hazards for buildings, J. W. Vellozzi and J. J. Healey, *BSS46*, pp. 126-138 (Feb. 1973).

Land use planning and natural disaster mitigation, W. J. Petak, M. McCoy, W. J. Monasch, J. E. Slosson, D. F. Moran, J. H. Wiggins, Jr., *BSS46*, pp. 139-178 (Feb. 1973).

Architectural approaches to hazard mitigation, E. C. Hillman Jr., A. E. Mann, *BSS46*, pp. 179-187 (Feb. 1973).

Procedures and criteria for earthquake resistant design, C. W. Pinkham, *BSS46*, pp. 188-208 (Feb. 1973).

Procedures and criteria for earthquake resistant design, N. M. Newmark and W. J. Hall, *BSS46*, pp. 209-236 (Feb. 1973).

Procedures and criteria for wind resistant design, J. W. Vellozzi and J. J. Healey, *BSS46*, pp. 237-252 (Feb. 1973).

Criteria for building services and furnishings, J. M. Ayres and T.-Y. Sun, *BSS46*, pp. 253-285 (Feb. 1973).

Behavior of structural elements. A review, B. Bresler, *BSS46*, pp. 286-351 (Feb. 1973).

Behavior of structural systems under dynamic loads, R. L. Sharpe, G. Kost, and J. Lord, *BSS46*, pp. 352-394 (Feb. 1973).

Survey and evaluation of existing buildings, F. E. McClure, *BSS46*, pp. 395-426 (Feb. 1973).

Abnormal loading on buildings and progressive collapse, N. F. Somes, *BSS46*, pp. 427-470 (Feb. 1973).

BSS47. **Structural deflections. A literature and state-of-the-art survey,** T. V. Galambos, P. L. Gould, M. K. Ravindra, H. Suryoutomo, and R. A. Crist, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 47, 104 pages (Oct. 1973) $1.25, SD Catalog No. C13.29/2:47.

Key words: Analysis; deflection; design; dynamic; experimental; human sensitivity; loading functions; specifications; static; structural engineering; subsystems; vibration.

A literature survey and state-of-the-art study was compiled using 233 primary source documents, research papers, and texts. Over 800 documents were scanned to arrive at the primary source documents. The problem of structural deflections is discussed and reviewed in its component areas of static and dynamic deflections as related to forcing functions and structural characteristics. Also the interactions of major structural deflections with building structures subsystems and human occupants is reviewed. Emphasis is placed on serviceability limit states of deflections. Detailed comparisons of human response to structural vibrations are also made. This report is broad in scope and covers the areas of analysis, design and experimentation.

BSS48. **Design, siting, and construction of low-cost housing and community buildings to better withstand earthquakes and windstorms,** W. F. Reps and E. Simiu, Eds., Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 48, 152 pages (Jan. 1974) SD Catalog No. C13.29/2:48.

Key words: buildings; construction; design; developing countries; earthquakes; low-cost housing; natural disasters; structures; windstorms.

The extensive loss of life and property caused in developing countries by earthquakes and windstorms (hurricanes, typhoons and tropical cyclones) may be reduced to a considerable degree by the adoption and implementation of improved design, siting and construction procedures practicable within the context of the cultural and socioeconomic constraints prevailing in these countries.

The report provides technical information regarding characteristics of materials and building systems, and discusses the structural performance of buildings subjected to the action of earthquakes and wind forces with specific reference to structures typical of developing countries. Potential ways are described in which structures can be made more resistant to such action. Siting considerations are discussed from a geological, seismic and climatological viewpoint, and recommendations relating to siting problems are made. Techniques of housing construction, both traditional and industrialized, are described and improvements resulting in better earthquake or windstorm resistance are suggested. Building codes, their improvement and their enforcement are also discussed.

The report discusses cultural and socio-economic constraints influencing the adoption of improved practices, describes various feasible technical improvements of construction materials, composite systems and building systems, identifies mechanisms for stimulating technical improvements and discusses the role of institutions in this regard. Throughout the report, specific references are made to Peru, the Philippines and Turkey, countries which suffer from frequent devastation from natural disasters such as earthquakes and typhoons and which were selected as case studies for the purpose of this report.

BSS49. **Laboratory studies of the hydraulic performance of one-story and split-level residential plumbing systems with reduced-size vents,** R. S. Wyly, G. C. Sherlin, and R. W. Beausoliel, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 49, 53 pages (Mar. 1974) SD Catalog No. C13.29/2:49.

Key words: hydraulic criteria for plumbing; hydraulic test loads; plumbing-vent sizing; reduced-size vents; sanitary DWV systems; secondary ventilation; testing plumbing systems; vents for plumbing.

A laboratory study on one-story and split-level experimental drainage systems where the vents in some cases were varied from one to six pipe-sizes smaller than those presently specified by codes showed satisfactory hydraulic and pneumatic performance under various loading conditions. The research was originally sponsored by the National Association of Home Builders and the National Bureau of Standards and more recently by a program of the Department of Defense through the Tri-Services Investigational Committee on Building Materials. This paper presents criteria recommended for the design and evaluation of systems using reduced-sized vents and a sizing table for one- and two-story systems. The laboratory work also contributed to the development of analytical and test procedures needed for evaluating the application of reduced-size venting to a broad range of innovative drain-waste-vent designs for buildings of any height.

This work indicates that, in some circumstances, reduced-size venting might be a good alternative to other types of drainage

stems for multistory buildings which use either conventional innovative venting concepts. Because this study involved only limited number of drainage system designs, it is recommended at ongoing field and laboratory studies be explored if code anges are contemplated to permit the use of smaller vents.

SS50. **Weather resistance of porcelain enamels—15-year inspection of the 1956 exposure test,** M. A. Baker, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 50, 15 pages (July 1974) SD Catalog No. C13.29/2:50.

Key words: acid resistance; color; gloss; pH; porcelain enamel; relative humidity; weather resistance.

In 1956, and exposure test of porcelain enamels at 4 urban and ocean shore sites in the continental United States was initiated the National Bureau of Standards and the Porcelain Enamel stitute. After 15 years, all exposed specimens were returned to e Bureau and the changes in gloss and color determined. The oss changes were found to be significantly different at all expore sites except Pittsburgh, Los Angeles and Dallas. The most vere changes occurred at the Kure Beach, N.C., site nearest e ocean, while the least changes occurred at Pittsburgh, Los ngeles and Dallas. The differences in behavior of the ecimens correlated with both the average relative humidity d the pH of the suspended particulate matter at the different tes.

A correlation appeared to exist between the acid resistance of e enamels and changes in gloss and color. The regular, glossy, id-resistant enamels on steel showed the best weather restance of the various types tested.

Comparison with enamel specimens exposed for 15 years in an rlier test showed that porcelain enamels produced in the early 50's were equally resistant to changes in gloss and color as ose produced in the late 1930's.

SS51. **Structural evaluation of steel faced sandwich panels,** J. H. Pielert, T. W. Reichard, and L. W. Masters, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 51, 43 pages (Apr. 1974) SD Catalog No. C13.29/2:51.

Key words: accelerated aging; adhesive bond; ductility; flexural shear; housing systems; local buckling; material variability; moisture conditioning; Operation BREAKTHROUGH; paper honeycomb; structural sandwich; sustained load.

A series of structural evaluation tests performed on components and materials intended for use in one of the Operation REAKTHROUGH housing systems is described. Four samples of steel faced, paper honeycomb, sandwich panel material d four full size prototype roof panels were evaluated.

The samples of sandwich panel material were used to evaluate e variability of panel material properties and the effect of aging tensile and shear strength. The roof panels were used to determine the behavior in service considering the effects of adverse vironmental conditions on ultimate strength and mode of ilure. In addition, the performance of one panel under stained loading was evaluated.

SS52. **The effect of impact loadings on the performance of wood joist subflooring systems,** H. S. Lew, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 52, 35 pages (May 1974) SD Catalog No. C13.29:2/52.

Key words: concentrated load; deflection; floor; hardboard; housing; impact energy; Operation BREAKTHROUGH; plywood; subfloors; underlayment; wood; wood joists.

This report presents the results of an experimental study of ood-joist subflooring systems subjected to impact load. Six diffent types of subflooring systems were tested following the test method described in the ASTM Standard Methods (ASTM Designation E-72). The magnitude of impact load was varied by dropping a 60-lb bag from different heights.

A concentrated static load of 400 lb was applied to the subfloor after it was exposed to impact load. It is suggested that the deflection under this concentrated load be used as a measure of the impact resistance of the subfloor. Supersedes NBSIR 73-187 (PB 221-188).

BSS53. **Study of the local resistance of conventional plywood subflooring to concentrated load,** F. Y. Yokel, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 53, 43 pages (May 1974) SD Catalog No. C13.29:2/53.

Key words: evaluation criteria; floors; hardboard; load capacity, performance criteria; plywood subflooring; subflooring; underlayment; wood-frame construction.

Representative specimens, simulating the performance of five conventional plywood floor systems, were tested under concentrated load in order to compare their performance with that stipulated by performance criteria developed on the basis of anticipated occupancy loads.

In 24 out of 26 tests the performance of the specimens exceeded that required by the criteria. Data on failure loads, load-deflection characteristics and failure modes are presented and discussed. Supersedes NBSIR 73-116 (PB 220-432/9).

BSS54. **Health and medical facilities design.** Proceedings of the First Federal Agency Workshop, held at the National Bureau of Standards Gaithersburg, Md., December 5, 1972, R. J. Kapsch, Ed., Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 54, 87 pages (July 1974) SD Catalog No. C13.29/2:54.

Key words: architecture; design; hospital design; medical facilities; medical facility research.

The Federal Agencies have a large involvement in this area of Medical Facility Design; both in directly operated Federal facilities and indirectly through grant, loan and funding programs. Because of the impact of technology and because of the very large cost for new medical facilities in the last few years, there has been the rise of a field best described as medical facility research. These papers, presented at a National Bureau of Standard's Federal Agency Workshop, describe the latest medical facility research efforts by the Federal Agencies including, the Department of Defense, Department of Health, Education, and Welfare, the Veterans' Administration and the National Bureau of Standards. *These proceedings include the following papers (indented):*

The new generation hospital, S. I. Gerber, *BSS54*, 1-12 (July 1974).

Key words: architecture; design; hospital design; medical facilities; military construction; new generation military hospital; system design.

The Department of Defense has some 240 major hospitals and 460 dispensaries serving over 10 million people and employing about one quarter of a million medical and allied personnel. In 1968, a new project was initiated; A New Generation of Military Hospitals. The objectives of this project were to provide a more efficient health care delivery system through the extensive use of technology. The project consisted of two phases; Phase I was the systems analysis study of military and civilian hospitals and Phase II was the design and construction of a test bed military hospital. A number of recommendations resulted from Phase I, including use of a completely computerized hospital, convenience food system, light care nursing, outpatient surgery and others. Travis Air Force Base in California was selected as the site for implementation of

Phase II. The organization and the planning of this project are discussed. The beneficial occupancy of the Phase II, Travis Hospital is scheduled for 1977.

Rationale for change—The Hill-Burton Program, J. W. Reese, *BSS54*, pp. 13-24 (July 1974).

Key words: architecture; building regulations; construction standards; design; Hill-Burton; hospital design; medical facilities.

The Hill-Burton Program was established in 1946 for the financing of needed health facilities in the United States. An important function of the Hill-Burton Program is the continual updating of minimum construction requirements with which Hill-Burton projects must comply. Many States, architects, and engineers use these requirements for all health facility contstruction. Some of the newly proposed changes described include modification of Fire Safety requirements to make them compatible with other government agencies; improved parking facilities; increased emphasis on making health facilities accessible to the physically handicapped; a new section for intensive and coronary care units, and a new section dealing with natural disasters. Government building regulations will continue to change, probably in the direction of making the environment more livable and in the increased concern for conserving human resources.

Space planning and equipment requirements—application of advanced technologies to hospital design in the Veterans' Administration, H. J. Fogarty, *BSS54*, pp. 25-26 (July 1974).

Key words: criteria; hospital planning; medical facilities; planning; Veterans' Administration.

Prior to 1958, the Veterans' Administration (VA) used a 500 bed prototype as the basis of all design and construction. This proved undesirable since almost all new VA hospitals were to be teaching facilities with widely varying requirements not well suited to any single prototype. At the end of the 1950's the Bureau of the Budget issued the Federal Space Planning Criteria. The VA expanded and refined this criteria and has been successfully applying it for over ten years.

Use of the computer in planning hospitals—application of advanced technologies to hospital design in the Veterans' Administration, B. D. Keane, *BSS54*, pp. 27-30 (July 1974).

Key words: computer-aided planning; design; electronic data processing; hospital planning; medical facilities; planning; Veterans' Administration.

In 1965, the Veterans' Administration (VA) began developing the facilities Planning and Construction Requirements System to aid the VA in planning new facilities. This system is presently in use today. This computerized system utilizes files containing medical statistics, staffing, criteria and other information necessary for hospital planning. This system produces a master plan. This master plan provides a listing of medical functions, projected staffing, space requirements and other information. After review and approval of this master plan, it is used by architects and engineers for the design of VA hospitals. Future work on this system will include provisions for equipment, addition of special environmental factors and extension of the system to field station manangement.

Veterans' Administration Hospital Building System—application of advanced technologies to hospital design in the Veterans' Administration, J. C. Cook, *BSS54*, pp. 31-44 (July 1974).

Key words: architecture; building systems; design; hospital design; medical facilities; modular design; performance; Veterans' Administration.

The Veterans' Administration (VA) Hospital Building System was begun to provide new VA Hospitals with improved cost control, improved performance, increased adaptability, a reduction in the time to go from planning to beneficial occupancy and to provide a system that could be continuously updated. The Building System is composed of three parts; the data base, the planning modules and the building subsystems. The data base contains the "user needs" necessary to determine functional and performance requirements for new VA Hospitals. The planning modules are areas of space large enough to accomodate a wide variety of hospital activities. Four types of planning modules are used: a structural bay with a constant width of 22.5 feet (6.86 meters); a service module of from 5000 square feet (464.5 square meters) to 15,000 square feet (1393.5 square meters); a space module, which is a sub-unit of the service module and a fire section not to exceed 20,000 square feet (1858.0 square meters). The building subsystems are the components of the VA Hospital Building System. Six subsystems have been developed in detail; structure; partitions; ceiling; heating-ventilating-cooling; plumbing distribution; and electrical distribution. Advantages of the application of the VA Hospital Building System include better response to the medical program, more accurate estimate and control of costs, improved performance, better functioning of the building and increased adaptability.

Introduction—current issues in health care facility delivery, D. D. Boyle, *BSS54*, pp. 45-48 (July 1974).

Key words: architecture; construction; design; hospital design; management; medical facilities; performance specifications.

Some of the issues of concern to Health Care Facility Delivery are better planning, better prediction of facility needs, improved sensitivity to the need for responsive facilities, containment of parochial attitudes, restatement of the emphasis in planning and design and improvement of the management process. Failures in this area include lack of consideration of life cycle cost, non-utilization of available management and procedural skills and the numerous Federal, regional, State and local building and life safety codes that hamper technological advance. In a recent report to Congress, the General Accounting Office (GAO) identified these items and others and provided detailed recommendations. The Facilities Engineering and Construction Agency (FECA) presently has three projects dealing with these issues and problems. These projects include the investigation of the design process, the construction of three office buildings to performance specifications and using new management concepts and the third is the construction of five Indian Health Service hospitals using a sophisticated management plan.

Application—current issues in health care facility design, J. D. Russo, *BSS54*, pp. 49-62 (July 1974).

Key words: architecture; building systems; construction management; design; hospital design; medical facilities; performance; planning; programming.

The Facilities Engineering and Construction Agency (FECA) is presently accomplishing a project for the delivery of five health facilities. Unlike conventional projects, FECA commissioned an Executive Architect/Engineer (A/E) to review the programs of requirements

develop a functional definitive design kit upon which schematics would be based and to oversee the work of five regional A/E's who would be responsible for final design. Other unique aspects of this project include the use of a flexible management system, the use of a functional definitive design kit, the requirement for a guaranteed maximum price early in the design process from the construction manager and other innovations. Benefits include better quality Health Facilities delivered in shorter time and at a lower cost than through traditional means and the basis for continuous improvements of future health care facilities.

An evaluation methodology for hospital nursing units, R. Wehrli, *BSS54,* pp. 63-76 (July 1974).

Key words: architecture; design; evaluation; hospitals; medical facilities; nursing units.

Hospital planners and designers are facing the twin trends of greater construction costs and greater demand to access to the health care delivery systems. Because of these twin trends, these planners and designers must become increasingly aware of the various requirements involved in nursing units. One method of achieving this is through evaluation. The evaluation methodology that was developed by the Architectural Research Section relies on the research aids of architectural psychology, building systems and the performance approach. In this methodology, requirements are systematically identified and schematic drawings of nursing units are weighted and rated based on these requirements. When allied with costs, this methodology permits a comparison of various schemes on a performance-cost basis. It also aids the designer in improving his design of nursing units.

SS55. **Preliminary performance criteria for bituminous membrane roofing,** R. G. Mathey and W. C. Cullen, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 55, 16 pages (Nov. 1974) SD Catalog No. C13.29/2:55.

Key words: bituminous roof membranes; performance attributes; performance criteria; physical and engineering properties; test methods.

This report is the first in a series of publications on performance criteria for built-up roof membranes. The development a performance approach to bituminous built-up roof membranes is described and preliminary performance criteria are commended. A number of test methods have been developed order to obtain data to evaluate roofing membranes against the commended criteria. Twenty attributes that effect the performance of roof membranes under service conditions are entified and laboratory tests are described for measuring the gineering properties of the membrane that pertain to many of ese attributes. A level of performance is recommended for nine the identified performance attributes.

SS56. **Development of improved design criteria for low-rise buildings in developing countries to better resist the effects of extreme winds,** Proceedings of a Workshop held at the Dr. Paulino J. Garcia Memorial Hall, National Science Development Board, Manila, Philippines, Nov. 14-17, 1973, N. J. Raufaste, Jr., and R. D. Marshall, Eds., Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 56, 171 pages (Oct. 1974) SD Catalog No. 13.29/2:56.

Key words: codes and standards; information transfer; low-rise buildings; pressure transducers; socio-economic; structural design; technology implementation; wind effects; wind loads.

An International Workshop held in Manila, Philippines, on ovember 14-17, 1973, addressed the state-of-the-art in mitigatg building damages from winds. The workshop was jointly sponsored by the United States Agency for International Development (USAID), the Philippine Advisory Committee (formed in conjunction with this research project), and the U.S. National Bureau of Standards (NBS). This report presents the proceedings derived from the workshop. The proceedings present recommendations, the workshop program, five reports, and nine technical articles. The technical articles addressed four primary topics which were used to guide subsequent workshop discussions. The topics addressed were: wind and aerodynamics, structural related technology, socio-economic and architectural considerations, and codes and standards.

The results of the workshop will serve a twofold purpose. The first suggests improved building practices for developing countries. This was accomplished through the development of recommendations designed to upgrade to a minimum acceptable level design critera for low-rise buildings. The second involves integrating appropriate workshop information into the overall three-year AID sponsored research project to develop improved design criteria for low-rise buildings in developing countries to better resist the effects of extreme winds. *These proceedings include the following papers (indented):*

Climatology and wind related problems in the Philippines, R. L. Kintanar, *BSS56,* pp. 28-62 (Oct. 1974).

Aerodynamics of structures and wind tunnel modeling, R. D. Marshall, *BSS56,* pp. 63-76 (Oct. 1974).

Some problems in the analysis of lateral wind force resisting systems, J. Ma. de Castro, *BSS56,* pp. 78-90 (Oct. 1974).

Socio-economic and architectural considerations in housing, G. V. Manahan and J. M. Ramos, *BSS56,* pp. 91-98 (Oct. 1974).

Lessons learned from post wind disaster investigation, E. O. Pfrang, *BSS56,* pp. 99-101 (Oct. 1974).

Low-rise low-cost housing and extreme wind related problems in Bangladesh, J. R. Choudhury, *BSS56,* pp. 102-120 (Oct. 1974).

Low-cost housing and extreme-wind-related problems in Jamaica, A. D. Adams, *BSS56,* pp. 123-139 (Oct. 1974).

Wind pressure provisions of the National Building Code Republic of the Philippines, A. R. Flores, *BSS56,* pp. 140-152 (Oct. 1974).

Standardization in the Philippines today, A. R. Flores, *BSS56,* pp. 153-155 (Oct. 1974).

Wind research in the United Kingdom, K. J. Eaton, *BSS56,* pp. 156-159 (Oct. 1974).

BSS57. **Comparison of measured and computer-predicted thermal performance of a four bedroom wood-frame townhouse,** B. A. Peavy, D. M. Burch, F. J. Powell, and C. M. Hunt, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 57, 62 pages (Apr. 1975) SD Catalog No. C13.29/2:57.

Key words: air leakage measurement; building heat transfer; computer programs; dynamic thermal performance; heat flow analysis; heating and cooling loads; temperature predictions; thermal analysis; thermostat setback; transient heat flows.

Measurements of the dynamic heat transfer in a four bedroom townhouse were made under controlled conditions in a large environmental chamber to explore the validity of a computer program developed at NBS, labelled NBSLD, for predicting heating and cooling loads and inside air temperatures. This study was supported jointly by the Department of Housing and Urban Development and the National Bureau of Standards, and is a

part of a broader research program supported by both agencies to improve performance test procedures and criteria for housing.

The test house was a factory-produced four bedroom townhouse of modular design and of lightweight (wood) construction. Tests were performed with simulated outside summer, winter and fall diurnal temperature cycles. The inside temperature was maintained at about 75 °F. Also during the tests, the activities of a six-member family were simulated.

The time-varying energy requirements were measured, and these values were compared with computer predicted values. For example, the disparity between predicted and measured daily heating energy requirements averaged 3.1 percent with a maximum departure of 4.9 percent for five tests. The computer program NBSLD was experimentally validated for predicting the peak heating and cooling loads and the energy requirements for the test house.

The air leakage of the house was measured by a tracer gas technique over a range of outdoor conditions, and algorithms were developed to account for its effect on heating loads and energy requirements.

Separate tests were also performed to investigate the energy savings achieved by night temperature setback. An 8-h 9 °F setback from 75 °F produced an 11 percent diurnal savings in energy for an average nighttime temperature of 20 °F and a 9 percent savings in energy was achieved for the same setback when the average nighttime temperature was 2 °F.

BSS58. **State-of-the-art of structural test methods for walls, floors, roofs and complete buildings,** C. W. C. Yancey and L. E. Cattaneo, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 58, 136 pages (Nov. 1974) SD Catalog No. C13.29/2:58.

Key words: building construction; complete buildings; floors; roofs; standardization; test methods; walls.

As part of a comprehensive research program concerned with the structural testing of building components, conducted for the U.S. Department of Housing and Urban Development (HUD), a search for information was conducted. This search was undertaken in order to document existing information pertaining to structural testing of wall, floor and roof assemblies. Various information sources were consulted to trace the evolution of structural testing of building construction from the 1930's to the present time. This task was a prerequisite to defining the state-of-the-art and to identifying the test areas requiring fundamental research.

Based on information obtained from a review of the literature and from liaison with committees concerned with the development and revision of voluntary standards, it was found that there is a dearth of research information contributing directly to the development of test methods. Most of the research conducted on building components has been carried out either to observe the behavior of a sample of a particular type of construction or to evaluate the performance of a specimen against some performance requirements. However, helpful interferences can be made on the basis of some of the documentation, especially that contained in reports of full-scale tests on housing.

As a result of comparing the test methods used by the National Bureau of Standards in HUD project Operation BREAKTHROUGH with American Society for Testing and Materials (ASTM) Standard methods, several recommendations have been made by the authors for improving present structural test practice.

An up-to-date status report of voluntary test standards activities (in the U.S.) was prepared through verbal and written communication with members of the technical subcommittees of ASTM Committee E-6 on Performance of Building Construction.

BSS59. **The adherence of porcelain enamel to aluminum,** M. A. Baker, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 59, 39 pages (Nov. 1974) SD Catalog No. C13.29/2:59.

Key words: adherence; aluminum; electron microprobe; electron microscope; porcelain enamel; spalling; x-ray diffraction.

Electron microscopy, electron microprobe, and x-ray diffraction techniques were used to determine the mechanisms of adherence of porcelain enamel to aluminum. Adherence appears to depend upon diffusion of aluminum into the enamel and further the diffusion zone should be relatively free of reaction products for the enamel-metal system to retain good adherence after exposure to chemical solutions or to weathering. Round-robin testing of 6063 aluminum extrusions indicated that this alloy could be enameled if care were exercised in the selection of the enamel and the pretreatment.

BSS60. **Hydraulic performance of a full-scale townhouse drain-waste- vent system with reduced-size vents,** M. J. Orloski and R. S. Wyly, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 60, 43 pages (Aug. 1975) SD Catalog No. C13.29/2:60.

Key words: DWV; performance testing; reduced-size vents; trap-seal retention; venting; venting criteria; vents, reduced-size.

This report describes the experimental findings of tests on a full-scale two-story plumbing system with reduced-size vents under a range of operating conditions including tests with the earlier work on full-scale systems of substantially different geometry, criteria for sizing reduced-size vents are given for general application to conventional 1-2 story housing units. In addition to the practical evidence in terms of acceptable trap performance, the current study provided fundamental evidence of the excessive present design criteria. For the first time measurements were obtained which relate traditional design criteria (air flow and vent pressure) to presently recommended performance criteria (trap-seal retention) under dynamic conditions. These findings indicate that the vents can be sized on the basis of 1.5 in water gage (equals 372 pascals) suction in the vent rather than the 1.0 in W.G. (equals 248.8 Pa) presently specified in the plumbing codes. Also air demands measured were significantly less than assumed in current practice for short stacks and for systems with vent networks.

BSS61. **Natural hazards evaluation of existing buildings,** C. G. Culver, H. S. Lew, G. C. Hart, and C. W. Pinkham, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 61, 958 pages (Jan. 1975) SD Catalog No. C13.29/2:61.

Key words: buildings; damage; disaster; dynamic analysis; earthquakes; hurricanes; natural hazards; structural engineering; tornadoes; wind.

A methodology is presented for survey and evaluation of existing buildings to determine the risk to life safety under natural hazard conditions and estimate the amount of expected damage. Damage to both structural and nonstructural building components resulting from the extreme natural environments encountered in earthquakes, hurricanes, and tornadoes is considered. The methodology has the capability of treating a large class of structural types including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. Three independent but related sets of procedures for estimating damage for each of the natural hazards are included in the methodology. The first set of procedures provides a means for qualitatively determining the damage level on the basis of data collected in field surveys of the building. The second set utilizes a structural analysis of the building to determine the damage level as a function of the behavior of critical elements. The third set is based on

omputer analysis of the entire structure. All three sets of rocedures are based on the current state of the art. The rocedures are presented in a format which allows updating and fining. Numerical examples illustrating application of the rocedures are included.

SS63. **Analysis of current technology on electrical connections in residential branch circuit wiring,** W. J. Meese and R. L. Cilimberg, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 63, 23 pages (Mar. 1975) SD Catalog No. C13.29/2:63.

Key words: contact resistance; electrical codes; electrical connections; fire safety; house wiring; materials properties; performance testing.

In the Operation BREAKTHROUGH research and demonstration program the U.S. Department of Housing and Urban Development became concerned with the inability to properly evaluate innovative electrical connections. Long life requirements, fire safety considerations, the lack of adequate technical information, and long established conventional practices and evaluation procedures have led to slow-changing regulations concerning electrical connections used in branch circuit wiring in housing. This report discusses the present methods of evaluating electrical connections, the technical parameters involved, and innovative electrical connection developments. Innovations involving electrical connections may lead to significant advancements in housing construction if it could be demonstrated that functional and safety requirements over the expected life of the electrical connections were adequately satisfied. Research is needed to enable prediction of long term performance of electrical connections based on the results of accelerated performance tests.

SS64. **Retrofitting existing housing for energy conservation: An economic analysis,** S. R. Petersen, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 64, 76 pages (Dec. 1974) SD Catalog No. C13.29:2/64.

Key words: benefit-cost analysis; building economics; building envelope; economic analysis; economic efficiency; energy conservation; engineering economics; insulation; life-cycle costs; marginal analysis; thermal efficiency.

This study examines the economic aspects of energy conservation techniques suitable for retrofitting into existing housing, including insulation, storm windows and doors, and weather stripping. The objective of this study is to determine that combination of techniques which will maximize net dollar savings in life-cycle operating costs for heating and cooling operations in existing homes, subject to specific climate conditions, fuel costs, and retrofitting costs. Using microeconomic marginal analysis we find that such a combination must be economically balanced i.e., the ratio of savings to cost must be equal at the margin for each technique) and that each technique should be utilized up to the point where the present value of the life-cycle savings generated by the last increment will just cover the costs of that last increment. Thermal engineering data is combined with the economic analysis in a computer-assisted model which estimates such optimal combinations for a wide range of climatic conditions and fuel costs. These combinations include levels of application higher than what has been previously recognized as "economical."

BSS65. **Nonmetallic coatings for concrete reinforcing bars,** J. R. Clifton, H. F. Beeghly, and R. G. Mathey, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 65, 41 pages (Aug. 1975) SD Catalog No. C13.29/2:65.

Key words: bridge decks; chloride ions; concrete; corrosion; deicing salts; epoxy coatings; organic coatings; polyvinyl chloride coatings; steel reinforcing bars.

This work was undertaken to ascertain the feasibility of using organic coatings, especially epoxies, to protect the steel reinforcing bars embedded in concrete of bridge decks from rapid corrosion. This corrosion is caused by the chloride ions from the most commonly applied deicing salts, sodium chloride and calcium chloride. Altogether, 47 different coating materials were evaluated to some extent, consisting of 21 liquid and 15 powder epoxies; 5 polyvinyl chlorides; 3 polyurethanes; 1 polypropylene; 1 phenolic nitrile; and one zinc rich coating. The chemical and physical durabilities, chloride permeabilities, and protective qualities of coatings were assessed. The bonds between coated and uncoated bars and concrete were measured by both pullout and creep tests.

The results indicate that both epoxy and polyvinyl chloride coatings, if properly applied, should adequately protect steel reinforcing bars from corrosion. However, only the epoxy coated bars had acceptable bond and creep characteristics when embedded in concrete. The powder epoxy coatings overall performed better than the liquid epoxies, and four powder epoxy coatings have been identified as promising materials to be used on reinforcing bars embedded in concrete decks of experimental bridges.

BSS66. **Underground heat and chilled water distribution systems,** T. Kusuda, Ed., Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 66, 146 pages (May 1975) SD Catalog No. C13.29/2:66.

Key words: corrosion of underground pipes; district heating; hot and chilled water systems; insulation of underground pipes; specifications for underground systems.

This publication contains the keynote address and all the technical papers presented during the Symposium on Underground Heat and Chilled Water Distribution Systems, which was held on November 26 and 27, 1973 in Washington, D.C.

The Symposium was sponsored jointly by the National Bureau of Standards, the National Capital Chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the Building Research Institute and the Association of Physical Plant Administrators.

The subject matter covered in the papers includes energy, economics, design criteria, heat transfer, corrosion protection, specification, operation, and maintenance related to underground pipes. *These proceedings include the following papers (indented):*

The energy situation and central plant, T. R. Casberg, *BSS66*, pp. 5-8 (May 1975).

Key words: central plant system; coal gasification; heat pump system; heat recovery and conservation system; nuclear fuel; on-site power generation system; petroleum problems.

Several optimistic myths regarding the energy situation in the United States are clarified by using factual data leading to an inevitable conclusion that there exists a real, rough and long lasting energy shortage.

The author stresses that the energy crisis demands engineers to forget yesterdays' data on building design practices and fuel cost, and to play an entirely new ball game that requires new thinking, a fresh approach, and a daring attitude. Several innovative approaches pertaining to central plant concept, such as on-site power generation, solar energy utilization, large scale heat pumps and energy storage are discussed.

Economic advantages of central heating and cooling systems, J. E. Mesko, *BSS66*, pp. 9-17 (May 1975).

Key words: central heating and cooling plants; cost analysis; cost comparison; economics; future trend; local building heating/cooling plants, Southeast Federal Area, Washington, D.C.

Economic comparisons between central and local building heating and cooling plants have been prepared and analyzed. Inherent and basic economic advantages in the distribution of heat and cooling from a single central district plant, over those practically attainable from individual local building plants, are analyzed and presented graphically. Factors contributing to the economic advantages of central plants are described.

The cost comparison performed for a 30-year future time period for the Southeast Federal Area of Washington, D.C., indicates that by year 2000 it will cost 15 to 20 percent less annually to own and operate a properly selected and phased central plant system than the optimum cost local plant systems.

Heat transfer studies of underground chilled water and heat distribution systems, T. Kusuda, *BSS66*, pp. 18-41 (May 1975).

Key words: chilled water pipe; earth temperature; heat transfer; multiple pipe system; underground pipe.

Heat transfer theory of underground pipe systems which include systems of more than one pipe at different temperatures buried in the same trench is summarized in this paper. Experimental observation made on a two-pipe chilled water system connecting the Pentagon and another Federal Office Building (FOB2) in Washington, D.C., was used to verify the theoretical analysis. In addition, the paper presents a concept of using integrated 10 ft average temperatures I10ET of selected earth temperature stations in the United States for design calculations.

The I10ET's could be used for selecting the pipe insulation in lieu of the ground water temperatures on certain average temperatures, which are currently being used.

Design criteria of underground heat and chilled water distribution systems for corrosion protection, J. H. Fitzgerald, III, and K. J. Moody, *BSS66*, pp. 42-51 (May 1975).

Key words: anodes; cathodic protection; coatings; corrosion; deterioration; inhibitors; materials selection; nonmetallics; rectifiers; water treatment.

Corrosion failures occur in all types of heat and chilled water distribution systems unless precautions are taken. Failures are expensive and cause shutdowns, hazardous conditions, occasional catastrophies and inconvenience to involved personnel and the general public. Corrosion leaks cause wetting of thermal insulation, resulting in thermal losses. For new construction, a corrosion survey should be made to determine best course of action, materials to use and the precautions needed to achieve the desired life of the piping. Cathodic protection is necessary for steel conduit or direct burial piping. Protection is also needed for steel pipe in insulative backfills. Mini-tunnels need to be kept dry or protection used. Internal corrosion is controlled with inhibitors. Nonmetallic materials and various means of construction should be considered to establish the best long-term approach. For existing systems, a survey should be made to determine if protection, repairs or replacement is the best course. Several case histories illustrate typical corrosion problems.

which will affect Agency Specifications, and plans f revising the present specifications are discussed.

Specifications for an underground heated and chilled wat system for private sector contracts, G. S. Campbell, *BSS6* pp. 78-87 (May 1975).

Key words: cascade heater; insulated underground pipin insulation; limitation of liability; "or equal" specificatior performance specifications; schematic diagrams; specific tions; specification writer.

Based on 30 years experience in Consulting Engineerir an over-view is given of the technical specifications r quired (1) to show the designers' intent, (2) to set out clear the material and equipment required under the propos contract, and (3) to establish the construction metho which will be required for certain operations. The necessa capabilities of a specification writer are suggested. The tr scope of a complete specification is outlined and a workab format is given. The impossibility of following the "3 nam and catalogue numbers" approach is shown. A comment to the practicality of the performance specification given. Certain design considerations underlying an unde ground heated and chilled water system are enumerate The need for accurate site utility information is emphasize The need for accurate delineation of contract limits in tl Contract Documents is shown. The typical equipment the Central Energy Plant serving an underground syste is enumerated. The various types of piping materials a their applications are discussed. Particular attention given: cascade heaters, pumps, and insulated undergrou piping. The problems of protecting insulation are explore Several thoughts on unexpected design and installati problems are given. The need for Limitation of Design Liability is explained. Finally, a method is suggested obtain maximum competition at minimum contract cost.

Fiberglass reinforced plastic pipe in underground condensa return service, H. O. Andersen, *BSS66*, pp. 88-101 (M 1975).

Key words: condensate return; epoxy; fiberglass rei forced plastic; filament-wound; insulated; molded; morp oline; prefabricated steel conduit; Qualified Products Lis tieline.

In 1967 approximately 3,700 lineal feet of uninsulate fiberglass reinforced plastic (FRP) pipe was installed f condensate return service in a steel conduit with an i sulated steam line at the Naval Weapons Center, Chi Lake, California. The FRP fittings failed. Factors co tributing to the failures were: (1) improper supports for th FRP line which prevented free movement; and, (2) th FRP elbows installed had a lower pressure rating tha specified. The testing procedure followed to evaluate th product of another FRP pipe manufacturer and measur taken to provide a successful condensate return system a discussed.

Inter-building heat energy distribution systems: growt operation and maintenance experience, W. L. Viar, *BSS6* pp. 102-115 (May 1975).

Key words: anchor; controls; corrosion; gorwth; meterin modern; museum; primary; reliability; renovation; secon ary; system; variable.

District heating concepts are used in heat energy supp to the vast majority of buildings at the University of Vi

Available types of underground heat distribution systems, H. A. Borger, *BSS66*, pp. 52-59 (May 1975).

Key words: heat distribution; heating; high temperature water; hot water; insulation; piping; steam; underground piping.

This paper briefly discusses the main features and characteristics of various types of currently-available underground heat distribution system, including concrete trenches, clay tile conduits, pressure testable steel conduits, sectionalized conduits, insulating envelopes, and sealed insulation systems.

Design criteria for auxiliary equipment for underground heating and cooling distribution systems, R. O. Couch, *BSS66*, p. 60-72 (May 1975).

Key words: accesses; ball joints; concrete manholes; expansion joints; expansion loops; o-ring gaskets; prefabricated manholes; restrained piping.

Manholes are an important and necessary part of any distribution system. They may be made of concrete or prefabricated steel. Design considerations must be given to sizing, accesses, ventilation, sumps, and miscellaneous equipment. Expansion provisions must also be provided for piping in distribution systems by using natural piping flexibility, expansion joints, ball joints, or gasketed couplings on the pipe.

Federal agency specification for underground heat distribution systems, L. V. Irvin, Jr., *BSS66*, pp. 73-77 (May 1975).

Key words: ASTM; criteria; Federal Construction Council; interagency; prequalification; system performance; triservice; underground heat distribution.

Past and present efforts of the Federal Construction Council (FCC) Task Group on Underground Heat Distribution Systems are reviewed. It is pointed out that the present FCC criteria, properly implemented by Inter-Agency performance specifications, have been very successful in reducing the number of system failures. It is also noted that these criteria are too inflexible, and have resulted in the use of unnecessarily expensive systems in some areas and prevented the acceptance of promising new concepts. The FCC criteria are now being updated and are expected to be made available in early 1974. General provisions of the proposed criteria, activities in other areas such as ASTM, ginia. Building ages and construction methods range from 1825 to the present. A number of buildings are too distant from the central heating plant, and are heated by their respective small fired-furnace circulating water systems. Services distributed underground from the central plant include multi-pressure steam lines, medium temperature hot water and domestic hot water. Demands have increased severely on all systems, particularly since 1952. During the period 1965–75 University building space will have been increased by about 112 percent; not all new loads will be placed on central heating facilities. Growth, renovation and upgrading effects on operation and maintenance of heat generating and distributing equipment and personnel have been encumbering at times. Proper planning, scheduling, design and construction followed by satisfactory performance of equipment, systems and personnel have been combined to achieve adequate winter conditioning for this institution, with continuity. Summer air conditioning is relatively new here. Refrigeration units are scattered, vary from one-half to 1,000 tons capacity, have been added in less than systematic fashion, to be generous. There is no inter-building distribution of chilled liquids to date. It is envisioned that central heating and central cooling concepts will ultimately be blended here for most efficient utilization and rejection of heat energy in the pursuit of controlled environment.

Cathodic protection can be an effective means for preventing corrosion on underground metallic structures, R. C. Young, *BSS66*, pp. 116–119 (May 1975).

Key words: cathodic protection; insulating joints; nonconducting coating; sacrificial anodes; soil resistivity.

Cathodic protection can effectively prevent electrochemical corrosion on underground metallic piping and other structures for as long as the use of the piping is required. However, the system must be designed to suit the soil environment, and physical makeup of the structure by someone fully experienced in such work. Thorough inspection must be maintained during installation to assure that the system is properly installed as verified by a completion check by a knowledgeable person. Included in the final report should be a maintenance program to monitor the cathodic protection system preferably one that can be made by regular maintenance personnel. The maintenance program should be carried out fully, and any failures that occur should be remedied promptly otherwise early failure of the structure may be experienced.

Operation and maintenance of steel conduit systems, R. J. Ruschell, *BSS66*, pp. 120–121 (May 1975).

Key words: design specification; guide and installation procedures; steel conduit system.

Thousands of manhours have been devoted to preparing a "Guide Specification for Military Construction, Heat Distribution Systems Outside of Buildings". This specification has been in mandatory use since 1965 by the Department of Defense and other Federal and State agencies. The system design and installation procedures have incorporated the knowledge and experience of many of the most able mechanical engineers from government and private industry. Only minor changes have been made to the Guide Specification during the past twelve years. No guide or procedure has been issued in regard to maintaining these underground systems. Additional years of useful, economic life could be realized from a program of inspection and prompt repair procedures where indicated.

Experience with central heat distribution systems in cold regions, W. Tobiasson, *BSS66*, pp. 122–135 (May 1975).

Key words: air leakage; Arctic; central heat distribution systems; construction materials; drainage; insulation; permafrost; seasonal frost; snow drifting; utilidors; ventilation.

Buried, on-grade and elevated central heat distribution systems have been built in the cold regions of the Northern Hemisphere. Heating lines are frequently routed along with water lines, sewers and other utilities in conduits known as utilidors. In areas where the ground is permanently frozen, systems are generally designed to prevent thaw and subsidence of the supporting soil as well as prevent freezing liquids in the lines. One approach is to support the utilidor on piles. Such utilidors are often elevated several feet above the surface to minimize snow drifting problems. Elevated utilidors can be obstructions to the movement of individuals and vehicles in a community. Elevated utilidors subjected to differential heave and settlement have developed gaps through which cold air infiltrated and caused freezeups.

The bulb of thaw created around a buried conduit containing warm utilities can be a collecting point for ground water, especially in the spring. Flooding can result unless the conduit is watertight or provisions are made to redirect the ground water. Many large buried utilidors in Siberia are ventilated in the winter to annually refreeze the surrounding soil.

Provisions for winter maintenance are important features of all central heat distribution systems in cold regions.

To illustrate the above points, design and performance data are presented in this paper for several central heat distribution systems in Alaska, Canada, Greenland and Siberia.

BSS67. **Abnormal loading on buildings and progressive collapse. An annotated bibliography,** E. V. Leyendecker, J. E. Breen, N. F. Somes, and M. Swatta, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 67,* 60 pages (Jan. 1976) SD Catalog No. C13.29/2:67.

Key words: abnormal loading; alternate path; annotated bibliography; bibliography; building code; building regulations; collapse; failures; progressive collapse; specific resistance.

This bibliography on the subjects of abnormal loading and progressive collapse is an annotated listing of articles that have appeared in the technical literature from 1948 through 1973. The entries have been arranged chronologically by year and alphabetically within years. Both subject and author indexes have been included. The references listed have been selected as most representative of the historical background and best representing the origin and present state-of-the-art of current practice without undue repetition of data.

References pertaining to characteristics, frequencies, incidents, tests, design procedures, and regulations for many types of abnormal loadings are included. Among these are various types of accidental impacts, construction loads, explosions, faulty practices, and extreme atmospheric loads. Heavy emphasis was placed on referencing applicable building codes and regulations pertaining to the subjects of progressive collapse and abnormal loadings. This bibliography also contains numerous references to contemporary professional opinion as expressed in editorials and discussions of the subject and particularly, on the various regulations proposed. A large number of proposed analysis and design procedures, as well as applicable test results, are referenced. In addition to the general reference material, a careful search was made of the ten most recent years (1964-1973) of *Engineering News Record* to identify and annotate possible progressive collapse examples from building failures reported by that publication.

BSS68. **Review of standards and other information on thermoplastic piping in residential plumbing,** R. S. Wyly, W. J. Parker, D. E. Rorrer, J. R. Shaver, G. C. Sherlin, and M. Tryon, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 68, 65 pages (May 1975) SD Catalog No. C13.29:2/68.

Key words: fire performance of piping; functional performance of piping; performance characteristics for piping; thermal/structural performance of piping; thermoplastic piping in plumbing.

The paper is a review of existing information on the physical characteristics of thermoplastic piping that are of particular interest in considering its potential for use in residential, aboveground plumbing. The presentation is oriented to considerations of adequacy of functional performance of plumbing systems from the user's/owner's viewpoint in contrast with the typical product-specifications oriented format reflected in current standards.

Not only are the physical characteristics emphasized that re late most directly to the determination of functional performanc of installed systems, but the importance of design and installatio detail in the context is discussed.

In conclusion, this review indicates the need for better use c existing knowledge as well as for some research and tes development work particularly in the areas of thermal propertie response to building fires, and resistance to water hammer.

BSS69. **NBSLD, the computer program for heating and coolin loads in buildings,** T. Kusuda, *Nat. Bur. Stand. (U.S.), Bldg Sci. Ser. 69,* 398 pages (July 1976) SD Catalog No C13.29/2:69.

Key words: ASHRAE task group on energy requirement conduction transfer functions; heating and cooling load; Na tional Bureau of Standards heating and cooling load com puter program.

A comprehensive computer program called NBSLD, the Na tional Bureau of Standards Load Determination program, ha been developed at NBS to reflect the time change of the man building parameters which are pertinent to accurate estimatio of energy usage for heating and cooling. Current status of heatin and cooling load techniques is reviewed. Of general interest a unique features of NBSLD which are not available in existin computer programs. A summary of various subroutines NBSLD is given along with the detailed procedures for then These subroutines constitute the recommended subroutine a gorithms of the ASHRAE Task Group on Energy Requir ments. Complete Fortran listing of NBSLD and data preparatic forms are given for those who wish to use the program. Tl NBSLD computation is on the basis of the detailed solution simultaneous heat balance equations at all the interior surfac of a room or space. Transient heat conduction through exteri walls and the interior structures is handled by using conductic transfer functions. The use of heat balance equations, althou time-consuming in calculation, can avoid the vagueness and u certainties inherent in the more popularly used weighting fact approach. In addition, it is more accurate for a specific buildi design.

BSS70. **Windows and people: A literature survey. Psychologic reaction to environments with and without windows,** B. L. Co lins, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 70, 92 pag (June 1975) SD Catalog No. C13.29/2:70.

Key words: daylight; fenestration; psychological; sol glass; spaciousness; sunshine; view; windowless; window

An understanding of human requirements for windows buildings can be developed through a survey of the literature c the reaction to environments with and without windows. Evalu tion of the response to a variety of windowless situations revea that although the attitudes toward a windowless space are ofte somewhat unfavorable, the most adverse reaction occurs in small, restricted and essentially static environment. This su gests that one function performed by a window is the addition a dynamic, active quality to an interior environment. Consider tion of the response to the actual presence of windows indicat that another essential function of a window is the provision of view of the external world. Although almost any view is accept ble, there is some evidence that views with a high informatic content are preferable. In addition, windows admit illuminatio in the form of daylight and sunshine which furnish a dynami changing character to a room. Yet, the functions of windows e tend beyond view and illumination to an enhancement of th basic character of a room, such that the mere presence of a wi dow may cause a room to appear more spacious. Finally, the o timum size and shape of a window for fulfilling these vario functions is discussed.

BSS71. **A proposed concept for determining the need for air conditioning for buildings based on building thermal response and human comfort,** J. E. Hill, T. Kusuda, S. T. Liu, and F. J. Powell, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 71, 155 pages (Aug. 1975) SD Catalog No. C13.29/2:71.

Key words: air conditioning criteria; building thermal response; comfort indices; human comfort; predicted indoor habitability index.

Determining the need for air conditioning can be based on a wide variety of factors. To date, the only criteria that have been written and can be referenced are those of several federal organizations and many are not really criteria in the true sense of the word. They are guidelines to be used in the determination of fund allocation; in other words, provisions are made to air condition federal facilities in specific geographical locations if pertinent weather characteristics of that locality meet certain requirements. This paper presents the concept that a true criteria can be established based both on weather characteristics of the locality as well as characteristics of the building or structure under consideration.

The paper gives the details of a study showing the feasibility of such a scheme. A simulation was made of two proposed residences in several geographical localities. For the simulation, actual hour-by-hour weather data was used in conjunction with a sophisticated computer program. The results revealed for the non air-conditioned spaces, the extent and duration of undesirable indoor conditions based upon generally accepted comfort indices. The concept of a new "comfort" or "discomfort" index called Predicted Indoor Habitability Index (PIHI) is introduced. The authors indicate the way in which a criterion could be established that would be in the form of tables, indicating for a given specified building and geographical locality, whether mechanical cooling should or should not be installed.

BSS72. **Fire endurance of gypsum board walls and chases containing plastic and metallic drain, waste and vent plumbing systems,** W. J. Parker, M. Paabo, J. T. Scott, D. Gross and I. A. Benjamin, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 72, 114 pages (Sept. 1975) SD Catalog No. C13.29/2:72.

Key words: ABS; DWV; fire endurance; fire spread; fire test; gases; plastic pipe plumbing; PVC; smoke.

The use of plastic pipe in plumbing systems of multiple-occupancy buildings has raised considerations regarding fire safety. To provide needed data, ten full-scale fire endurance tests were performed involving a total of 39 plumbing chase and wall assemblies containing plastic and metal drain, waste, and vent (DWV) systems typical of installations serving one or two story buildings. Two tests were conducted using plumbing chase configurations simulating kitchen sink drain systems. The PVC DWV piping in these installations did not contribute to spread of fire from one side of the construction to the other. Six fire endurance tests were conducted in which the performance of ABS, PVC, copper and iron was compared directly in kitchen sink drain systems as installed in wood-stud and gypsum-board walls. The stacks ranged from 2 inch to 4 inch in diameter and laterals from 2-1/2 inch to 4 inches. In these tests it was noted that the plumbing configuration and wall construction details, particularly the sealing of plumbing penetrations, seriously affected the fire endurance of the barrier. Satisfactory performance was achieved when certain conditions were met. In the two tests involving nominal 2 by 4 steel-stud-and-gypsum-board walls it was determined that the one-hour fire resistance rating of the wall was reduced considerably when ABS or PVC DWV was installed within it using the construction details described in this report. These details included back to back 1-1/2-in diameter laterals feeding directly into 2-in diameter stacks.

BSS73. **Structural performance of masonry walls under compression and flexure,** S. G. Fattal and L. E. Cattaneo, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 73,* 65 pages (June 1976) SD Catalog No. C13.29/2:73.

Key words: brick; buckling; composite walls; compressive strength; concrete block; constitutive relations; flexural strength; masonry; masonry walls; mortar; slenderness ratio; standards; stiffness; structural stability; walls.

Ninety-five prisms and fifty-six walls of brick, concrete block and composite brick and block masonry construction were tested under various combinations of compressive and transverse loads. Constitutive relations for masonry are developed from test results. By using rational analysis it is shown that prism strength can be predicted on the basis of linear behavior at failure. It is also shown that wall strength can be predicted on the basis of prism strength when an appropriate allowance is made for the effect of wall slenderness on sectional capacity.

BSS74. **The buffeting of tall structures by strong winds,** E. Simiu and D. W. Lozier, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 74, 90 pages (Oct. 1975) SD Catalog No. C13.29/2:74.

Key words: accelerations; buffeting; building codes; buildings; deflections; dynamic response; gust factors; structural engineering; wind engineering; wind loads.

Certain shortcomings of current procedures for computing alongwind structural response have been shown to result in unrealistic estimates of tall building behavior under the action of strong winds. Differences between predictions of fluctuating response based on various such procedures may be as high as 200 percent. In recent years, advances in the state of the art have been made which provide a basis for significantly improved alongwind response predictions. The purpose of the present work is to present a procedure for calculating alongwind response which incorporates and utilizes these advances. The basic structural, meteorological and aerodynamic models employed are described, and expressions for the alongwind deflections and accelerations, consistent with those models, are derived. A computer program is presented for calculating the alongwind response of structures with unusual modal shapes or for which the contribution of the higher modes to the response is significant. For more common situations, a simple procedure is presented which makes use of graphs and on the basis of which rapid manual calculations of the alongwind deflections and accelerations can be performed. Numerical examples are given to illustrate the use of the computer program and of the graphs. Results of numerical calculations are used to discuss some of the approximations and errors inherent in the models employed.

BSS76. **Analysis of reinforced concrete beams subjected to fire,** B. Ellingwood and J. R. Shaver, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 76,* 83 pages (July 1976) SD Catalog No. C13.29/2:76.

Key words: creep; fire endurance; fire tests; reinforced concrete; sensitivity analysis; steel; structural mechanics; uncertainty.

Methods for analytically predicting the behavior of simply supported reinforced concrete beams subjected to fire are presented. This is generally a two-step process involving a thermal analysis followed by a stress analysis. This study emphasizes the latter, wherein the determination of moment-curvature-time relationships for the beam cross section incorporates the temperature-dependent strength degradation in the steel and concrete as well as thermal and creep strains. The sensitivity of the predictions to various phases of analytical modeling is in-

vestigated to establish the parameters most important for the prediction of beam behavior and to indicate where additional data should be gathered. A comparison of predicted behavior with that observed in fire tests shows excellent agreement when realistic reinforcement temperature histories are used.

BSS77. **Acoustical and thermal performance of exterior residential walls, doors and windows,** H. J. Sabine, M. B. Lacher, D. R. Flynn, and T. L. Quindry, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 77, 170 pages (Nov. 1975) SD Catalog No. C13.29/2:77.

Key words: acoustics; air infiltration; air leakage; architectural acoustics; building acoustics; doors; energy conservation; heat loss from buildings; heat transfer; sound transmission loss; thermal resistance; thermal transmittance; windows.

Laboratory tests of sound transmission loss, thermal transmittance, and rate of air leakage were conducted on full scale (9 feet high × 14 feet wide; 2.7 × 4.3 meters) specimens of typical residential exterior wall constructions, either unbroken or penetrated by a door or window. The walls were of wood frame construction with gypsum board drywall interior finish and exterior finishes of wood siding, stucco, or brick veneer. Additional acoustical tests were run on a number of individual doors and windows. A total of 109 acoustical tests and 48 thermal tests are reported. The resultant data are compared with literature data on similar constructions. Correlations developed among the several quantities measured will assist more rational design where both energy conservation and noise isolation must be considered.

BSS78. **Pre-design analysis of energy conservation options for a multi-story demonstration office building,** T. Kusuda, J. E. Hill, S. T. Liu, J. P. Barnett, and J. W. Bean, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 78, 64 pages (Nov. 1975) SD Catalog No. C13.29/2:78.

Key words: building design; building energy analysis; energy conservation options; energy design optimization; heating and cooling load calculation.

The design phase of the GSA-Manchester Building included extensive analysis of the building design and operation to determine the potential for energy conservation. Described in this report are highlights and a summary of the calculations performed during the design phase. The analysis included a study of the exterior shell, ventilation rate, lighting and occupancy levels, room temperature controls, and nighttime flushing of the building using outdoor air, on the predicted yearly energy consumption of the building.

BSS79. **Energy conservation potential of modular gas-fired boiler systems,** G. E. Kelly and D. A. Didion, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 79, 54 pages (Dec. 1975) SD Catalog No. C13.29/2:79.

Key words: boiler oversizing; efficiency vs. heating load; modular boilers; modular concept; seasonal efficiency.

The modular concept of boiler operation was examined in a laboratory test of five gas-fired, cast iron, hydronic boilers. Four of the boilers, each having an input rating of 85,000 Btu per hour, were arranged so that they could either be operated like a single boiler (i.e., all of the boilers either on or off) or as a modular installation in which the boilers are sequentially fired to match the number in operation with the heating load. The fifth boiler had an input rating of 300,000 Btu per hour and was operated as a single boiler installation. Efficiency vs. heating load curves were obtained for the single boiler installation, the four small boilers run like a single boiler and the modular installation operated with and without water flowing through the "idle" modules. These efficiency curves were then used to theoretically predict the effect of the modular concept and boiler oversizing on the seasonal efficiency of gas-fired heating plants. It was found that under certain conditions the use of a gas-fired modular boiler installation instead of a single large boiler could result in considerable energy savings.

BSS80. **Safety during construction of concrete buildings—A status report,** H. S. Lew, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 80,* 56 pages (Jan. 1976) SD Catalog No. C13.29/2:80.

Key words: building; codes; concrete; construction; falsework; formwork; loads; reshoring; safety; shoring; standards.

The current state-of-the-art of safety in concrete building construction is reviewed and summarized. The material presented considers only the technical aspects of the construction safety. Safety of the individual in using equipment and in following construction procedures is not included in this study.

The report presents comparative accident frequencies in concrete construction. Based on reported construction failures, the relative vulnerability of various categories of concrete construction is estimated. The report examines causes of construction failures and reviews major regulatory standards at the federal, state, city and industry level affecting safety in concrete construction.

The factors which affect safety in concrete construction are examined relative to the state-of-the-knowledge and, where appropriate, recommendations are made for areas needing improved standards.

BSS81. **Survey of ground fault circuit interrupter usage for protection against hazardous shock,** R. W. Beausoliel and W. J. Meese, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 81,* 19 pages (Mar. 1976) SD Catalog No. C13.29/2:81.

Key words: branch circuit protection; electrical safety; electric shock; ground fault; leakage current; prevention of electrocution.

The ground fault circuit interrupter (GFCI) is increasingly becoming an integral part of building electrical systems to protect human life. Building researchers, designers, and contractors should have a working knowledge of their purpose and operational characteristics. This report describes the functional principles of GFCIs and relates their performance to effects of electric current on the human body. Information concerning the history, research and testing, installation practices, fire protection aspects, types, manufacturers and costs of GFCIs are included. The trend of requiring installation of GFCIs on more and more electrical circuits by regulatory authorities for safety purposes is outlined. Controversies concerning feasibility, reliability, nuisance tripping and other problems are discussed; laboratory and field investigations addressing these problems should be undertaken.

Permanent installations of GFCIs are being made in new residential and other construction, but very few are being installed in older buildings. The rationale for this needs to be examined. Because of higher leakage currents probable in most older construction, GFCIs manufactured under present standards may not be feasible in older buildings.

BSS82. **A new look at the research basis for lighting level recommendations,** G. T. Yonemura and Y. Kohayakawa, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 82,* 13 pages (Mar. 1976) SD Catalog No. C13.29/2:82.

Key words: gratings; illuminating engineering; lighting;

modulation transfer function; suprathreshold visibility; visibility; vision.

The validity of using threshold studies as the basis for lighting vel recommendations is questioned. The performance of the e at suprathreshold levels was investigated with sine- and uare-wave gratings. The results of the study indicate that the havior of the eye is significantly different at suprathreshold vels as opposed to threshold levels. For threshold studies, hen contrast is plotted against luminance, the function is a onotonically decreasing function. At suprathreshold levels the nction indicates the existence of a definite minimum, luminances greater or less requiring more contrast to appear subtively equal. It is recommended that lighting levels be based laboratory studies that appraise visual requirements and permance simulating conditions encountered in real world enronments.

SS83. **Polymer impregnated hardened cement pastes and mortars,** J. R. Clifton, J. E. Fearn, and E. D. Anderson, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 83,* 21 pages (Apr. 1976) SD Catalog No. C13.29/2:83.

Key words: cement; compressive strength; flexural strength; fracture mechanics; polymer impregnated cement; polymer impregnated mortar; porosity; scanning electron microscopy.

Polymer impregnated hardened cement pastes and mortars ve been prepared and their properties compared to those of ntrol specimens. Specimens were made by impregnating dried d evacuated precast hardened cement pastes and mortars with ethyl methacrylate, under pressure, which was thermally lymerized. The effects of the microstructure of the cement stes and mortars on the performance of polymer impregnated rtars were determined by preparing specimens with a wide nge of porosities by varying the water to cement ratio and the uring times prior to impregnation.

The properties of impregnated and control specimens were inestigated by: scanning electron microscopy; porosity deterinations; fracture mechanics studies; and strength determinaons. The polymer impregnated materials had compressive and exural strengths, moduli of elasticity, and fracture toughnesses hich were substantially higher than unimpregnated materials.

SS85. **Survey results for fire loads and live loads in office buildings,** C. G. Culver, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 85,* 157 pages (May 1976) SD Catalog No. C13.29/2:85.

Key words: buildings; fire loads; load surveys; occupancy live loads; structural engineering.

Fire load and live load data obtained from a survey of 23 office uildings located in various regions throughout the United States e presented. The survey design is described including the haracteristics of the building population used to select the samle. Data are presented on the magnitude and distribution of the ads. Information is also included on the characteristics of ofce loads such as the type of items (furniture, equipment, etc.) nd their properties (material type, dimensions, exposure, etc.). tatistical summaries of the data and a determination of the uilding and occupancy characteristics affecting these loads are resented. The data do not indicate any significant differences etween the loads in private and government buildings. imilarly, geographic location, building height, and building age ere not found to have a significant influence on load magnitude. he use of the rooms surveyed, however, did affect load magitude. A mathematical model developed from a regression analsis of the survey data is presented for calculating fire loads and ve loads in offices. The data presented may be used to evaluate rrent requirements for design loads for buildings.

BSS86. **Engineering aspects of Cyclone Tracy, Darwin, Australia, 1974,** R. D. Marshall, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 86,* 39 pages (June 1976) SD Catalog No. C13.29/2:86.

Key words: buildings; cyclones; disasters; structural engineering; tides; wind.

During the early morning hours of December 25, 1974, the city of Darwin was devastated by the most damaging cyclone ever to strike the Australian Continent. Winds of up to 75 m/s caused extensive damage to housing in particular, requiring the evacuation of approximately half of the 45,000 residents to other major cities in Australia. This report is a result of the author spending several days on temporary assignment with the Department of Housing and Construction – Australian Government to inspect the damage, and to participate in discussions regarding the establishment of new design criteria and construction practices for cyclone areas. The fact that most of the damage was caused by wind forces rather than a combination of wind and storm surge greatly simplified the assessment of damage and structural performance. The experience at Darwin points out the danger in depending too heavily upon past experience and intuition in the design of housing. It also makes clear the need for additional research into the behavior of certain building materials under repeated loads and missile impact, and the racking strength of walls subjected to uplift loads.

BSS87. **Model documents for the evaluation, approval, and inspection of manufactured buildings,** P. W. Cooke, R. D. Dikkers, H. R. Trechsel, H. K. Tejuja, and L. P. Zelenka, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 87,* 296 pages (July 1976) SD Catalog No. C13.29/2:87.

Key words: building codes; certification; compliance assurance; evaluation; inspection; manufactured building; model documents; NCSBCS; standards; state regulation.

To assist the states in developing their building regulatory activities and functions, the Coordinated Evaluation System (CES) Project has defined and developed model informational documentation pertaining to the functional areas of (1) data submission, (2) evaluation, (3) approval, (4) compliance assurance, and (5) installation data.

This report gives the results of the project's investigations and presents sample model documents pertaining to manufactured buildings and building components. The model documentation is based on the Model Rules and Regulations for manufactured buildings developed by a Department of Commerce sponsored working task group, and the results of a comprehensive state-of-the-art study of most state building regulatory programs. The documentation presented covers all functional areas except owner information which is not usually subject to regulation. Emphasis was placed on developing documentation applicable primarily to one and two family detached dwellings.

BSS88. **Energy conservation in buildings—A human factors/systems viewpoint,** A. I. Rubin, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 88,* 19 pages (Nov. 1976) SD Catalog No. C13.29/2:88.

Key words: energy conservation; human factors; people in buildings.

The current emphasis on energy conservation in buildings must be balanced by a careful consideration of how proposed approaches affect building occupants. A head-long rush toward building designs which conserve energy at the expense of the quality of buildings as judged by occupants, would be a very shortsighted approach. There must be a continual awareness and sensitivity of the consequences on people when selecting among alternative "technical" options designed as a result of energy

conservation needs. We need an increasing understanding of such factors as thermal comfort and illumination needs in buildings, as decisions likely to influence these requirements are made by designers.

Another area of concern which should not be overlooked is the interactions of people with their environments. "Hardware" approaches to energy conservation problems are often defeated by building occupants. Tight seals around doors and windows are useless if doors and windows are kept open. Building occupants have no choice but to turn all of the lights on or off if these are the only control options available to them. Building managers, operators and occupants have an important, though not well understood role to play in any energy conservation program. This problem deserves serious attention.

BSS89. **The incidence of abnormal loading in residential buildings,** E. V. Leyendecker and E. F. P. Burnett, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 89,* 10 pages (Sept. 1976) SD Catalog No. C13.29/2:89.

Key words: bombs; building codes; design criteria; explosions; gas; hazardous materials; loads; progressive collapse; sonic boom; vehicular collision.

The findings of an analysis of available U.S. statistics concerning the incidence of abnormal loading events in residential buildings are presented. The study evaluates natural gas explosions, bomb explosions, motor vehicle collision, sonic boom aircraft collision, and explosion of hazardous materials.

It is concluded that the gas related explosion, bomb explosion, and vehicular collision are of significance in building design for progressive collapse. Of these, the natural gas explosion is the most significant in terms of incidence. The gas explosion causing severe damage occurs with an annual frequency of 1.6 per million dwelling units and approaches a probability of 1×10^{-3} per apartment building per year.

BSS90. **The structure of building specifications,** S. J. Fenves, K. Rankin, and H. K. Tejuja, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 90,* 83 pages (Sept. 1976) SD Catalog No. C13.29/2:90.

Key words: building code provisions; building codes; building component classification; building specifications; building standards; performance concept.

This paper provides a scientific basis for the formulation and expression of performance standards and specifications and for explicit attention to performance in procedural and prescriptive standards and specifications.

The provisions of the NBS-developed *Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings,* a performance specification, are classified in terms of the physical entities addressed, the attributes of the built environment, and the properties which group together particular physical entities which may be subject to similar dysfunctions. These provisions are also subjected to a linguistic analysis which examines in detail the wording used and formalizes certain key concepts which are realized in the wording.

The provisions of the *Uniform Plumbing Code,* a prescriptive code, are classified in terms of the physical entities addressed and the performance attributes which can be inferred (though they are not explicitly addressed).

Guidelines for the expression of provisions in performance codes and specifications are presented. These guidelines are based on the classification studies and the linguistic analysis mentioned above.

BSS91. **The development of an improved test for evaluating the racking resistance of wall panels,** C. W. C. Yancey, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 91,* 75 pages (Nov. 1976) SD Catalog No. C13.29/2:91.

Key words: lateral loads; loading rate; racking; test method; vertical loads; wall panels; walls.

An experimental investigation of the primary factors involved in the laboratory testing of prototype wall panels, under simulated wind-induced racking loads, is reported. The objective of the investigation was to recommend a static racking test method, generally applicable to a variety of wall construction types, that features realistic boundary and loading conditions. Initially, a literature survey was conducted for the purpose of evaluating the test methods which have been, or are being employed in determining the resistance of wall panels to static racking loads. In the experimental program, 17 exploratory tests were conducted on a sample comprised of two types of wall panel construction. The 8 ft by 8 ft steel-frame and wood-frame panels were subjected to a combination of vertical and horizontal loading and their resulting deformation behavior was systematically monitored. Modifications to the testing procedure and to the boundary condition at the top of the panels were introduced as the experiments progressed. Detailed descriptions of the laboratory procedures used are presented. As the tests were developmental in nature and not intended for performance evaluation of the types of construction, selected results are presented. A static racking test method, applicable to traditional and innovative wall construction was derived as a result of the laboratory study and the literature survey. The principal new features of the proposed standard method are: (a) the application of distributed vertical loading, (b) the capability of testing panels of various height-to-width ratios and (c) the provision of top and bottom boundary conditions which do not force unrealistic modes of failure.

BSS92. **The viscosities of roofing asphalts at application temperatures,** W. J. Rossiter, Jr., and R. G. Mathey, *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 92,* 44 pages (Nov. 1976) SD Catalog No. C13.29/2:92.

Key words: application temperature; asphalt; built-up roofing; interply thickness; roofing membranes; viscosity.

The optimum range of viscosity over which hot asphalt should be applied in the fabrication of built-up roofing membranes was determined to be 50 to 150 centistokes (mm^2/s). This viscosity range was based on the relationship between interply thickness and application temperature of asphalt obtained from roofing membrane specimens fabricated in the field. Because laboratory measurements showed a wide range of viscosities for roofing asphalts of the same type over their application temperature ranges, it was recommended that asphalts be applied at temperatures based on viscosity and not empirically determined temperature limits. In practice, the viscosity-temperature relationship should be determined for each roofing asphalt for the application temperature range prior to use. Using this relationship and the optimum viscosity range, the temperature range for applying each asphalt can be determined.

3.13. FEDERAL INFORMATION PROCESSING STANDARDS PUBLICATIONS

Publications in this series collectively constitute the Federal Information Processing Standards Register. Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations). This series is available only from the National Technical Information Services, Springfield, VA 22161. See page 17 for price list.

FIPS PUB 0. **General description of Federal Information Processing Standards register,** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 0, 8 pages (Nov. 1, 1968).

Key words: Federal Information Processing Standards Register; general description.

This document defines the responsibilities for the Register, defines its contents and categories of standards, and suggests a method for establishing and maintaining standards within an activity.

FIPS PUB 1. **Code for information interchange. Hardware standard interchange codes and media,** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 1, 4 pages (Nov. 1, 1968).

Key words: Federal Information Processing Standard; code for interchange.

This document provides administrative, policy, and guidance information relative to the implementation and utilization of the standard code for information interchange.

The technical specifications of this standard are available to Federal Government activities from the General Services Administration Specifications Activity at a cost of 40 cents per copy. Refer to FIPS 1. Others may obtain copies from the United States of America Standards Institute for $2.00 per copy. Refer to USA Standard X3.4-1968. The technical specifications define a code and character set for use in Federal information processing systems, communications systems and associated equipments.

FIPS PUB 2. **Perforated tape code for information interchange. Hardware standard interchange codes and media,** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 2, 4 pages (Nov. 1, 1968).

Key words: Federal Information Processing Standard; perforated tape code for information interchange.

This document provides administrative, policy, and guidance information pertaining to the implementation and utilization of the standard perforated tape code for information interchange. The technical specifications of this standard are available to Federal Government activities from the GSA Specifications Activity at 45 cents per copy. Refer to FIPS 2. Others may obtain copies from the United States of America Standards Institute for $1.50 per copy. Refer to USA Standard X3.6-1965. The technical specifications of the standard specify the representation of the Federal Standard Code for Information Interchange (FIPS) on perforated tape used in Federal information processing systems, communications systems, and associated equipments.

FIPS PUB 3, Superseded by FIPS PUB 3-1.

FIPS PUB 3-1. **Recorded magnetic tape for information interchange (800 CPI, NRZI),** P. S. Johnson, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process Stand. Publ. (FIPS PUB) 3-1, 4 pages (1973) 20 cents, SD Catalog No. C13.52:3-1.

Key words: Communications; computers; computer system hardware; data processing; data processing equipment; information systems; magnetic tape recording; magnetic tapes; magnetic tape transports; standards.

This standard specifies the recorded characteristics of 9-track, one-half inch wide magnetic computer tape, including the data format for implementing the Federal Standard Code for Information Interchange at the recording density of 800 characters per inch (CPI). It is one of a series of Federal Standards implementing the Federal Standard Code for Information Interchange (FIPS 1) on magnetic tape media. This revision to FIPS PUB 3 reflects a change in scope from the earlier version of X3.22-1967, and encompasses the recorded tape requirements only. The unrecorded tape standard will include the requirements for the physical properties of the tape and reels that were previously included in FIPS 3. Supersedes NBS FIPS PUB 3.

FIPS PUB 4. **Calendar date (Federal general data standard representations and codes),** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 4, 4 pages (Nov. 1, 1968).

Key words: Calendar date; Federal Information Processing Standard.

This publication announces the adoption of a Federal standard for representing calendar dates used in the interchange of formatted machine sensible coded data between and among agencies. The technical specifications (FIPS 4) are affixed to the FIPS PUB.

FIPS PUB 5, Superseded by FIPS PUB 5-1.

FIPS PUB 5-1. **States and outlying areas of the United States. Federal General Data Standard Representations and Codes,** Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub) 5-1, 4 pages (1970).

Key words: ADP standards; computers; data elements and codes; data processing; Federal Information Processing Standards; geography; information processing standards; information systems; National Government; representations and codes; standards; states; statistical data.

This publication provides names, abbreviations, and codes for representing the 50 States, the District of Columbia, and the outlying areas, all of which are considered to be "first order subdivisions" of the United States for use in the interchange of formatted machine sensible data. (Supersedes FIPS Pub. 5.)

FIPS PUB 6, 6-1, Superseded by FIPS PUB 6-2.

FIPS PUB 6-2. **Counties and county equivalents of the states of the United States. Federal general data standard representations and codes,** *(ANS X3.31-1973),* H. E. McEwen, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 6-2, 35 pages (1973) 65 cents, SD Catalog No. C13.52:6-2.

Key words: ADP standards; computers; data elements and codes; data processing; Federal Information Processing Standards; geography; information processing standards; information systems; national government; representation and codes; standards; statistical data.

This publication provides names and codes for representing the Counties of the 50 States or county equivalents thereof for use in the interchange of formatted machine sensible data. Also included in the set of codes are the independent cities of Maryland, Missouri, Nevada, and Virginia and the Census Divisions and boroughs of Alaska. Supersedes NBS FIPS PUB. 6-1.

FIPS PUB 7. **Implementation of the code for information interchange and related media standards. Hardware standards interchange codes and media,** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 7, 14 pages (Mar. 7, 1969).

Key words: Federal Information Processing Standard; hardware standards interchange codes.

This FIPS PUB provides further details covering the implementation of the Code for Information Interchange (FIPS 1), Perforated Tape Code for Information Interchange (FIPS 2), and Recorded Magnetic Tape Code for Information Interchange (800 CPI, NRZI) (FIPS 3). The publication includes a letter of approval of these standards by the President of the United States and a letter with attachments by the Secretary of Commerce providing details and policy of their implementation.

FIPS PUB 8,8-1,8-2,8-3, Superseded by FIPS PUB 8-4.

FIPS PUB 8-4. **Standard Metropolitan Statistical Areas,** H. E. McEwen, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 8-4, 20 pages (1974) SD Catalog No. C13.52:8-4.

Key words: computers; data processing; Federal Information Processing Standards Publication; representations and codes; Standard Metropolitan Statistical Areas.

This publication provides standard identifications and codes for representing Standard Metropolitan Statistical Areas for the interchange of machine sensible data among agencies. It supersedes FIPS 8-3, Standard Metropolitan Statistical Areas, dated 1973 August 15. The general concept of a Standard Metropolitan Statistical Area, commonly referred to as "SMSA" is one of an integrated economic and social unit with a recognized large population nucleus. The codes are available on Hollerith punched cards. The following data elements are provided: SMSA Title (Name) and SMSA Code. Supersedes FIPS PUB 8-3.

FIPS PUB 9. **Congressional districts of the United States. Federal general data standard representations and codes,** H. S. White, Jr., Editor, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 9, 4 pages (November 14, 1969).

Key words: Congressional districts of the United States; Federal Information Processing Standard.

Congressional districts are considered to be any of the districts into which a State is divided for the purpose of electing representatives to the House of Representatives of the United States Congress. This standard provides codes for representing the congressional districts identified in the various Congresses of the United States.

FIPS PUB 10,10-1, Superseded by FIPS PUB 10-2.

FIPS PUB 11, Superseded by FIPS PUB 11-1.

FIPS PUB 12, 12-1, Superseded by FIPS PUB 12-2.

FIPS PUB 12-2. **Federal information processing standards index,** H. E. McEwen, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 12-2, 195 pages (1974) SD Catalog No. C13.52:12-2.

Key words: American National Standards; computers; data elements and codes; data processing systems; Federal Information Processing Standards; management information systems; International Organization for Standardization; standards; U.S. Government.

This publication provides material concerning standardization activities in the area of information processing at the Federal, National, and International levels. Also included are related policy and procedural guideline documents. A list of Federal Government participants involved in the development of Federal Information Processing Standards is provided. This FIPS PUB is revised and updated annually. Supersedes NBS FIPS PUB 12-1.

FIPS PUB 13. **Rectangular holes in twelve-row punched cards** H. S. White, Jr., Nat. Bur. Stand. (U.S.), Fed. Info. Process Stand. Publ. (FIPS Pub.) 13, 4 pages (1971).

Key words: American Standard Code for Information Interchange; ASCII; card punch; card reader; data communications; data interchange; data processing; EAM cards electric accounting machine; Federal Information Processing Standard; Hollerith punched cards; information interchange; information processing; punched cards; rectangular holes.

This publication provides information on the size, location and dimensional tolerances of rectangular holes in 12-row, 3 1/4 inch wide punched cards. It applies to card reading and punching equipment used in data processing, communications and similar operations in the Federal government. This Federal standard adopts in whole a revised version of American National Standard X3.21-1967, Rectangular Holes in 12-Row Punched cards.

FIPS PUB 14. **Hollerith punched card code,** H. S. White, Jr. Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 14, 4 pages (1971).

Key words: American Standard Code for Information Interchange; ASCII; card punch; card reader; data communications; data interchange; data processing; EAM cards electric accounting machine; Federal Information Processing Standard; Hollerith punched card code; Hollerith punched cards; information interchange; information processing; punched cards.

This publication provides a standard set of 128 hole patterns which represent the 128 characters of the Federal Standard Code for Information Interchange (ASCII) FIPS 1, in 12-row 80 column, rectangular hole, "Hollerith" punched cards, or the subsets of ASCII as specified in FIPS 15, Subsets of the Standard Code for Information Interchange. It adopts one-half of the 256 hole patterns given in the American National Standard X3.26-1969, Hollerith Punched Card Code.

FIPS PUB 15. **Subsets of the standard code for information interchange,** H. S. White, Jr., Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 15, 10 pages (1971).

Key words: American Standard Code for Information Interchange; ASCII; coded character subsets; codes; da

communication; data interchange; data processing; Federal Information Processing Standards; graphic character subsets; graphic subsets; information interchange; information processing; standards; subsets.

This publication provides three subsets of 95, 64 and 16 raphic characters derived from the Federal Standard Code for nformation Interchange (FIPS 1), which was adopted from the merican Standard Code for Information Interchange (ASCII) 3.4-1968. These subsets are for use in Federal printers, display evices, punched card equipment, and other data processing or ommunication equipments which utilize a character subset less an the full 128-character set of FIPS 1.

IPS PUB 16, Superseded by FIPS PUB 16-1.

IPS PUB 17, Superseded by FIPS PUB 17-1.

IPS PUB 18, Superseded by FIPS PUB 18-1.

IPS PUB 19. **Guidelines for registering data codes,** H. S. White, Jr., Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 19, 7 pages (1972).

Key words: Data codes; data elements; data processing systems standards; Federal information processing standards; management information systems; United States Government.

Office of Management and Budget Circular No. A-86, Standardization of data elements and codes assigns to the National Bureau of Standards responsibility for maintaining registers of data elements and codes, and to Federal departments and agencies the responsibility for registering program and agency codes with NBS. This publication provides guidelines for registering data codes with NBS and for reporting the use of the codes to maintaining agencies for purposes of receiving changes.

IPS PUB 20. **Guidelines for describing information interchange formats,** H. S. White, Jr., Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 20, 11 pages (1972).

Key words: Data processing systems standards; Federal Information Processing Standards; formatted records; information interchange; United States Government.

This publication provides guidelines which identify and escribe the various characteristics of formatted information that ould be considered whenever formatted information is interchanged. The objective is to clarify and improve the documentation necessary to effectively provide, process, or use the information involved. The guidelines provided are to be used roughout the Federal Government as a checklist for preparing fective documentation of formatted information interchange.

IPS PUB 21, Superseded by FIPS PUB 1-1.

PS PUB 21-1. **COBOL,** M. V. Vickers, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 21-1, 5 pages (Dec. 1, 1975) SD Catalog No. C13.52:21-1.

Key words: COBOL; data processing; Federal Information Processing Standard; information interchange; information processing; programming language; software; standards conformance.

This FIPS PUB announces the adoption of the American National Standard COBOL (X3.23-1974) as the Federal Standard OBOL. This revision supersedes FIPS PUB 21 and reflects ajor changes and improvements to the COBOL specifications. he American National Standard defines the elements of the OBOL Programming Language and the rules for their use. The standard is used by implementors as the reference authority in developing compilers and by users for writing programs in COBOL. The primary purpose of the standard is to promote a high degree of interchangeability of programs for use on a variety of automatic data processing systems.

The COBOL language is intended for use in computer applications that emphasize the manipulation of characters, records, and files.

FIPS PUB 22, Superseded by FIPS PUB 22-1.

FIPS PUB 23. **Objectives and requirements of the Federal Information Processing Standards Program,** H. S. White, Jr., Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 23, 8 pages (1972) 35 cents, SD Catalog No. C13.52: 23.

Key words: Computers; data processing; Federal Information Processing Standards; management; standards; U.S. Government.

Public Law 89-306 (the Brooks legislation) was enacted to provide for the economic and efficient purchase, lease, maintenance, operation and utilization of automatic data processing equipment by Federal departments and agencies. Among the other provisions of PL89-306, the Secretary of Commerce is authorized to make appropriate recommendations to the President relating to the establishment of uniform Federal automatic data processing standards. The Federal Information Processing Standards Program was established in response to this part of the legislation. The purpose of this document is to outline the objectives of the Federal Information Processing Standards Program and to identify requirements for specific standards necessary to accomplish these objectives.

FIPS PUB 24. **Flowchart symbols and their usage in information processing,** M. Keplinger, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 24, 4 pages (1973) 20 cents, SD Catalog No. C13.52:24.

Key words: Computer programming; computers; data processing, Federal Information Processing Standards; flow charting; flowchart symbols; information processing; standards.

This publication establishes standard flowchart symbols and specifies their use in the preparation of flowcharts in documenting information processing systems. This standard applies to any Federal information processing operation where symbolic representation is desirable to document the sequence of operations and the flow of data and paperwork.

FIPS PUB 25. **Recorded magnetic tape for information interchange (1600 CPI, phase encoded),** P. S. Johnson, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process Stand. Publ. (FIPS PUB) 25, 4 pages (1973) 20 cents, SD Catalog No. C13.52:25.

Key words: Communications; computers; computer systems hardware; data processing; data processing equipment; information systems; magnetic tape recording; magnetic tapes; magnetic tape transports; standards.

This standard specifies the recorded characteristics of 9-track, one-half inch wide magnetic computer tape, including the data format for implementing the Federal Standard Code for Information Interchange at the recording density of 1600 characters per inch (CPI). It is one of a series of Federal Standards implementing the Federal Standard Code for Information Interchange (FIPS 1) on magnetic tape media.

FIPS PUB 26. **One-inch perforated paper tape for information interchange,** P. S. Johnson, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 26, 4 pages (1973) 20 cents, SD Catalog No. C13.52:26.

Key words: Data processing; Federal Information Processing Standard; information interchange; information processing; paper tape; paper perforator tape.

This standard specifies the physical dimensions and tolerances of one-inch wide paper tape, including the size and location of the perforations used for recording information.

FIPS PUB 27. **Take-up reels for one-inch perforated tape for information interchange,** P. S. Johnson, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process Stand. Publ. (FIPS PUB) 27, 4 pages (1973) 20 cents, SD Catalog No. C13.52:27.

Key words: Data processing; Federal Information Processing Standard; information interchange; information processing; paper tape; paper perforator tape.

This standard specifies the physical dimensions of paper tape take-up (or storage) reels, with either fixed or separate flanges. The two types of reels specified differ in the size and shape of the drive hub, but both are intended for use with one-inch perforated paper tape devices.

FIPS PUB 28. **Standardization of data elements and representations,** H. S. White, Jr., Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 28, 12 pages (1973) SD Catalog No. C13.52:28.

Key words: computers; data elements and representations; data processing systems; Federal Information Processing Standards; management information systems; standards; U.S. Government.

Pursuant to the authority delegated to the Secretary of Commerce by Executive Order 11717 (38 FR 12315, dated May 11, 1973), Subtitle A of Title 15 of the Code of Federal Regulations has been amended to add a new Part 6 which implements the provisions of Section III (f) (2) of the Federal Property and Administrative Services Act of 1949, as amended (79 Stat. 1127). This new Part 6 supersedes and replaces in its entirety the provision of Office of Management and Budget Circular A-86 entitled, "Standardization of data elements and codes in data systems," dated September 30, 1967 which was rescinded by the Director of the Office of Management and Budget on August 29, 1973. Part 6 provides policy and identifies responsibilities of executive branch departments and independent agencies for a government-wide program for the standardization of data elements and representations used in Federal automated data systems. This publication provides a copy of Part 6 and other documents relating to this amendment.

FIPS PUB 29. **Interpretation procedures for Federal Standard COBOL,** R. E. Rountree, Jr., Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 29, 4 pages (1974) SD Catalog No. C13.52:29.

Key words: COBOL; compilers; data processing; Federal Information Processing Standard; information interchange; information processing; programming language; software.

This FIPS PUB defines the procedures that will be followed in requesting interpretations of the Federal Standard COBOL and in providing responses to those requests. The provisions of this document apply to all Federal departments and agencies and to vendors of COBOL compilers in their dealings with the Federal Government.

FIPS PUB 30. **Software summary for describing computer programs and automated data systems,** B. Marron, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 30, 5 pages (1974) SD Catalog No. C13.52:30.

Key words: computer programs; computers; computer software; data processing; Federal Information Processing Standards; information processing.

This publication provides a standard software summary form (SF-185) together with instructions for describing computer programs and/or automated data systems for identification, reference, and dissemination purposes. Federal Information Processing Standard Software Summary Form (SF-185) will be used in documenting summaries or abstracts of programs and/or automated data systems that are developed or acquired by Federal departments and agencies. This form will also be used by the General Services Administration in the establishment of a centralized registry of selected government software.

FIPS PUB 31. **Guidelines for automatic data processing physical security and risk management,** S. K. Reed, Ed., Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS Pub.) 31, 92 pages (1974) SD Catalog No. C13.52:31.

Key words: ADP security; computer reliability; contingency plans; Federal Information Processing Standard; fire safety; natural disasters; physical security; risk analysis; security audit; security awareness; supporting utilities.

This publication provides guidelines to be used by Federal organizations in structuring physical security programs for their ADP facilities. It treats security analysis, natural disasters, supporting utilities, system reliability, procedural measures and controls, off-site facilities, contingency plans, security awareness and security audit. It contains statistics and information relevant to physical security of computer data and facilities and references any applicable publications for a more exhaustive treatment of specific subjects.

FIPS PUB 32. **Optical character recognition character sets,** P. Mantek, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 32, 78 pages (1974) SD Catalog No. C13.52:32.

Key words: alternate character; centerline drawings; character positioning; character sets; character shape; character sizes; font; lower case character; Optical Character Recognition; upper case character.

This standard provides the description, scope, and identification for standard sets of graphic shapes to be used in the application of Optical Character Recognition (OCR) systems. Two font styles, known as Style A and B, are described. Style A comprises a font of 92 characters which is designed to provide a maximum of machine efficiency in reading under a wide variety of applications. Style B comprises a font of 96 characters, which stresses esthetic appearance, but which may be applied under a substantial range of applications. Three sizes of characters designated as Size I, III and IV are presented. The basic requirements related to character positioning are also specified. Individual character drawings for both styles of character sets are included.

FIPS PUB 33. **Character set for handprinting,** R. E. Rountree, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 33, 4 pages (1974) SD Catalog No. C13.52:33.

Key words: character sets; character shape; character size; Federal Information Processing Standards; handprinting; Optical Character Recognition.

This FIPS PUB announces the adoption of the American National Standard X3.45-1974, Character Set for Handprinting as a Federal Standard. This standard provides the description, scope, and application rules for a character set for handprinting. A major purpose of this standard is to reduce the cost of data input into ADP systems which use Optical Character Recognition (OCR) equipment.

FIPS PUB 34. **Guide for the use of International System of Units (SI)**, R. R. Roundtree, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 34, 4 pages (1975) SD Catalog No. C13.52:34.

Key words: ADP standards; computers; data processing, Federal Information Processing Standards; metric conversion; SI units; standards.

The use of SI (International System of Units) within the United States is increasing. The Secretary of Commerce has established the policy that publications of the Department will provide dual-dimensions to the extent practicable.

The Federal Information Processing Standards (FIPS) Program in response to Public Law 89-306 (the Brooks Act) strives to improve the utilization of ADP equipment, goods and services within the Federal Government through the establishment of uniform Federal automatic data processing standards. These standards and guidelines which are published by the National Bureau of Standards as FIPS contain specifications which should be expressed as dual-dimensions. Accordingly, this guideline will be used in the preparation of all new FIPS PUBS and existing FIPS PUBS when revised.

FIPS PUB 35. **Code extension techniques in 7 or 8 bits**, J. L. Little, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 35, 4 pages (1975) SD Catalog No. C13.52:35.

Key words: American Standard Code for Information Interchange; ASCII, coded character subsets; codes; data communication, data interchange, data processing; Federal Information Processing Standards; graphic character subsets; graphic subsets; information interchange; information processing; standards; subsets.

This FIPS PUB announces the adoption of the American National Standard X3.41-1974, Code Extension Techniques for use with the 7-Bit Coded Character Set of ASCII. This standard specifies methods of extending the 7-bit code of ASCII (FIPS 1), remaining in a 7-bit environment or increasing to an 8-bit environment, building upon the structure of ASCII to describe various means of extending the control and graphic sets of the code. It also describes techniques for constructing codes related to ASCII so as to allow application dependent usage without preventing the interchangeability of their data and describes 8-bit codes for general information interchange in which ASCII is a subset.

FIPS PUB 36. **Graphic representation of the control characters of ASCII (FIPS 1)**, J. L. Little, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 36, 4 pages (1975) SD Catalog No. C13.52:36.

Key words: American Standard Code for Information Interchange; ASCII, coded character subsets; codes; data communication, data interchange, data processing; Federal Information Processing Standards; graphic character subsets; graphic subsets; information interchange; information processing; standards; subsets.

This FIPS PUB announces the adoption of the American National Standard X3.32-1973, Graphic Representation of the Control Characters of American National Standard Code for Information Interchange. This standard specifies graphical representations for the 34 characters of ASCII (FIPS 1) for which a graphic representation is not indicated in FIPS 1. Graphical representations are given for the 32 control functions of columns 0 and 1 as well as the characters "Space" and "Delete." Two forms of graphical representations for each of the 34 characters are provided: a pictorial symbol, and a 2-letter alphanumeric code.

FIPS PUB 37. **Synchronous high speed data signaling rates between data terminal equipment and data communications equipment**, G. E. Clark, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 37, 4 pages (1975) SD Catalog No. C13.52:37.

Key words: data communication equipment; data processing terminal equipment; data transmission (high speed); Federal Information Processing Standards; synchronous signaling rates; teleprocessing; wide band.

This FIPS PUB announces the adoption of the American National Standard X3.36-1975, Synchronous High Speed Data Signaling Rates Between Data Terminal Equipment and Data Communication Equipment, and is the same as Federal Standard Number 1001. This standard specifies a series of signaling speeds for synchronous high speed serial data transfer.

FIPS PUB 38. **Guidelines for documentation of computer programs and automated data systems**, B. Marron, Standards Coordinator, *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 38*, 50 pages (1975).

Key words: automated data systems; computer programs; documentation; documentation content guidelines; FIPS guidelines; software.

These guidelines provide a basis for determining the content and extent of documentation for computer programs and automated data systems. Software development phases and related document types are identified, several examples of documentation options are given, and content guidelines for ten document types are provided. The ten document types are: Functional Requirements Document; Data Requirements Document; System/Subsystem Specification; Program Specification; Data Base Specification; Users Manual; Operations Manual; Program Maintenance Manual; Test Plan; Test Analysis Report.

The guidelines are intended to be a basic reference and a checklist for general use throughout the Federal Government to plan and evaluate documentation practices.

FIPS PUB 39. **Glossary for computer systems security**, D. Branstad and R. Krell, *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 39*, 19 pages (Jan. 1976).

Key words: computer; data processing; definitions; Federal Information Processing Standards Publication; information processing; privacy; security; terms; vocabulary.

This glossary provides an alphabetic listing of approximately 170 terms and definitions pertaining to privacy, and security related to data, information systems hardware and software. Multiple word terms are listed in natural order, synonyms are referenced, and glossary terms appearing within a definition are indicated.

FIPS PUB 40. **Guideline for optical character recognition forms**, T. C. Bagg, Standard Coordinator, *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 40*, 60 pages (1976).

Key words: business forms; computers; data entry systems; information processing systems; information processing standards; OCR; OCR forms; optical character recognition; standards.

This publication provides materials relating to the design, preparation, acquisition, inspection, and application of OCR forms in data entry systems. Since the materials are advisory and tutorial in nature this publication has been issued as a guideline rather than as a standard in the FIPS publication series. Full color illustrations are employed to show specific features of reflective ink applications, a phenomena unique to OCR forms requirements. Appropriate references are made to cognizant standards in the OCR area.

FIPS PUB 41. **Computer security guidelines for implementing The Privacy Act of 1974**, T. C. Lowe, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 41, 20 pages (1975) SD Catalog No. C13.52:41.

Key words: access controls; ADP security; computer security; Federal Information Processing Standards; information management; personal data; physical security; privacy risk assessment.

This publication provides guidelines for use by Federal ADP organizations in implementing the computer security safeguards necessary for compliance with Public Law 93-579, the Privacy Act of 1974. A wide variety of technical and related procedural safeguards are described. These fall into three broad categories: Physical security, information management practices, and computer system/network security controls. As each organization processing personal data has unique characteristics, specific organizations should draw upon the material provided in order to select a well-balanced combination of safeguards which meets their particular requirements.

FIPS PUB 42, 42-1, Superseded by FIPS PUB 42-2.

FIPS PUB 43. **Aids for COBOL program conversion (FIPS PUB 21 to FIPS PUB 21-1)**, M. V. Vickers, Standards Coordinator, Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 43, 54 pages (1975) SD Catalog No. C13.52:43.

Key words: COBOL; Federal Standard COBOL; program conversion; programming aids; programming languages.

Since COBOL is a "living" language, in the sense that it is under constant development and clarification, the Federal community which relies heavily on COBOL to satisfy their programming needs has a large degree of assurance that COBOL will continue to meet their data processing needs as future generation systems are introduced. However, along with the advantage of having more sophisticated and better COBOL tools to interact with new systems requirements, there is a short term disadvantage. As clarifications and new facilities are added, they must interact with the language specifications already standardized, and this interaction sometimes requires changes in source programs. An analysis, in the form of narrative descriptions and syntax comparisons, is provided to aid in the transitioning of COBOL programs for use with compilers developed in accordance with the 1968 COBOL Standard (FIPS PUB 21) to compilers developed in accordance with the 1974 COBOL Standard (FIPS PUB 21-1).

FIPS PUB 44. **COBOL coding form**, M. V. Vickers, Standards Coordinator, *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 44*, 3 pages (1976).

Key words: COBOL; COBOL coding form; Federal Information Processing Standard; Federal Standard COBOL; software; standards conformance.

This publication provides a standard COBOL Coding Form (SF-268) together with an explanation of its use and physical specifications. The standard form is based upon a review and analysis of numerous COBOL coding forms being used throughout the Federal Government. The development of the standard form was accomplished through the cooperative efforts of FIPS Task Group 9 (COBOL) under the auspices of the National Bureau of Standards and the Interagency Reports and Standards Forms Division of the National Archives. It is anticipated that significant economic benefits will be realized by Federal departments and agencies as a result of the availability of a single standard form for government-wide use. This standard conforms to the provisions of Federal Standard COBOL (FIPS 21-1).

FIPS PUB 45. **Guide for the development, implementation and maintenance of standards for the representation of computer processed data elements**, H. S. White, Ed., *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 45, 51 pages (1976).*

Key words: American National Standards; computers; data; data elements; data processing; information; information processing; International Standards; U.S. Government.

Provides technical and administrative guidelines for the development, use and maintenance of standards for representing data elements used in computer based systems. Basic concepts and terminology of data standardization are provided in addition to evaluation criteria for assessing various coding alternatives. The guide is used as a basic reference document in the development of Federal and voluntary national and international standards for data. The guide was developed by the X3L81 Standards Task Group of the American National Standards Institute and has been adopted for use by the International Organization for Standardization.

3.14. COMMERCIAL STANDARDS

The name of this series was changed to Product Standards in 1965.

This series define the quality levels for products in accordance ith the principal needs of the trade. Their use is voluntary.

CS188-66. **Cast iron soil pipe and fittings,** NBS Comm. Std. 188-66 (July 1, 1966).

Key words: Cast iron pipe, requirements; soil pipe and fittings; soil pipe dimensions.

This standard covers pipe and fittings of the following patterns and, when so designated, may apply to any other patterns that conform with the requirements given therein. (Supersedes CS188-59).

CS236-66. **Mat-formed wood particleboard,** NBS Comm. Std. 236-66 (Apr. 15, 1966).

Key words: Mat-formed particleboard; particleboard requirements; particleboard, wood; wood particleboard.

This Commercial Standard covers two types of mat-formed wood particleboard; one for interior applications and one for certain exterior applications in addition to interior applications. Each type is further divided into several density grades which are subdivided into strength classifications. It is intended that the applications of the products will be consistent with the properties of the respective density grades and strength classifications described. Also included are definitions, dimensional tolerances, test methods, inspection practices, and methods of marking and certification to identify products that comply with all requirements of this Standard. (Supersedes CS236-61).

CS251-63. **Hardboard,** NBS Comm. Std. 251-63 (Nov. 15, 1966).

Key words: Fiber board; hardboard; ligno-cellulosic fibers; and lignin and hot pressed fibers.

This standard sets forth the standard commercial types, and sizes of hardboard, and gives information on special hardboards available. It provides specifications for physical requirements and test methods for static bending (modulus of rupture), tensile strength, water absorption, and thickness swelling. It includes a glossary of terms used in the hardboard industry, and recommends a uniform means of marking and certifying for the consumer hardboards that comply with this Standard. (Reprinted April 1967 with Amendments effective November 15, 1966).

CS274-66. **TFE-fluorocarbon (polytetrafluoroethylene) resin sintered thin coatings for dry film lubrication,** NBS Comm. Std. 274-66 (Jan. 20, 1966).

Key words: Coatings, dry film; dry film lubrication; polytetrafluoroethylene; resin sintered coatings; and TFE-fluorocarbon.

This standard establishes the requirements and methods of test for the material, thickness, workmanship, and properties of TFE-fluorocarbon resin coatings 0.001 inch or less in thickness for the purpose of dry film lubrication. Methods of marking and indicating compliance with this standard are included.

3.15. SIMPLIFIED PRACTICE RECOMMENDATIONS

The name of this series was changed to Product Standards in 1965.

This series list the staple sizes, kinds, types, and applicable methods for certain commodities produced and stocked in greatest quantity, to aid in holding variety to a minimum. Their use is voluntary.

SPR174-65. **Cast-iron radiators,** NBS Simpl. Prac. Recomd. 174 65 (Dec. 31, 1965).

Key words: Cast iron radiators; radiators, cast iron; radiator ratings; radiator sizes.

This recommendation covers sizes, types and dimensions of radiators, stock assemblies and general provisions. It does not cover baseboard type of radiation. (Supersedes SPR174-47.)

3.16. PRODUCT STANDARDS

Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. The National Bureau of Standards administers the Voluntary Product Standards program as a supplement to the activities of the private sector standardizing organizations.

PS0-70. **Editorial format for Voluntary Product Standards,** D. R. Mackay, Nat. Bur. Stand. (U.S.), Prod. Stand. 0-70, 13 pages (Mar. 1971).

Key words: Editorial format; format; Product Standards; standard; Voluntary Product Standards.

This publication is intended to assist individuals, organizations, and agencies which are concerned with the writing of standards. It establishes and describes the material to be contained in a standard and provides specific instructions for writing standards. It is primarily intended for those developing initial drafts of standards to be submitted to the Bureau under the *Procedures for the Development of Voluntary Product Standards* published by the Department of Commerce. Supersedes NBS PS0-67.

PS1-74. **Construction and industrial plywood.** *(ANS A199.1-1974),* K. G. Newell, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 1-74, 34 pages (Mar. 1975) SD Catalog No. C13.20/2:1-74.

Key words: construction and industrial plywood; industrial plywood; plywood, construction, and industrial.

This Voluntary Product Standard covers requirements and methods of test for the wood species, veneer grading, glue bonds, panel construction and workmanship, dimensional tolerances, marking, moisture content, and packing of plywood intended for construction and industrial uses.

Also included are a glossary of trade terms and a quality certification program. Information regarding generally available

sizes, methods of orderings, and reinspecting practices, is provided in the appendix.

PS2-66. **Standard sizes of blackboard slate,** NBS Prod. Std. 2-66 (May 15, 1966).

Key words: Blackboards; dimensions; natural markings; slabs; slate; standard sizes; thickness; tolerances.

This recommendation covers dimensions for blackboard slabs and dimensions of blackboard slates for other than wall use. Also included are requirements for thickness, finish, and color and imperfections of natural slate. (Supersedes SPR15-35).

PS3-66. **TFE-fluorocarbon (polytetrafluoroethylene) resin skived tape,** NBS Prod. Std. 3-66 (Sept. 1, 1966).

Key words: Electrical tape, plastic; plastic tape; polytetrafluoroethylene; resin skived tape; skived tape; TFE-fluorocarbon.

This standard establishes requirements and methods of test for the material, dimensions, workmanship, and the physical and electrical properties of three grades of skived tape manufactured entirely of TFE-fluorocarbon resin in accordance with good commercial practice. The materials covered range in thickness from 0.002 inch to 0.125 inch, and are normally manufactured by skiving.

PS4-66. **Standard stock light-duty 1 3/8- and 1 3/4-inch thick flush-type interior steel doors and frames,** NBS Prod. Std. 4-66 (Nov. 1, 1966).

Key words: Interior steel doors; standard interior steel doors; steel door frames, steel doors, interior.

This Product Standard covers sizes, types, materials, construction, hardware installation, and finishing of the doors, frames, and accessories. They are intended to be stock items for use in light-duty applications where low cost flush doors are desired. The standard also provides a uniform method of marking, identifying, and labeling. (Supersedes CS211-57).

PS5-66. **Porcelain enameled formed steel plumbing fixtures,** NBS Prod. Std. 5-66 (Nov. 1, 1966).

Key words: Abrasion resistance; chemical resistance; porcelain enamel; sanitary ware; sheet steel.

The standard covers materials, dimensions, construction and methods of inspection, testing, and labeling. Definitions are given for certain trade terms. The types and sizes of fixtures in general use and demand are listed for bathtubs, lavatories, kitchen sinks and sink-and-laundry-tray combinations. (Supersedes CS144-47).

PS6-66. **Trim for water-closet bowls, tanks and urinals (dimensional standards),** NBS Prod. Std. 6-66 (Nov. 1, 1966).

Key words: Bowls; brass; dimensions; nuts; plastic; plumbing equipment; tanks; valves.

The purpose of this standard is to establish a basis for dimensional interchangeability for those items of trim for water-closet bowls, tanks and urinals known as spuds, lock nuts for spuds, flush valves for staple low tanks, float valves, flush elbows, and coupling nuts. It is also intended to provide a basis for understanding between buyers and sellers for the dimensions and tolerances that govern the fit of trim in the fixtures and connecting parts of trim. (Supersedes CS172-50).

PS7-66. **Wire bar supports for reinforced concrete construction,** NBS Prod. Std. 7-66 (Aug. 1, 1966).

Key words: Bars, concrete reinforcement; concrete construction, supports; reinforced concrete construction; reinforcement bars; wire bar supports.

The standard lists twelve types of wire bar supports and the sizes of each in greatest demand. The minimum size of wire is given for each type of bar support. Maximum spacings at which the bar supports will function properly in ordinary slabs, joists, beams, and girders are included. The standard also lists a number of modifications of the standard bar supports for special applications in concrete reinforcement, which are not regularly stocked but may be obtained as standard items when specified.

PS8-67. **Grading of abrasive grain on coated abrasive products,** NBS Prod. Std. 8-67 (Jan. 9, 1967).

Key words: Abrasive grain; accumulation curve; coated abrasive products; grain, abrasive; micron; overgrade; sedimentation; sieve; standard sieve.

The scope of this Product Standard is confined to a determination of the grit sizes of the abrasive grain on the coated product. However, the information may also be of use in the preparation of abrasive grain for making coated abrasive products. It has been developed to cover, insofar as possible, the grading of the grit sizes of abrasive grain on the standard coated abrasive products listed in Simplified Practice Recommendation R89-55. (Supersedes CS217-59).

PS9-68. **Fabrics for book covers,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 9-68, 13 pages (Apr. 1968).

Key words: Bookbinders; book cloths; book covers; buckrams; starch filled: impregnated; testing procedures.

This Standard covers the requirements and test procedures for seven groups of plain finished book cloths and buckrams which are impregnated or starch filled and which are used in the bookbinding industry for book covers. Definitions which apply to this standard are also included. (Supersedes NBS Commercial Standard CS7-40.)

PS10-69. **Polyethylene (PE) plastic pipe (schedule 40—inside diameter dimensions),** H. A. Philo, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 10-69, 14 pages (Mar. 1970).

Key words: Dimensions; inside diameter; materials; pipe; polyethylene plastic; schedule 40.

This Product Standard covers the principal materials, sizes and pressure ratings for commercially available PE plastic pipe made in Schedule 40 size with the inside diameter controlled for use with insert fittings. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, burst pressure, and environmental stress cracking.

PS11-69. **Polyethylene (PE) plastic pipe (SDR),** H. A. Philo, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 11-69, 14 pages (Mar. 1970).

Key words: Inside diameter dimensions; materials; pipe; polyethylene (PE); pressure; standard dimension ratio (SDR).

This Product Standard covers the principal materials, sizes and pressure ratings for commercially available PE pipe made in Standard Dimension Ratios with the inside diameter controlled for use with insert fittings. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, burst pressure, and environmental stress cracking.

PS12-69. **Polyethylene (PE) plastic pipe (schedules 40 and 80—outside diameter dimensions),** H. A. Philo, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 12-69, 14 pages (Mar. 1970).

Key words: Dimensions; materials; outside diameter; pipe; polyethylene (PE); schedule size (40 and 80).

This Product Standard covers the principal types, grades, sizes, and pressure ratings for commercially available PE plastic pipe made in Schedule 40 and 80 sizes with the outside diameter controlled for use with socket-type fittings. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, burst pressure, and environmental stress cracking.

PS13-69. **Uncored slab urethane foam for bedding and furniture cushioning,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 13-69, 6 pages (Dec. 1969).

Key words: Cellular; flexible; slab; uncored; urethane foam.

The foam covered by this Product Standard is intended for uses such as inserts for mattresses and cushions for indoor and outdoor furniture. This Standard provides material and dimensional requirements for uncored slab urethane foam and requirements and methods of test for the specific properties of load bearing capacity, permanent set, moisture resistance, fatigue resistance, and resiliency. The fatigue requirements will be revised to incorporate dynamic fatigue specifications when adequate data are available. Methods for marking and labeling to indicate compliance with this Standard are also provided.

PS14-69. **Salt packages,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 14-69, 9 pages (May 1970).

Key words: Salt; salt packages; sodium chloride.

This Product Standard specifies the recommended salt packages for each kind of salt, the labeled net weight of the packages, and the type and capacity of shipping containers. Definitions and uses for salt are also included. While no attempt is made to list all of the packages, sizes, and containers which might be packed by one or more producer, table 1 includes those items common to the entire industry.

PS15-69. **Custom contact-molded reinforced-polyester chemical-resistant process equipment,** D. R. Stevenson. Technical Standards Coordinator. Nat. Bur. Stand. (U.S.), Prod. Stand. 15-69, 28 pages (June 1970).

Key words: Chemical-resistant; contact-molded; ducts; equipment; plastic; reinforced-polyester; tanks.

This Product Standard covers materials, construction and workmanship, physical properties, and methods of testing reinforced-polyester materials for process equipment and auxiliaries intended for use in aggressive chemical environments, including but not limited to pipe, ducts, and tanks. The Standard is based on the technology of fabrication by hand lay-up or contact pressure molding. Methods for identifying products which comply with the requirements of this Standard are included.

PS16-69. **Types and sizes of forms for one-way concrete joist construction,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 16-69, 16 pages (June 1970).

Key words: Concrete; floor and roof; forms joist; one-way.

This Product Standard covers four types of forms for one-way concrete joist construction and standard sizes for these types. Definitions of concrete joist construction and one-way joist construction are provided under section 4. (Supersedes NBS Simplified Practice Recommendation 87-32.)

PS17-69. **Polyethylene sheeting (construction, industrial, and agricultural applications),** D. R. Stevenson, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 17-69, 20 pages (June 1970).

Key words: Agricultural; composition; construction; industrial; polyethylene; properties; sheeting.

This Product Standard covers polyethylene sheeting of 10 mils (0.010 inch) or less in thickness and establishes requirements for the composition, impact resistance, mechanical properties, reflectance, opaqueness (low luminous transmittance), water vapor transmission, weight, and appearance of the sheeting. Also included are tolerance requirements for the thickness width and length of the sheeting. Provisions for identifying polyethylene sheeting conforming to this Standard are also provided. (Supersedes Commercial Standard CS238-61.)

PS18-69. **Acrylonitrile-butadiene-styrene (ABS) plastic pipe (schedules 40 and 80),** K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 18-69, 15 pages (June 1970).

Key words: Acrylonitrile-butadiene (ABS), outside diameter; dimensions; pipe; schedule size (40 and 80).

This Product Standard covers the principal types, grades, sizes, and pressure ratings for commercially available ABS plastic pipe made in Schedule 40 and 80 sizes with the outside diameter controlled. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, and burst pressure. Methods of marking and labeling to indicate compliance with this Standard are also provided. (Supersedes Commercial Standard CS218-59.)

PS19-69. **Acrylonitrile-butadiene-styrene (ABS) plastic pipe (Standard dimension ratio),** K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 19-69, 13 pages (June 1970).

Key words: Acrylonitrile-butadiene-styrene (ABS); outside diameter dimensions; pipe; standard dimension ratio (SDR).

This Product Standard covers the principal types, grades, sizes, and pressure ratings of commercially available ABS plastic pipe made in Standard Dimension Ratios (SDR) with the outside diameter controlled. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, and burst pressure. Methods of marking and labeling to indicate compliance with this Standard are also provided. (Supersedes Commercial Standard CS254-63.)

PS20-70. **American softwood lumber standard,** D. R. Mackay, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 20-70, 26 pages (Jan. 1970).

Key words: Grades; lumber; sizes; softwood; species; timber.

This Product Standard covers the principal trade classifications and sizes of softwood lumber for yard, structural, and shop use. It provides a common basis of understanding for the classification, measurement, grading, and grade marking of rough and dressed sizes of various items of lumber, including finish, boards, dimension, and timbers. (Supersedes NBS Simplified Practice Recommendation 16-53.)

PS21-70. **Poly(vinyl chloride) (PVC) plastic pipe (schedules 40, 80, and 120),** K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 21-70, 16 pages (June 1970).

Key words: Dimensions; hydrostatic design stress; materials; pipe; poly(vinyl chloride) (PVC); pressure; pressure rating (PR); schedule 40, 80, and 120 sizes.

This Product Standard covers the principal types, grades, sizes, and pressure ratings for commercially available PVC plastic pipe made in Schedule 40, 80, and 120 sizes, with the outside diameter controlled. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion

quality. Methods of marking and labeling to indicate compliance with this Standard are also provided. (Supersedes Commercial Standard CS207-60.)

PS22-70. **Poly(vinyl chloride) (PVC) plastic pipe (standard dimension ratio),** K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 22-70, 14 pages (June 1970).

Key words: Class T; dimensions; hydrostatic design stress; materials; pipe; poly(vinyl chloride) (PVC); pressure; pressure rating (PR); standard dimension ratio (SDR); threads.

This Product Standard covers the principal types, grades, sizes, and pressure ratings for commercially available PVC plastic pipe made in Standard Dimension Ratios (SDR) with the outside diameter controlled. Included are requirements and methods of test for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking and labeling to indicate compliance with this Standard are also provided. (Supersedes Commercial Standard CS256-63.)

PS23-70. **Horticultural grade perlite,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 23-70, 9 pages (May 1970).

Key words: Horticultural grade; perlite horticultural grade.

This Product Standard includes requirements for the grading, density, pH value, and sterility of horticultural grade perlite and gives test methods for these requirements with the exception of sterility. A provision for identifying a product as conforming to the Standard is included.

PS24-70. **Melamine dinnerware (alpha-cellulose-filled) for household use,** D. R. Stevenson, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod Stand. 24-70, 9 pages (Aug. 1970).

Key words: Alpha-cellulose-filled; dinnerware; household alpha-cellulose filled melamine dinnerware; household use; melamine dinnerware; melamine plastic.

This Product Standard covers the properties, the methods of test, and the thickness and weight of household dinnerware molded from alpha-cellulose-filled melamine-formaldehyde and other amino-triazine-formaldehyde plastic materials. Requirements for the finish and decorations are also covered by the Standard. Methods for identifying melamine dinnerware complying with the requirements of this Standard are provided.

This Standard does not cover the design or color of melamine dinnerware.

PS25-70. **Heavy-duty alpha-cellulose-filled melamine tableware,** D. R. Stevenson, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 25-70, 8 pages (Aug. 1970).

Key words: Alpha-cellulose-filled, heavyduty; heavyduty alpha-cellulose-filled melamine tableware; melamine tableware; tableware.

This Product Standard covers the thickness, properties, and methods of test for heavy-duty tableware molded from alpha-cellulose-filled melamine-formaldehyde and other amino-triazine-formaldehyde plastic materials. Requirements for the finish and decoration are also covered by the Standard. Methods for identifying melamine tableware complying with the requirements of this Standard are provided.

This Standard does not cover the design, size, or color of the melamine tableware.

PS26-70. **Rigid poly(vinyl chloride) (PVC) profile extrusions,** D. R. Stevenson, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 26-70, 7 pages (Oct. 1970).

Key words: Extrusions; poly(vinyl chloride); profile; profile extrusions; PVC profile extrusions; rigid PVC.

This Product Standard establishes requirements for the material and properties, including dimensional stability and extrusion quality, of rigid PVC profile extrusions. Methods for identifying profile extrusions that comply with the requirements of this Standard are provided.

PS27-70. **Mosaic-parquet hardwood slat flooring,** W. H. Furcolow, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 27-70, 13 pages (Sept. 1970).

Key words: Flooring; hardwood flooring; mosaic-parquet flooring; slat flooring.

This Product Standard covers requirements for grading, moisture content, dimensions, construction, and finish for mosaic-parquet hardwood slat flooring which is intended for use in residential, institutional, and commercial buildings. A method for marking and labeling to indicate compliance with the Standard is also provided. Manufacturers' recommendations on ordering and installation are included in an appendix. The Standard does not cover flooring squares or blocks which are fabricated from conventional tongue and groove type strips.

PS28-70. **Glass stopcocks with polytetrafluoroethylene (PTFE) plugs,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 28-70, 10 pages (Sept. 1970).

Key words: Glass stopcocks with PTFE plugs; glass with PTFE plugs; PTFE plugs for glass stopcocks; stopcocks.

This Product Standard covers the design, dimensions, tolerances, and performance criteria for glass stopcocks with PTFE plugs. Also included are methods of marking and labeling to indicate compliance with this Standard. This Product Standard does not cover glass stopcocks with glass plugs, nor glass stopcocks intended for use in high vacuum work.

PS29-70. **Plastic heat-shrinkable film,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 29-70, 16 pages (Jan. 1971).

Key words: Balanced and unbalanced film; film, plastic; orientation release stress; plastic heat-shrinkable film; retraction ratio; shrink film, plastic.

This Voluntary Product Standard covers plastic film which, within its useful temperature range, will shrink at least 20 percent in either or both the machine and the transverse directions. Included are requirements and methods of test for shrink properties, dimensions, yield, weight, and slip.

PS30-70. **School chalk,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 30-70, 14 pages (May 1971).

Key words: Calcium carbonate; calcium sulfate; chalk; chroma; toxicity; whiting.

This standard provides requirements for the dimensions, material, breaking strength, characteristics, toxicity, workmanship, and chroma (as applicable) for six types and several classes and grades of school chalk. Test methods for determining the material content, breaking strength, and chroma are provided. Standard packages are given, and methods for labeling to indicate compliance with the standard are provided.

PS31-70. **Polystyrene plastic sheet,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 31-70, 14 pages (Jan. 1971).

Key words: Impact resistance, plastic sheet; oriented sheet; plastic sheet; polystyrene plastic sheet; sheet; plastic.

This Voluntary Product Standard covers requirements and methods of test for dimensions, and mechanical and physical properties of hot-melt extruded polystyrene plastic sheet. The standard does not cover polystyrene foam or biaxially oriented

sheet.

PS32-70. **Hinged interior wood door units,** W. H. Furcolow, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 32-70, 15 pages (Mar. 1971).

Key words: Door units, wood; hinged door units, interior; prefabricated door units; wood door units.

This Voluntary Product Standard covers the designs, grades, sizes, materials (including hardware), and construction of prefabricated wood door units, as well as a means of identifying units represented as conforming to the standard, and definitions of terms used in the standard.

PS33-70. **Polytetrafluoroethylene (PTFE) plastic lined steel pipe and fittings,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 33-70, 12 pages (Mar. 1971).

Key words: Pipe and fittings, steel, plastic lined; plastic lined steel pipe; polytetrafluoroethylene plastic lined pipe; PTFE lined pipe; steel pipe and fittings, plastic lined.

This Voluntary Product Standard covers requirements and methods of test for the material, dimensions, construction, and performance of commercially available steel pipe and fittings lined with polytetrafluoroethylene (PTFE) plastic intended to be used for conveying acids, gases, solvents, and other corrosive materials.

PS34-70. **Fluorinated ethylene-propylene (FEP) plastic lined steel pipe and fittings,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 34-70, 12 pages (Mar. 1971).

Key words: FEP lined pipe; fluorinated ethylene-propylene plastic lined pipe; pipe and fittings, steel, plastic lined; plastic lined steel pipe; steel pipe and fittings, plastic lined.

This Voluntary Product Standard covers requirements and methods of test for the material, dimensions, construction, and performance of commercially available steel pipe and fittings lined with fluorinated ethylene-propylene (FEP) plastic intended to be used for conveying acids, gases, solvents, and other corrosive materials.

PS35-70. **Poly(vinylidene fluoride) (PVF_2) plastic lined steel pipe and fittings,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 35-70, 12 pages (Mar. 1971).

Key words: Pipe and fittings, steel, plastic lined; plastic lined steel pipe; poly(vinylidene fluoride) plastic lined pipe; PVF_2 lined pipe; steel pipe and fittings, plastic lined.

This Voluntary Product Standard covers requirements and methods of test for the material, dimensions, construction, and performance of commercially available steel pipe and fittings lined with poly(vinylidene fluoride) (PVF_2) plastic intended to be used for conveying acids, gases, solvents, and other corrosive materials.

PS36-70. **Body measurements for the sizing of boys' apparel,** C. W. Devereux, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 36-70, 24 pages (Dec. 1971).

Key words: Apparel, boys'; body measurements, boys'; pattern sizes, boys'; size designations, boys'; span charts, boys' sizing.

This Voluntary Product Standard covers standard size designations, size classifications, and body measurements for the sizing of boys' apparel. The standard includes sections on applications of the system, recommended methods of identification, methods of measuring, and clothing allowances. The measurements given in this standard are body, not garment, measurements.

PS37-70. **Package quantities of instant nonfat dry milk,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 37-70, 9 pages (Apr. 1971).

Key words: Dry milk package quantities; instant nonfat dry milk; nonfat dry milk, package quantities of; package quantities of dry milk.

This Voluntary Product Standard covers package quantities of instant nonfat dry milk based on quart equivalents within the range of 3 to 20 quarts. It also establishes the weight of instant nonfat dry milk required to make 1 quart. This Standard covers all types of packages of instant nonfat dry milk intended for household use including those containing individual quart or multi-quart equivalent envelopes.

PS38-70. **Steel bi-fold closet door units, frames, and trim,** C. W. Devereux, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 38-70, 12 pages (May 1971).

Key words: Bi-fold doors, steel; closet doors, steel bi-fold; doors, steel bi-fold; steel bi-fold doors.

This Voluntary Product Standard covers sizes, types, materials, construction, hardware, and finishing of steel bi-fold closet door units and frames intended to be stock items not subject to variations according to the customer's special requirements. Methods of marking and labeling are included so that products which comply with the standard may be clearly identified. Provisions for the erection of doors, frames, and accessories are not included in the standard, but certain recommendations for storage and erection as generally endorsed by the manufacturers are given for information and guidance.

PS39-70. **Clinical thermometers (maximum-self-registering, mercury-in-glass),** W. H. Furcolow, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 39-70, 12 pages (May 1971).

Key words: Clinical thermometers; glass thermometers, clinical; mercury-in-glass thermometers; thermometers, self-registering, clinical.

This Voluntary Product Standard covers the requirements and methods of testing maximum-self-registering, mercury-in-glass thermometers of the types commonly used for measuring body temperatures, such as oral and rectal types in both regular and basal temperature scales. It is intended to serve as a nationally recognized basis for certification of compliance by manufacturers and for procurement purposes by consumers. The standard includes requirements for bulb and stem glasses, mercury, dimensions, temperature scale ranges, and graduations, and performance criteria for thermometer aging, hard shaking determination, and accuracy of scale reading.

PS40-70. **Package quantities of green olives,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 40-70, 9 pages (May 1971).

Key words: Green olives, package quantities of; olives, green, package quantities of; package quantities of green olives.

This Voluntary Product Standard covers a range of package quantities that are recommended for green olives and establishes specific packaging requirements in terms of net drained weight. Methods of labeling products which comply with this Standard are provided.

PS41-70. **Package quantities of instant mashed potatoes,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand.

(U.S.), Prod. Stand. 41-70, 8 pages (Apr. 1971).

Key words: Instant mashed potatoes, package quantities of; mashed potatoes, instant, package quantities of; package quantities of instant mashed potatoes; potatoes, instant mashed, package quantities of.

This Voluntary Product Standard covers a range of package quantities based on servings and establishes the definition of a serving which is based on the weight of the reconstituted product.

PS42-70. **Body measurements for the sizing of women's patterns and apparel,** C. W. Devereux, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 42-70, 29 pages (Sept. 1971).

Key words: Apparel, women's; body measurements, women's; classifications, women's size; grading charts, women's size; pattern size, women's; size designations, women's; span charts, women's sizing.

This Voluntary Product Standard covers standard size classifications, size designations, and body measurements to aid in the consistency of sizing of women's apparel and, by doing so, provides a means for the consumer to identify her body type and size for proper fit. This standard also covers applications of the system, definitions, methods of measurement, adjustments to compensate for the effect of foundation garments, spanning charts, and a recommended method of identification. The measurements given in this standard are body, not garment, measurements.

PS43-71. **Fluorinated ethylene-propylene (FEP) plastic tubing,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 43-71, 12 pages (Sept. 1971).

Key words: Chemical, mechanical, and electrical tubing; FEP tubing; fluorocarbon plastic tubing; plastic tubing, fluorinated ethylene-propylene; tubing, FEP-fluorocarbon.

This Voluntary Product Standard covers plastic tubing made from fluorinated ethylene-propylene (FEP) resin intended for chemical, mechanical, or electrical use. It provides requirements and methods of test for materials, dimensions, and physical and chemical properties of FEP tubing. A method for identifying products which comply with this standard is provided.

PS44-71. **Paper ice bag sizes,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 44-71, 12 pages (Sept. 1971).

Key words: Bag sizes, ice; ice bag sizes; paper ice bag sizes.

This Voluntary Product Standard covers the dimensions and the capacities of paper ice bags intended for use in the packaging of cubed, sized, crushed, and block ice. Methods of measuring and for identifying bags that conform to this standard are provided.

PS45-71. **Body measurements for the sizing of apparel for young men (students),** C. W. Devereux, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 45-71, 16 pages (Jan. 1972).

Key words: Apparel, young men's (students'); body measurements, young men's (students'); classification, young men's (students') size; grading charts, young men's (students') size; size designations, young men's (students').

This Voluntary Product Standard covers size categories, size designations, and body measurements for the sizing of apparel for boys designated young men or students. The young men (students) category is intended to include those boys and young men who have achieved most of their adult height, but not adult girth. The Standard includes the following: applications of the body sizing system, methods of measuring the body, an explanation of the development of the Standard (appendix A) and sizing grades (appendix B). Also included is a method of identifying products that are sized using the measurements and designations in the Standard.

PS46-71. **Flame-resistant paper and paperboard,** J. W. Eisele, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 46-71, 10 pages (Oct. 1971).

Key words: Flame-resistant; paper and paperboard; paper, paperboard, flame-resistant; paperboard, paper, flame-resistant.

This Voluntary Product Standard covers requirements and test methods for flame-resistant paper and paperboard which are 0.060 inch or less thick. Definitions are provided, and a method for identifying products conforming to the standard is given. Two classifications of flame-resistant paper and paperboard are covered: Type I, which if flame-resistant only before water leaching and Type II, which is flame-resistant both before and after water leaching.

PS47-71. **Heat-shrinkable fluorocarbon plastic tubing,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 47-71, 14 pages (Sept. 1971).

Key words: FEP heat-shrinkable tubing; fluorocarbon plastic heat-shrinkable tubing; plastic tubing, fluorocarbon PTFE heat-shrinkable tubing; tubing, heat-shrinkable fluorocarbon plastic.

This Voluntary Product Standard covers commercially available PTFE and FEP plastic tubing which can be reduced to a predetermined inside diameter by the application of heat. Included are requirements and methods of test for material, dimensions, and physical and electrical properties. A method for identifying products which comply with this standard is provided.

PS48-71. **Package quantities of cubed, sized, crushed, and block ice,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 48-71, 10 pages (Nov. 1971).

Key words: Block ice, package quantities of; crushed ice, package quantities of; cubed ice, package quantities of; package quantities of ice; sized ice, package quantities of.

This Voluntary Product Standard covers the net weights of the package quantities recommended for cubed, sized, crushed, and block ice. Definitions of terms and methods for identifying products packaged in accordance with this Standard are included.

PS49-71. **Portable picnic coolers,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 49-71, 9 pages (Oct. 1971).

Key words: Coolers, portable picnic; picnic coolers, portable; portable picnic coolers.

This Voluntary Product Standard covers portable picnic coolers in which the smallest of the internal dimensions exceed 6 inches and the total continuous volume exceeds 1.1 cubic feet. Included in the Standard are requirements relating to the construction of coolers and to the closures, release devices, and handles of picnic coolers. A test for determining the force required to release the closure is included also. Methods of identifying products which conform to the Standard are provided.

For the purposes of this Standard, the term "picnic cooler" shall be used to include "beverage coolers," "ice chests," portable "food chests," and the like, which are designed to be carried by an individual.

PS50-71. **Package quantities of toothpaste,** C. B. Phucas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 50-71, 8 pages (July 1971).

Key words: Package quantities of toothpaste; toothpaste, package quantities.

This Voluntary Product Standard covers the net weights of the package quantities recommended for toothpaste having specific gravities within the range of 1.45 to 1.75. This standard also provides for the package quantities of toothpaste having specific gravities below 1.45 and above 1.75.

PS51-71. **Hardwood and decorative plywood,** P. R. Sutula, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 51-71, 18 pages (Jan. 1972).

Key words: Decorative plywood; hardwood plywood; plywood, hardwood and decorative; softwood plywood, decorative; veneer grades, decorative softwood and hardwood.

This Voluntary Product Standard for hardwood and decorative plywood establishes the nationally recognized marketing classifications, quality criteria, test methods, definitions, and grade-marking and certification practices for plywood produced primarily from hardwoods. It is intended for voluntary use by reference in trade literature, catalogs, sales contracts, building codes, and procurement specifications to describe the quality aspects of the product and the means to determine conformance.

Requirements are given for wood species, veneer grading, lumber-core, particleboard-core, hardboard-core, glue bond, panel constructions, dimensions, moisture content, sanding, and finishing. Sampling and testing provisions cover dry shear, cyclic-boil, three cycle wet and dry, and cold soak test methods for plywood delamination determinations, and field and laboratory moisture content measuring methods. A glossary of trade terms is provided for better communication and understanding, and provisions are made for panel grade-marking and certification to indicate compliance. Supersedes NBS CS 35-61.

PS52-71. **Polytetrafluoroethylene (PTFE) plastic tubing,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 52-71, 12 pages (Apr. 1972).

Key words: Chemical, mechanical, and electrical tubing; fluorocarbon plastic tubing; plastic tubing, polytetrafluoroethylene; PTFE tubing; tubing, PTFE-fluorocarbon.

This Voluntary Product Standard covers commercially available PTFE tubing intended for chemical, mechanical, and electrical applications. Included are requirements and methods of test for materials, dimensions, and physical and chemical properties. A method for identifying products which comply with this Standard is provided.

PS53-72. **Glass-fiber reinforced polyester structural plastic panels,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 53-72, 13 pages (Apr. 1972).

Key words: Glass-fiber reinforced polyester panels; panels, glass-fiber reinforced polyester; plastic panels, structural; structural panels.

This Voluntary Product Standard covers two types of plastic panels furnished in three weights and seven geometrical configurations, including flat panels, intended for use in structural applications. The Standard covers requirements for the sizes, configurations, weights, and squareness of the panels. Included are requirements for materials, appearance, color uniformity, light transmission, transverse load, bearing load, flammability, packing, and marking. Methods for identifying products that conform to this Standard are also included. Information on chemical resistance and available panels is provided in an appendix.

PS54-72. **Body measurements for the sizing of girls' apparel,** C. W. Devereux, II, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 54-72, 19 pages (July 1973) 30 cents, SD Catalog No. C13.20/54-72.

Key words: Apparel, girls'; body measurements, girls'; classifications, girls' size; grading charts, girls' size; size designations, girls'; span charts, girls' sizing.

This Voluntary Product Standard establishes a nationally recognized sizing system for girls, based on body measurements. The standard covers three classifications: slims, regulars, and chubbies. In each classification, sizes 7, 8, 10, 12, 14, and 16 are defined by 33 body measurements.

PS55-72. **Rigid poly (vinyl chloride) (PVC) plastic siding,** L. H. Breden, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 55-72, 11 pages (Nov. 1972).

Key words: Building materials; flammability of outdoor siding; plastic material; poly (vinyl chloride) siding; siding, poly (vinyl chloride); weathering of plastic siding.

This Voluntary Product Standard establishes requirements and methods of test for the materials, dimensions, weight, warp, shrinkage, flammability, impact strength, weatherability, expansion, and appearance of extruded single wall siding, manufactured from rigid PVC compound. Methods of indicating compliance with this Standard are also provided.

PS56-73. **Structural glued laminated timber,** *(ANS A190. 1-1973),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 56-73, 12 pages (Oct. 1973) 45 cents, SD Catalog No. C13.20/2:56-73.

Key words: Glued laminated timber; laminated timber; structural glued laminated timber; timber, structural glued laminated.

This Voluntary Product Standard covers requirements for the dimensions, grade combinations, lumber for laminating, appearance grades, adhesive, and laminating of structural glued laminated timber as well as inspection and test procedures, marking, and the certification by a qualified inspection and testing agency. Definitions of the trade terms used are given, and guides for ordering and information on inspection practices are provided in the appendices.

PS57-73. **Cellulosic fiber insulating board.** *(ANS A194.1-1973),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 57-73, 8 pages (Nov. 1973) SD Catalog No. C13.20/2:57-73.

Key words: board, cellulosic fiber insulating; cellulosic fiber insulating board; fiber, cellulosic insulating board; insulating, cellulosic fiber board.

This Voluntary Product Standard covers requirements and applicable methods of test for the composition, construction, dimensions, moisture content, and physical properties of cellulosic fiber insulating board. Methods of identifying products which comply with this standard are included and information concerning surface finishes and edge details is given in appendix A. Supersedes CS42-49 and R179-63.

PS58-73. **Basic hardboard.** *(ANS A135.4-1973),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 58-73, 6 pages (June 1974) SD Catalog No. C13.20/2:58-73.

Key words: basic hardboard; hardboard.

This Voluntary Product Standard covers requirements and methods of test for water resistance, modulus of rupture, tensile strength, surface finish, dimensions, squareness, edge straightness, and moisture content of five classes of basic hardboard. Methods of identifying hardboard that conforms to the standard are provided. Supersedes CS251-63.

PS59-73. **Prefinished hardboard paneling.** *(ANS A135.5-1973),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 59-73, 7 pages (Feb. 1974) SD Catalog No. C13.20/2:59-73.

Key words: hardboard paneling; paneling, hardboard; prefinished hardboard paneling.

This Voluntary Product Standard covers requirements and methods of test for the dimensions, squareness, edge straightness, and moisture content of prefinished hardboard paneling; for the physical properties of the hardboard substrate; and for the finish of the paneling. Methods of identifying products which conform to the requirements of the standard are included.

PS60-73. **Hardboard siding.** *(ANS A135.6-1973),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.) Prod. Stand. 60-73, 7 pages (Feb. 1974) SD Catalog No. C13.20/2:60-73.

Key words: hardboard siding; siding, hardboard.

This Voluntary Product Standard covers requirements and methods of test for the dimensions, straightness, squareness, physical properties, and surface characteristics of hardboard siding. Definitions of trade terms used and methods of identifying products that comply with the standard are included.

PS61-74. **Plastic containers (jerry-cans) for petroleum products.** *(ANS MH 17.1-1974),* K. G. Newell, Jr., Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 61-74, 6 pages (May 1975) SD Catalog No. C13.20/2:61-74.

Key words: containers for petroleum products; jerry-cans; petroleum products, containers for; plastic containers for petroleum products.

This Voluntary Product Standard covers requirements and methods of test for the material, design, and properties of plastic containers (jerry-cans) intended for use with petroleum products. Methods of identifying containers that conform to the requirements of the standard are included.

PS62-74. **Grading of diamond powder in sub-sieve sizes.** *(ANS Z300.1-1974),* C. W. Devereux, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 62-74, 5 pages (Jan. 1975) SD Catalog No. C13.20/2:62-74.

Key words: diamond powder, grading; grading of diamond powder; powder, diamond; sizes, sub-sieve of diamond powder.

This Voluntary Product Standard covers the quality requirements of sub-sieve sizes of diamond powder and establishes the standard particle size ranges for micron sizes. It establishes size designations of the size ranges and the grading limits that are acceptable in each size range. It also gives a method of inspection to determine compliance with this standard and directions for the labeling of powder to indicate such compliance.

PS63-75. **Latex foam mattresses for hospitals.** *(ANS Z 255.1-1975),* G. S. Chaconas, Technical Standards Coordinator, Nat. Bur. Stand. (U.S.), Prod. Stand. 63-75. 8 pages (Apr. 1975) SD Catalog No. C13.20/2:63-75.

Key words: foam mattresses; hospital mattresses; latex; latex foam mattresses; latex foam for hospitals; mattresses.

The purpose of this Voluntary Product Standard is to establish nationally recognized dimensional and quality requirements for latex foam mattresses intended for use in hospitals, and to provide producers, distributors, and users with a basis for common understanding of the characteristics of this product.

PS64-75. **School paste.** *(ANS Z 297.2-1975),* C. W. Devereux, Technical Standards Coordinator, *Nat. Bur. Stand. (U.S.) Prod. Stand. 64-75,* 6 pages (Apr. 1976) SD Catalog No. C13.20/2:64-75.

Key words: paste, water-based, semi-liquid; school paste.

The purpose of this Voluntary Product Standard is to establish nationally recognized quality, safety, and packaging requirements for school paste and to provide a basis for common understanding among producers, distributors, and users of this product.

PS65-75. **Paints and inks for art education in schools.** *(ANS Z297.1-1975),* G. S. Chaconas, Technical Standards Coordinator, *Nat. Bur. Stand. (U.S.), Prod. Stand. 65-75,* 7 pages (Mar. 1976) SD Catalog No. C13.20/2:65-75.

Key words: art education; inks for art education; paints and inks; schools, paints and inks.

This Voluntary Product Standard covers the establishment of requirements for preservatives, toxicity, course particle content, performance, working qualities, and packaging for school paints and inks, and provides producers, distributors, and users with a basis for common understanding of the characteristics of this product.

PS66-75. **Safety requirements for home playground equipment.** *(ANS Z 304.1-1975),* J. M. Tascher, Technical Standards Coordinator, *Nat. Bur. Stand. (U.S.), Prod. Stand. 66-75,* 1 pages (July 1976) SD Catalog No. C13.20/2:66.75.

Key words: home playground equipment, safety of; jungl gyms, safety of; playground equipment, safety of; safety of home playground equipment; slides, safety of; swing sets safety of.

This Voluntary Product Standard provides safety requirements for various types of home playground equipment intended for use by children aged from 2 through 10 years. The requirements are concerned with the design and performance of the units and their components, the structural integrity of the units and their components during and after exposure to static loads and the instructions and information to be enclosed with the equipment. Methods of identifying products which comply with this standard are given.

3.17. TECHNICAL NOTES

Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other Government agencies.

TN100-A, Supplement to Appendix C of TN100. **Loading factors and FDM-FM system performance calculations,** E. F. Florman, NBS Tech. Note 100-A (Sept. 1967).

Key words: Modulators; radio communications; radio receivers; transistors.

This supplement was written for the purpose of extending the scope of the original paper, by providing a more complete set of system-performance design equations, which apply to the Frequency Division Multiplex--Frequency Modulation type of multichannel telecommunication systems; these equations may be used for various types, and combinations of types, of message signals.

TN213. Unassigned.

TN246. **A survey of some empirical and semi-empirical interatomic and intermolecular potentials,** B. N. Axilrod, NBS Tech. Note 246 (Oct. 3, 1966).

Key words: Atoms; compressibility; heat of sublimation; molecules; potential functions; empirical and semi-empirical; transport properties; virial coefficients.

Many empirical and semi-empirical potential functions have been proposed or developed to represent the pairwise interaction of atoms and molecules. The simple pair potentials proposed usually contain parameters to be adjusted to fit certain properties, for example, when chemical combination does not occur, virial coefficients and similar quantities for the gaseous state, or compressibility and heat of sublimation for the crystalline state. In the present survey a number of potentials proposed recently are examined to indicate the variety of concepts employed and the suitability of the potential functions.

TN270-3. **Selected values of chemical thermodynamic properties. Tables for the first thirty-four elements in the standard order of arrangement,** D. D. Wagman, W. H. Evans, V. B. Parker, I. Halow, S. M. Bailey, and R. H. Schumm, Nat. Bur. Stand. (U.S.), Tech. Note 270-3, 267 pages (Jan. 1968).

Key words: Enthalpy of formation; entropy; Gibbs energy of formation; heat of formation; specific heat; thermodynamic properties.

The tables contain values where known of the enthalpy and Gibbs energy of formation, enthalpy, entropy, and heat capacity at 298.15 K (25 °C), and the enthalpy of formation at 0 K, for all inorganic substances and organic molecules containing not more than two carbon atoms, for the first thirty-four elements in the standard order of arrangement. (Supersedes NBS Tech. Notes 270-1 and 270-2.)

TN270-4. **Selected values of chemical thermodynamic properties. Tables for elements 35 through 53 in the standard order of arrangement,** D. D. Wagman, W. H. Evans, V. B. Parker, I. Halow, S. M. Bailey, and R. H. Schumm, Nat. Bur. Stand. (U.S.), Tech. Note 270-4, 152 pages (May 1969).

Key words: Enthalpy of formation; entropy; Gibbs energy of formation; heat capacity; heat of formation; thermodynamic properties.

Tables of selected values of the enthalpy and Gibbs energy of formation, enthalpy, entropy, and heat capacity at 298.15 K (25 °C) and the enthalpy of formation at 0 K, are given for compounds of mercury, copper, silver, gold, nickel, cobalt, iron, palladium, rhodium, ruthenium, platinum, iridium, osmium, manganese, technetium, rhenium, chromium, molybdenum, and tungsten.

TN270-5. **Selected values of chemical thermodynamic properties. Tables for elements 54 through 61 in the Standard Order of Arrangement,** D. D. Wagman, W. H. Evans, V. B. Parker, I. Halow, S. M. Bailey, R. H. Schumm, K. L. Churney, Nat. Bur. Stand. (U.S.), Tech. Note 270-5, 49 pages (Mar. 1971).

Key words: Enthalpy; entropy; Gibbs energy of formation; hafnium compounds; heat of formation; niobium compounds; scandium compounds; tantalum compounds; titanium compounds; vanadium compounds; yttrium compounds; zirconium compounds.

Contains tables of values for the standard heats and Gibbs (free) energies of formation, entropies and enthalpies at 298.15 K and heats of formation at 0 K for compounds of vanadium, niobium, tantalum, titanium, zirconium, hafnium, scandium, and yttrium (elements 54-61 in the Standard Order of Arrangement). These tables are a continuation of the comprehensive revision of NBS Circular 500.

TN270-6. **Selected values of chemical thermodynamic properties. Tables for the alkaline earth elements (elements 92 through 97 in the Standard Order of Arrangement),** V. B. Parker, D. D. Wagman, and W. H. Evans, Nat. Bur. Stand. (U.S.), Tech. Note 270-6, 119 pages (Nov. 1971).

Key words: Barium compounds; beryllium compounds; calcium compounds; enthalpy; entropy; Gibbs energy of formation; magnesium compounds; radium compounds; strontium compounds.

Contains tables of values for the standard heats and Gibbs (free) energies of formation, entropies and enthalpies at 298.15 K and heats of formation at 0 K for compounds of beryllium, magnesium, calcium, strontium, barium, and radium (elements 92-97 in the Standard Order of Arrangement). These tables are a continuation of the comprehensive revision of NBS Circular 500.

TN270-7. **Selected values of chemical thermodynamic properties. Tables for the lanthanide (rare earth) elements (elements 62 through 76 in the standard order of arrangement),** R. H. Schumm, D. D. Wagman, S. Bailey, W. H. Evans, and V. B. Parker, Nat. Bur. Stand. (U.S.), Tech. Note 270-7, 93 pages (Apr. 1973) $1.25, SD Catalog No. C13.46:270-7.

Key words: Cerium compounds; dysprosium compounds; enthalpy; entropy; erbium compounds; europium compounds; gadolinium compounds; Gibbs energy of formation; holium compounds; lanthanides; lanthanum compounds; lutetium compounds; neodymium compounds; praseodymium compounds; promethium compounds; rare-earth elements; samarium compounds; terbium compounds; thulium compounds; ytterbium compounds.

Contains tables of values for the standard heats and Gibbs (free) energies of formation, entropies and enthalpies at 298.15 K and heats of formation at 0 K for compounds of the rare-earth elements (the lanthanides; lutetium through lanthanum; elements 62 through 76 in the Standard Order of Arrangement). These tables are a continuation of the comprehensive revision of NBS Circular 500.

TN277. **Analytical Mass Spectrometry Section: instrumentation and procedures for isotopic analysis,** Edited by W. R. Shields, NBS Tech. Note 277 (July 25, 1966).

Key words: Mass spectrometry; instrumentation; procedures; isotopic analysis.

This report describes the general instrumentation of the Analytical Mass Spectrometry Section and the specific analytical techniques which have been devised for the measurement of isotopic ratios of Ag, Br, Cl, Cr, Cs, Cu, Mg, Pu, and U. Interim procedures for B, Li, Rb, and Sr are also given.

In the appendix some general statistical principles used in the design and analysis are briefly discussed; an example is given in detail illustrating the various steps involved leading from original data to the reported uncertainties for the isotopic ratio of bromine.

TN278. **Scanning electron probe microanalysis,** K. F. J. Heinrich, NBS Tech. Note 278 (Feb. 3, 1967).

Key words: Electron probe; microanalysis; x-ray spectrometry; scanning electron microscopy; electron backscatter; cathodoluminescence.

The combination of electron microprobe x-ray emission spectrometry with the scanning techniques first developed for the scanning electron microscope permits using the scanning electron probe as a microscope sensitive to elemental composition. This technique is particularly useful in the many applications in which spatial distribution of one or more elements in a specimen is more important than local composition. Although oscilloscope representation of probe scanning is usually obtained by the simple technique of producing a dot of light for each arriving photon, more sophisticated scanning techniques such as expanded contrast registration and concentration mapping can provide more quantitative information. Signals other than x-rays, such as target current, electron backscatter, or cathodoluminescence may be used for image formation. Electron beam scanning can also be performed in a discontinuous fashion, so that the electron beam irradiates in succession a number of spots arranged in a square or rectangular pattern, and the number of photons registered in each position is retained in the memory of a multichannel analyzer. The application of these diverse scanning techniques is illustrated.

TN292. **Procedures for precise determination of thermal radiation properties, November 1964 to October 1965,** J. C. Richmond, G. J. Kneissl, D. L. Kelley, and F. J. Kelly, NBS Tech. Note 292 (Feb. 10, 1967).

Key words: Emissivity; emittance; high temperature reflectance; infrared reflectance; radiation properties; reflectance; spectral emittance; spectral reflectance; thermal radiation; total emittance.

The broad overall objective of this continuing program is to develop equipment and procedures for measuring the important thermal radiation properties of materials, particularly those used in aircraft, missiles, and space vehicles, at temperatures up to the melting point of the most refractory material, and to develop physical standards for checking such equipment and procedures. During the period covered by this report the specific objectives were: (1) continued development of the laser-source integration sphere reflectometer, (2) an error analysis of the shallow cavity technique for measuring normal spectral emittance, and (3) a study of the feasibility of preparing emittance standards for use at temperatures above 1400 °K (about 2000 °F).

An error analysis of the shallow cavity technique for measuring total normal emittance of ceramic materials at very high temperatures showed that there was an error due to the translucency of the specimens that was as much as +60% for alumina, and a second error due to thermal gradients in the specimen that was on the order of -10%. Two new techniques were devised in the hope of greatly reducing the translucency error. Progress was made in developing codes to compute and correct for the thermal gradients present in the specimen. The laser-source integrating sphere reflectometer for measuring reflectance of specimens at very high temperatures was extensively redesigned to eliminate errors due to flux reaching the detector on the first reflection, and to convert the reflectometer from the substitution to the comparison mode. A literature search was made of techniques for measuring thermal radiation properties of solids at temperatures above 2500 °K (4000 °F).

TN293. **Research on crystal growth and characterization at the National Bureau of Standards, June 1966,** Editor, H. C. Allen, Jr., NBS Tech. Note 293 (Aug. 26, 1966.)

Key words: Crystal growth; crystal characterization; crystalline materials.

The National Bureau of Standards with partial support from the Advanced Research Projects Agency of the Department of Defense is continuing a wide program of studies involving crystalline materials. These include investigation of methods and theory of growth, study of detection and effects of defects, determination of physical properties, refinement of chemical analysis, and determination of stability relations and atomic structure. The types of materials range from organic compounds, through metals, and inorganic salts to refractory oxides. This report summarizes progress in those projects wholly or partially supported by ARPA.

TN294. **Notes on the state-of-the-art of benefit-cost analysis as related to transportation systems,** J. D. Crumlish, NBS Tech. Note 294 (Nov. 1, 1966).

Key words: Benefit-cost analysis; transportation economics; transport systems; systems analysis; state of the art.

This review of benefit-cost analysis as a tool for evaluating alternative courses of action describes the technique, discusses a number of benefit-cost studies, and indicates the difficulties inherent in this area of applied economics. The author concentrates on the application of the technique to large scale transport problems, reviews the literature and indicates in his conclusions where the technique can be helpful and where there is little chance for its success.

An accompanying matrix of benefit-cost studies and a commentary thereon is supplied by Marsha Geier, an NBS economist. Miss Geier's literature search failed to produce any analytic methods which were comprehensive, theoretically justifiable, operational or significant. This finding tended to support the views of the author. (Introduction by Alan J. Goldman, Applied Mathematics Division, Institute for Basic Standards, National Bureau of Standards.)

TN295. **Disclosures on: A transrotor engine; high temperature platinum resistance thermometer; dynamic analog correlation system; and combination metering and safety valve for filling sonde balloons with hydrogen,** Editors, D. Robbins and A. J. Englert, NBS Tech. Note 295 (Oct. 21, 1966).

Key words: Transrotor engine; platinum resistance; dynamic analog correlation system; combination metering and safety valve; high temperatures.

This note presents descriptions and drawings of four devices embodying interesting and unusual solutions to problems frequently encountered in their respective fields: a transroto

ngine, a dynamic analog correlation system, a high temperature atinum resistance thermometer, and a combination metering nd safety valve for filling sonde balloons with hydrogen.

Other disclosures on various subjects may be found in NBS echnical Notes 237, 253, 263, 282, and 287.

N296. **A grammar for component combination in Chinese characters,** B. K. Rankin, III, S. Siegel, A. McClelland, and J. L. Tan, NBS Tech. Note 296 (Dec. 1966).

Key words: Chinese characters; grammar; generative grammar; component combination; phrase structure grammar; linguistics; frame embedding; two-dimensional languages.

A linguistic analysis of one aspect of the structure of Chinese haracters is presented. The analysis is an extension into two imensions of a general approach to one-dimensional language tudy. Results of the analysis are in the form of a three-level enerative grammar. The first level formalizes restrictions overning the general complexity of well-formed Chinese haracters; the second level formalizes co-occurrence onstraints among character components and the particular patial arrangement of these components in classes of haracters; the third level constitutes a procedure for selecting ctual components from a lexicon. Finally an evaluation of the rammar is presented, in terms of criteria used in evaluating natural language grammars.

N297. **Evaluation of information systems: A selected bibliography with informative abstracts,** M. M. Henderson, NBS Tech. Note 297 (Dec. 1967).

Key words: Effectiveness; evaluation; performance; relevance; testing of information systems.

A survey of the literature on evaluation of information systems as been conducted by the Technical Information Exchange, Center for Computer Sciences and Technology, National Bureau of Standards. During the early stages of the survey, the literature was divided among descriptions of programs which compared the performance of two or more information systems, accounts of programs which studied the performance of one system, papers and reports which discussed the problems of evaluation programs, and documents which proposed new techniques for evaluation of systems. From the total literature collected, those references which were judged to be most directly concerned with the subject of evaluation of information systems were selected and abstracted. The abstracts are designed to give a summary of the content of the corresponding paper; the author's own wording was used extensively, in order to avoid misinterpretation. All of the references collected are listed, in alphabetic order of authors' names, in the appendix to the main body of this publication.

TN298. **A survey of ionization vacuum gages and their performance characteristics,** W. G. Brombacher, NBS Tech. Note 298 (Feb. 3, 1967).

Key words: Bayard-Alpert gages; cold cathode vacuum gages; conductance pressure dividers; hot cathode vacuum gages; ionization gages; vacuum gage calibration systems; vacuum gages; volumetric pressure dividers.

The design of various types of ionization gages is outlined, with particular attention to the design elements important to performance. The performance and the many factors affecting the performance of the various gages are reviewed. Methods of calibration are discussed in some detail, including the use of volumetric pressure dividers, conductance pressure dividers and constant rate of pressure change methods. About 365 references to the literature are cited.

TN299. **Calculation of the heating value of a sample of high purity methane for use as a reference material,** G. T. Armstrong, NBS Tech. Note 299 (Dec. 15, 1966).

Key words: Methane; heating value; heat of combustion; reference material; gross heating value.

The heat of combustion of CH_4 has been recalculated in kJ $(mol)^{-1}$, Btu $(mol)^{-1}$, Btu (cu ft)$^{-1}$ (dry basis) and Btu (std. cu ft)$^{-1}$ (saturated basis), using the best available experimental determinations of the heat of combustion and other measured quantities and the most recent generally accepted physical constants and defined physical units. The calculations are outlined in detail. The resulting quantities are applied to calculation of the heat of combustion of a reference sample of CH_4 submitted for analysis of composition and certification of heating value by the Institute of Gas Technology.

TN340. Unassigned.

TN341. **The long-term performance of two rubidium vapor frequency standards,** B. E. Blair and A. H. Morgan, NBS Tech. Note 341 (June 22, 1966).

Key words: Aging; calibration (USFS); frequency standards; gas cells; performance (long term); reliability; rubidium; stability.

Since mid-1961 the National Bureau of Standards has used two rubidium vapor frequency standards as transfer or Working Frequency Standards (WFS). The WFS provides a continuously available frequency which is periodically calibrated in terms of the United States Frequency Standard (USFS). This paper evaluates these calibration data over a 44.5-month period of time. It gives the long-term performance of the rubidium standards in terms of the USFS, compares them with a commercial cesium-beam frequency standard, and presents their reliability characteristics as shown by the mean-time-between-failures (MTBF). The calibration data are graphed with applicable tolerance limits for the between-adjustment periods. The average standard error of estimate about least squares lines fitted to the frequency data is about 2 parts in 10^{11}. The rubidium standards also show a rather consistent daily aging rate of parts in 10^{13}. This would indicate that the frequency of either unit would change a few parts in 10^{10} if operated continuously for one year without any frequency adjustments.

TN342. **Hydromagnetic wave propagation near 1 c/s in the upper atmosphere and the properties and interpretation of pc 1 micropulsations,** J. A. Dawson, NBS Tech. Note. 342 (June 30, 1966).

Key words: Alfven; dispersion; hydromagnetic; magnetosphere; multicomponent; pc 1 micropulsations; plasma; polarization; propagation.

Part I. Hydromagnetic wave propagation near 1 c/s in the upper magnetosphere: Dispersion and polarization relations are developed from basic considerations for a hydromagnetic wave at about 1 c/s propagating in a cold uniform plasma. The treatment is then extended to include the effects of ion-electron collisions. It is shown that the approximations used are valid in the earth's magnetosphere for heights between 10,000 and 50,000 km (2.6 to 8.8 earth radii). At lower elevations the plasma must be considered as nonuniform. Above 50,000 km the small amplitude assumption is invalid. Finally the theory is extended to include the effects of a multicomponent plasma.

Part II. The properties and interpretation of pc 1 micropulsations: A reasonable hydromagnetic model for the propagation of pc 1 micropulsations is one in which Alfven (left-hand) waves travel along field lines to reach the earth's surface at

auroral latitudes and then propagate equatorward as modified Alfven (right-hand) waves just above the ionosphere. The isotropic right-hand wave is constrained to a duct between 400 and 2000 km above the earth by refractive processes. It is shown how many of the observed properties of pc 1's can be related to such a model. Mechanisms for the generation of pc 1's are also discussed and it is concluded that particle instabilities are the most likely source.

TN343. **Temperature-entropy diagram for parahydrogen triple-point region,** C. F. Sindt and D. B. Mann, NBS Tech. Note 343 (June 22, 1966).

Key words: Enthalpy; entropy; parahydrogen; pressure-volume; properties; temperatures; triple-point region; T-S diagram.

The three-phase region at and near the triple point of parahydrogen is presented on the graphical coordinates of temperature and entropy. Isobars from 10 mm Hg to 340 atmospheres, temperatures from 11° to 23 °K and specific volumes covering the range of from 10.5 cc/gm to 15,000 cc/gm are included. The energy base of enthalpy and entropy are consistent with previous data published by this laboratory.

TN344. **A sensitive recording NMR ultrasonic spectrometer,** L. W. James, NBS Tech. Note 344 (Sept. 7, 1966).

Key words: Boxcar integrator; nuclear magnetic resonance; phonon nuclear interaction; ultrasonics.

Instrumentation is described for automatically obtaining a continuous recording of ultrasonic absorption lines. Ultrasonic power is added to the crystal lattice by a transducer mounted on a single crystal of the sample. The interaction of the ultrasonics with the nuclear spin system is recorded by using a pulse NMR system in conjunction with a boxcar integrator. This technique is more sensitive and provides more easily interpretable results than earlier systems.

TN345. **A new near-zone electric field-strength meter,** F. M. Greene, NBS Tech. Note 345 (Nov. 15, 1966).

Key words: Device, electro-explosive ordnance; field, near-zone electromagnetic; hazards, electromagnetic radiation; line, non-metallic electrical transmission; line, semi-conducting plastic transmission; meter, electric field-strength; telemetry, novel form of.

The National Bureau of Standards has recently completed the development of prototype instrumentation for measuring the electric-field components of complex, high-level, near-zone electromagnetic fields from 0.1 to 1000 volts per meter, at frequencies from 150 kHz to 30 MHz with a present uncertainty of less than ±2 dB. The design of the NBS meters is based on the use of a novel form of telemetry, employing a completely non-metallic electrical transmission line, which apparently has not been fully exploited heretofore. This avoids the perturbing effects on the field being measured, usually caused by field-strength meters employing metallic RF transmission lines. The design and performance of the meter are discussed in some detail.

TN346. **On the natural shift of a resonance frequency,** R. J. Harrach, NBS Tech. Note 346 (Sept. 29, 1966).

Key words: Atomic beam; frequency shift; radiation field; resonance; thallium.

The natural resonance frequency shift, caused by the transition-inducing radiation field, is examined for a magnetic dipole transition between hyperfine structure levels in the ground state of a thallium atom. A calculation predicts, for an atomic beam experiment, a natural shift magnitude of 1.4 parts in 10^{10} of the thallium resonance frequency, per mW/Oe. In th experiment, frequency shifts caused by overlap of neighborin resonances were observed, but the natural shift was unresolved indicating that its size is more than an order of magnitude belov the calculated value. Subsequently it has been shown that th natural shift was inhibited by the particular radiation field mod used in the experiment. When the theory correctly takes thi mode into account, the calculated natural frequency shift i consistent with the experimental results.

TN347. **A standard for accurate phase-angle measurements a audio frequencies,** W. W. Scott, Jr., NBS Tech. Note 347 (Oct 14, 1966).

Key words: Phase-angle; standard; audio frequency thermal voltage converter; inductive voltage divider measurement.

A method is described for the measurement of phase angle from 0 ° to 360 ° (except for a band ±10 ° about the 180 ° point with an uncertainty at audio frequencies of ±0.05 ° to ±0.01 ° depending on the phase-angle. The method utilizes readil available equipment which may be assembled and connected t serve as a standard. The principal advantage of this standard i in its potentially broad frequency-response; namely, 10 Hz to 1 kHz or higher. It makes use of inductive voltage dividers an thermal voltage converters to compare voltage magnitudes which are related to phase-angle by the law of cosines. Th thermal voltage converters are compared with each other befor each phase-angle measurement. Their outputs are connected s that short-time power supply variations do not affect th measurements. The repeatability of measurements with thi standard at a phase-angle of 60 ° is within a range of 0.001 °.

A model has been built which shows good measuremen precision, but it has not been thoroughly tested or studied a many frequencies and phase-angles for sources of error. Thi report serves as a record of the development work completed o this standard to date.

TN348. **Infrared reflectances of metals at cryogenic temperature — a compilation from the literature,** P. F. Dickson and M. C Jones, NBS Tech. Note 348 (Oct. 14, 1966).

Key words: Compilation; cryogenic; infrared; metals reflectance.

Spectral and total reflectances for metals at cryogeni temperatures in the infrared wavelength region are compile from the literature. Information concerning sample preparatio and purity, radiation source, and methods of reflectanc measurements are also presented. Observations regarding th effects on reflectance of temperature, oxide layer, wavelength and sample preparation are given.

TN349. **The design and operation of a high-voltage calibratio facility,** W. W. Scott, Jr., NBS Tech. Note 349 (Nov. 10 1966).

Key words: Alternating-current; calibration; direct-curren high-voltage; ratio; safety; standards enclosure transformer; voltage-divider; voltmeter.

The high-voltage calibration facility, in operation for seve years at the National Bureau of Standards Radio Standard Laboratory (RSL) but now at NBS Washington, is describe with emphasis on several novel construction features an calibration techniques. The more usual calibration technique are also outlined for the assistance of those personnel i standards laboratories assigned the task of calibrating with hig accuracy, electrostatic voltmeters, resistive dividers, an potential transformers at high voltage. Precautions, based o experience in the calibration and use of high voltage standard are given so that certain errors may be avoided by the users.

TN350. **The viscosity and thermal conductivity coefficients of dilute nitrogen and oxygen,** G. E. Childs and H. J. M. Hanley, NBS Tech. Note 350 (Oct. 31, 1966).

Key words: Dilute gases; nitrogen; oxygen; transport coefficients; Lennard-Jones; Kihara; Exp: 6; Morse potential functions; Eucken correction; correlation.

The coefficients of viscosity and thermal conductivity for dilute nitrogen and oxygen were examined using a method proved suitable for argon. Given the kinetic theory expressions for the transport coefficients, this method indicates a selection of a potential function and its parameters to correlate theory with experimental data. The potential functions chosen were the Lennard-Jones, Kihara, Exp: 6 and the Morse. It was found that the Kihara was most suitable and theoretical viscosity coefficients were computed with this function. The usual correction to the kinetic theory equation for thermal conductivity, the Eucken correction, was found not to be sufficient and it was decided to use an empirical polynomial equation to correlate the thermal conductivity coefficients. Tables of the transport coefficients for both gases are given between 100 and 1000 °K.

TN351. **Discussion of errors in gain measurements of standard electromagnetic horns,** R. W. Beatty, NBS Tech. Note 351 (Mar. 1967).

Key words: Antennas; calibration; comparison; effective aperture; electromagnetic horns; gain; measurement; microwave; mismatch errors; Rayleigh distance; standard gain horns.

In setting up a calibration service for measuring the gain of standard electromagnetic horns, one needs a reference horn in which one has developed a high degree of confidence. Although it is possible to calculate the gain of horns of certain design, confidence can be increased by carefully measuring the gain. This note examines a method for measuring the gain of two identical horns, listing the assumptions made in making such a measurement. The theory of 2-port waveguide junctions is applied to the analysis of the measurement technique. The method is shown to be essentially an attenuation measurement which has additional sources of error. Although these errors are not analyzed and evaluated in this note, the problem is perhaps more clearly stated than it was previously. The mismatch error in comparing two horns as receiving antennas is analyzed. Data is given on the aperture efficiency of standard horns which indicates that improvements in the design of such horns are feasible. It is concluded that, at present, an uncertainty limit of the order of tenths of decibels seems realistic, but hundredths of decibels seems unattainable until further refinements are made both in the standard horns themselves and in the measurement techniques.

TN352. **The viscosity and thermal conductivity coefficients of dilute neon, krypton, and xenon,** H. J. M. Hanley and G. E. Childs, NBS Tech. Note 352 (Mar. 23, 1967).

Key words: Dilute gases; neon; krypton; xenon; transport coefficients; correlations; m-6; Kihara; Exp: 6, Morse; potential functions.

The coefficients of viscosity and thermal conductivity for dilute neon, krypton, and xenon were examined by a method already proved successful for dilute argon, oxygen, and nitrogen. This method selects a suitable potential function, and its parameters, which is then used to correlate theory with experimental data, given the kinetic theory expressions for the transport coefficients. The method has recently been expanded and generalized and the results of this general study are applied in this note. The potential functions examined were members of the m-6, Kihara, Exp: 6, and Morse families. It was found that the Kihara was most suitable for neon, and the m-6, with m=17 and m=24, was most suitable for krypton and xenon, respectively. Viscosity and thermal conductivities were calculated from these functions and tables are given between 100 and 1000 °K.

TN353. **Connector for saturated standard cells,** J. J. Barth, NBS Tech. Note 353 (April 21, 1967).

Key words: Connector; electromotive force; oil baths; standard cells; thermoelectric.

This paper describes a connector used for making electrical connections to saturated standard cells in oil baths. The connector has at least three advantages over other methods in common use. These advantages are namely: (1) it does not generate thermoelectromotive forces; (2) it allows cell racks to be placed close together in the bath; and (3) it is economical to fabricate since it can be made from a common inside caliper.

TN354. **The single-engine Claude cycle as a 4.2 °K refrigerator,** R. C. Muhlenhaupt and T. R. Strobridge, NBS Tech. Note 354 (June 1, 1967).

Key words: Claude; cryogenics; refrigeration.

The performance of the 4.2 °K Claude-cycle refrigerator has been computed taking into account the efficiencies of the various components. The results are presented in graphical form. These charts give the input power requirements, mass flow rates for both the compressor and expander, pertinent temperatures, and allow selection of the optimum high pressure for a given set of component characteristics.

TN355. **Correlations for predicting leakage through closed valves,** J. Hord, NBS Tech. Note 355 (Aug. 1, 1967).

Key words: Leak detection; leak flow rates; leak rates; leakage through valves; predicting leak rates; seal leakage; valve seat leakage.

Safety, convenience, and economy often demand the inference of leakage of a given fluid from known leakage of another test fluid across valve seats, welded and threaded fittings, seals, etc. The temperatures of the fluids also may be different. An example is the prediction of gaseous hydrogen leakage at 20 °K from test data obtained with nitrogen gas at 77 °K. Various flow formulae (molecular, transition, and continuum) are examined, and two simple methods of correlating leakage for single-phase fluids are deduced. The correlations obtained (excluding transition flow through long channels) indicate the leakage is inversely proportional to the square root of the density, or inversely proportional to the absolute viscosity, of the fluid. Thus, for gases, the leakage is directly proportional to the sonic velocity of the gas. The proper relationship must be established by experiment for each valve, fitting, etc.

TN356. **Comparison of incompressible flow and isothermal compressible flow formulae,** J. Hord, NBS Tech. Note 356 (Aug. 17, 1967).

Key words: Compressible flow; flow comparison; fluid flow; incompressible flow; mass flow; pressure drop.

Mass flow formulae for incompressible and "modified-incompressible" flow are compared with the isothermal compressible flow relation under the following conditions: The gas flow is steady, isothermal, and fully developed in a horizontal pipe of constant cross section with a prescribed static pressure drop (P_1-P_2). The comparative data are limited to static pressure ratios (P_2/P_1) > ½, and subsonic isothermal flow. Laminar and turbulent flows are treated. Under the limitations of the comparison, modified-incompressible flow and isothermal gas flow relations are identical when $fL/2D \geqslant \ln(P_1/P_2)$. Graphical

plots idicate the degree of approximation or error involved in using incompressible relations to solve compressible flow problems. Pressure losses due to end effects are briefly discussed.

TN357. **Signal design for time dissemination: some aspects,** J. L. Jespersen, NBS Tech. Note 357 (Nov. 2, 1967).

Key words: HF; noise; satellite; synchronization; time and frequency dissemination; VHF; VLF.

The purpose of this paper is to discuss, in a general way, some problems of time signal dissemination in a noisy environment. Most of the paper applies to any timing system, but particular emphasis is given to a CW two-frequency system. This is done for two reasons: first, as will be shown, a two-frequency CW system evolves naturally from fundamental considerations to meet certain user requirements; and second, a two-frequency VLF system is being investigated experimentally at the present time.

TN358. **A review of studies made on the decade fluctuations in the earth's rate of rotation,** W. R. Davey, NBS Tech. Note 358 (Oct. 16, 1967).

Key words: Core-mantle coupling; decade fluctuations; dynamo theory; earth's core; geomagnetism; rotation of the earth; westward drift.

Studies of variations in the length of the day (l.o.d.) on the order of a few milliseconds over the period of a few decades are briefly reviewed. In this connection, studies of the dynamo theory of geomagnetism, the westward drift of the magnetic field, and electromagnetic core-mantle coupling preface the theory of the decade fluctuations in the l.o.d.

TN359. **Two-phase (liquid-vapor), mass-limiting flow with hydrogen and nitrogen,** J. A. Brennan, D. K. Edmonds, and R. V. Smith, Nat. Bur. Stand. (U.S.), Tech. Note 359, 24 pages (Jan. 30, 1968).

Key words: Choking; hydrogen; nitrogen; shocks; two-phase flow.

Experimental data on critical (choked) mass flow in a constant area test section are presented. The data are compared to some simple analytical models which have been recommended for design purposes. The data show the same general behavior as that reported for other noncryogenic fluids.

TN360. **On the selection of the intermolecular potential function: Application of statistical mechanical theory to experiment,** H. J. M. Hanley and M. Klein, NBS Tech. Note 360 (Nov. 20, 1967).

Key words: Correlation; equilibrium properties; experimental data; intermolecular potential function; theory; transport properties.

We have developed a method here to evaluate quantitatively the relationship between model intermolecular potential functions and macroscopic experimental properties. Specifically, we have studied the function families: m-6, Kihara, exp:6, and Morse, and the properties: viscosity coefficient, diffusion coefficient, second virial, and Joule-Thomson coefficient. Our method is not restricted to these functions and properties; it is valid for any function and any property provided the appropriate theoretical expressions are available.

The principal conclusions from this work are: 1. A temperature range exists (around room temperature for most

TN361, Revised October 1972. **Liquid densities of oxygen nitrogen, argon, and parahydrogen,** H. M. Roder, R. D. Mc Carty, and V. J. Johnson, Nat. Bur. Stand. (U.S.), Tech. Not 361 (Revised), 181 pages (Oct. 1972) $1.25, SD Catalog Nc C13.46:361 (Revised).

Key words: Argon; compressed liquid; density; graphs liquid; nitrogen; oxygen; parahydrogen; pressure; saturate liquid; tables; temperature; uncertainties; volume; volum correction factor.

Tables of pressure, volume, density and temperature for th saturated liquid and for compressed liquid states from the tripl point to the critical point, of oxygen, nitrogen, argon, an parahydrogen are presented. The table entries of temperature ar in Kelvin and Rankine, table entries in pressure are in a mospheres and psia. Volumes or densities are given in sever different units, and density ratios or "volume correction factors are tabulated for each entry. Estimates of the uncertainty for th tabulated data are given. The tables and graphs were prepared i the style and in the units preferred by users. They are intende as source for both technician and engineer. Revises and update NBS Technical Note 361, issued January 31, 1968.

TN361. (Revised). Metric Supplement. **Liquid densities of ox ygen, nitrogen, argon and parahydrogen,** H. M. Roder, Na Bur. Stand. (U.S.), Tech. Note 361 (Revised), (Metric Supple ment), 114 pages (June 1974) SD Catalog No. C13.46:36 (Rev.), Metric Supplement.

Key words: argon; compressed liquid; density; densit ratios; liquid; nitrogen, oxygen; parahydrogen; pressure saturated liquid; tables; temperature; uncertainties; volume

Tables of pressure, volume, density and temperature for th saturated liquid and for compressed liquid states from the tripl point to the critical point, of oxygen, nitrogen, argon, an parahydrogen are presented. The table entries of temperature ar in Kelvin and degrees Celsius, table entries in pressure are i bars and kp/cm^2. Volumes or densities are given in several di ferent units, and density ratios are tabulated for each entry. Est mates of the uncertainty for the tabulated data are given. The ta bles were prepared in the style and in the units preferred by th users. They are intended as source for both technician and en gineer.

TN362. **Thermodynamic properties of He^3-He^4 solutions wit applications to the He^3-He^4 dilution refrigerator,** R. Radebaugh NBS Tech. Note 362 (Dec. 29, 1967).

Key words: Cryogenics; dilution refrigerator; enthalpy entropy; Fermi-Dirac gas; helium-3; helium-4; liquid mixtures; osmotic pressure; quantum fluid; specific hea thermodynamic properties.

The thermodynamic properties of liquid He^3-He^4 solution between 0 and 1.5 °K are calculated by using the weakl interacting Fermi-Dirac gas model for He^3 in He^4. Certai experimental data below about 0.4 °K are used to evaluate som of the parameters in the model. The properties of both He^3 i He^4 and the total solution are calculated for concentrations He^3 up to 30 percent. All experimental data agree very well wit the calculated results, although little data exist below 0.4 °K The calculated properties are used to analyze the behavior of th He^3-He^4 dilution refrigerator in both the continuous and singl cycle processes. The maximum heat absorption below abou 0.04 °K is found to be 82 T^2 joules per mole of He^3 circulate The effect of an imperfect heat exchanger and He^4 circulation o the refrigeration capacity is discussed. An analysis of two ne types of single-cycle processes is also given.

N363. **Computer solutions for thermal-acoustical oscillations in gas-filled tubes,** M. T. Norton and R. C. Muhlenhaupt, Nat. Bur. Stand. (U.S.), Tech. Note 363, 86 pages (Nov. 30, 1967).

Key words: Cryogenics; liquid helium; thermal oscillations.

A digital computer program to determine solutions for hermal-acoustical oscillations in gas-filled pipes is described. sing a typical temperature gradient and tube length from test ata, the program calculates the effect of changes in heat transfer oefficient, friction factor, and pipe diameter. Details of the pro-ram are explained. A comparison is made between computation nd one particular test datum point. Although the calculations re based on helium as the media, the program can accommodate ny fluid treated as a perfect gas.

N364. **Slush hydrogen pumping characteristics,** D. E. Daney, P. R. Ludtke, D. B. Chelton, and C. F. Sindt, Nat. Bur. Stand. (U.S.), Tech. Note 364, 41 pages (Apr. 1968).

Key words: Cavitation; centrifugal pump; cryogenic pump; liquid-solid hydrogen mixtures; slush hydrogen.

The pumping characteristics of liquid-solid mixtures of arahydrogen (slush hydrogen) were investigated using a centrifugal type liquid hydrogen pump with a specific speed range of 600 to 3100. Performance tests at 8,000, 11,000, 14,000, and 9,000 rpm and cavitation tests at 11,000 and 14,000 rpm were nade. As predicted by theory, the developed head for liquid and slush hydrogen are the same when the difference in density is onsidered. The pump efficiency, cavitation constant and NPSH equirements for slush hydrogen are also the same as for the tri-le-point liquid. After 34 minutes running time with slush ydrogen out of a total running time of 79 minutes, the pump components showed no wear over that expected from operation n liquid.

TN365. **Survey of electrical resistivity measurements on 16 pure metals in the temperature range 0 to 273 °K,** L. A. Hall, Nat. Bur. Stand. (U.S.), Tech. Note 365, 114 pages (Feb. 1968).

Key words: Aluminum; beryllium; cobalt; copper; compilation; electrical resistivity; gold; indium; iron; lead; low temperature; magnesium; molybdenum; nickel; niobium; platinum; silver; tantalum; tin.

Experimental electrical resistivity data for 16 pure metals have been compiled, tabulated, and graphically illustrated for a temperature range of 0 to 273 °K. A section has been prepared for each particular metal which includes references, brief comments concerned with preparation of sample, purity, and any other pertinent information, tabulated data, and graph.

TN366. **An analysis of the Brayton cycle as a cryogenic refrigerator,** R. C. Muhlenhaupt and T. R. Strobridge, Nat. Bur. Stand. (U.S.), Tech. Note 366, 116 pages (Aug. 1968).

Key words: Brayton; cryogenics; refrigeration.

The performance of a Brayton-cycle refrigerator has been computed taking into account the efficiencies of the various components. The results are presented in graphical form. These charts give the input power requirements, mass flow rate, pertinent temperatures, and allow selection of the optimum high pressure for a given set of component characteristics.

TN367. **A bibliography of thermophysical properties of methane from 0 to 300 °K,** L. A. Hall, Nat. Bur. Stand. (U.S.), Tech. Note 367, 121 pages (May 1968).

Key words: Bibliography; equation of state; low temperature; mechanical properties; methane; thermodynamic properties; transport properties.

References together with an abbreviated abstract are presented for mechanical, thermodynamic, and transport properties of methane from 0 to 300 °K published up to December 1967. A total of 660 articles have been indexed. Each article has been reviewed and coded with regard to properties studied, type of article (i.e., experimental, theoretical, etc.), and method of presentation of data. The temperature and pressure ranges for each property under consideration are also given. An index has been prepared according to property with four sub-categories: solid, liquid, gas up to 200 °K, and gas above 200 °K.

TN368. **Solution of the Abel integral transform for a cylindrical luminous region with optical distortions at its boundary,** E. R. Mosburg, Jr., and M. S. Lojko, Nat. Bur. Stand. (U.S.), Tech. Note 368, 27 pages (July 12, 1968).

Key words: Abel inversion; Abel transform; emissivity profile; plasma diagnostics; radiance profile.

The use of orthogonal polynomial expansions in the calculation of the Abel integral transform is discussed. Particular attention is directed to the effects of optical and instrumental distortions when the luminous region is contained by a cylindrical glass tube. An easily calculable solution of the Abel integral is presented which reduces the effect of such distortions by employing a weighting function which has a maximum at the center and vanishes at the boundary. This approach results in a more accurate solution of the Abel integral transform in the case where significant optical and instrumental distortions are present near the boundary of the luminous region.

TN369. **Interferometric measurements of the complex dielectric constant of liquids,** W. S. Lovell and L. M. Thiel, Nat. Bur. Stand. (U.S.), Tech. Note 369, 89 pages (Aug. 1968).

Key words: Approximation errors; complex dielectric constant; convergence confidence interval; contour diagrams; dielectric liquid; diffraction; experimental apparatus; Fresnel equations; generalized Newton iteration function; imperfect reflections; interferometric measurements; interferometry; least squares iteration function; liquid dielectrics; method of selected points; millimeter waves; multiple reflections; outliers; perpendicular polarization; quasi-optics; reflection coefficient; transverse displacement; vector solution.

Paper I. Errors in the "perfect square" approximation.— Errors arising from the use of a "perfect square" approximation in treating free-space, interferometric measurements of the complex dielectric constant of liquids are described. It is shown that such errors (1) are generally positive, (2) often exceed values previously estimated for the measurement technique as a whole, and (3) are not generally predictable without some prior knowledge of the dielectric properties of the material being investigated. In addition, these errors depend upon the dielectric thickness over which data are incorporated into the calculations. Finally, an anomaly in the calculations previously attributed to experimental error is shown to arise from the "perfect square" approximation itself. It is concluded that this approximation may at best provide initial estimates for ϵ' and ϵ'' which may then be used in a more complete mathematical treatment.

Paper II. Experiment apparatus.— Design details of a free-space, millimeter-wave interferometer are described. The apparatus radiates at oblique incidence to an air-dielectric-metal configuration placed between dissimilar horns. Errors arising from the quasi-optical nature of this radiation are described, and quantitative data are presented which demonstrate techniques for minimizing such errors. The techniques employed should have general applicability in millimeter-wave measurements. For

the particular instrument described, the errors are shown to be of such magnitude that experimental reflection coefficient profiles should conform to an adequate theoretical description. A means for more accurate measurements of the complex dielectric constant of liquids is then provided.

Paper III. Derivation of the absolute reflection coefficient. — For measurements of the complex dielectric constant of liquids by free-space reflection and interference of electromagnetic radiation, a theoretical reflection coefficient for the air-dielectric-metal configuration is derived. The derivation is based on a model which treats multiple reflections within the dielectric explicity. As an extension of earlier theory, this reflection coefficient incorporates effects of (1) imperfect reflections at the dielectric-metal interface, together with other losses, and (2) radiation sources presenting nonplanar wavefronts and having finite bandwidths. Effects arising from a finite sample or receiving surface are also discussed.

Paper IV. A numerical method for determining the best complex dielectric constant. — A numerical method is presented for determining the best complex dielectric constant $\epsilon^* = \epsilon' - i\epsilon''$ from an experimental record obtained at millimeter-wavelengths from free-space, interferometric measurements of liquids. The method of selected points is applied to the reflection coefficient expression to obtain a set of simultaneous equations which is solved for an initial vector solution using the generalized Newton iteration function. The principle of least squares is then applied to achieve the best fit between the reflection coefficient expression and experimental record. The desired values of ϵ' and ϵ'' are included as components of a final vector solution of the best fitting theoretical curve.

TN370. **Calibration principles and procedures for field strength meters (30 Hz to 1 GHz),** H. E. Taggart and J. L. Workman, Nat. Bur. Stand. (U.S.), Tech. Note 370, 157 pages (Mar. 1969).

Key words: Calibration procedures; dipole antennas; field strength meters; loop antennas.

The National Bureau of Standards has been calibrating many types of field strength meters and their related antennas at frequencies up to 1000 MHz for several years. Various techniques of measurement have been investigated regarding accuracy, calibration time, ease of operation, and reliability. This report discusses some of these calibration techniques in detail, and in some cases lists step-by-step procedures for performing the complete calibration. Typical calibration data are used to take the reader from the beginning of the calibration to the completed test report. All measurement setups are clearly illustrated, listing the equipment necessary to perform the calibration. Methods of calibrating two basic types of antennas are described: (1) the loop antenna at frequencies from 30 Hz to 30 MHz and (2) half-wavelength dipole antennas from 30 to 1000 MHz. Two methods of calibrating loop antennas are discussed in detail, the standard-field method and the injection method. The standard-antenna method of calibrating dipole antennas is fully described. Measurement uncertainties of various methods are discussed. This report was written to help technical personnel actively participate in antenna calibration work. Hopefully this information will help people to set up new calibration services and to improve existing calibrating facilities.

TN371. **Transistorized low voltage regulator circuits and design,** J. H. Rogers, Nat. Bur. Stand. (U.S.), Tech. Note 371, 38 pages (Sept. 1968).

Key words: D-C amplifier; design equations; differential amplifier; dual regulator; integrated circuit; output resistance; power dissipation; power supply; preregulat regulation factor; ripple voltage; transistor; voltage regu tion; zener diode.

Simplified design equations and circuits are presented f three separate transistor voltage regulator circuits covering t range of 2 to 30 volts. Examples of design, use of equatio selection of components and performance data are presented. appendix is included to show the use of recent integrated circ (I.C.) voltage regulators.

TN372. **Mathematical techniques for EPR analysis of S = 5/2 io in C_2 symmetry. Application to Fe^{3+} in quartz,** R. L. Petersc L. M. Matarrese, and J. S. Wells, Nat. Bur. Stand. (U.S Tech. Note 372, 23 pages (June 1969).

Key words: Electron paramagnetic resonance; ferric io synthetic quartz.

Various formulas and mathematical techniques useful for t analysis of the EPR spectra of ions of angular momentum 5/2 sites of C_2 symmetry are presented. Special emphasis is given the spectrum of Fe^{3+} in synthetic brown quartz. Included a matrix elements of the Racah operators for arbitrary direction the axis of quantization relative to the crystalline electric fi axes, spectral line-position formulas based upon a usage second-order perturbation theory which is somewhat differe from the usual, and line-intensity formulas.

TN373. **Radio-frequency measurements in the NBS Institute f Basic Standards,** R. S. Powers and W. F. Snyder, Editors, N Bur. Stand. (U.S.), Tech. Note 373, 116 pages (June 1969).

Key words: Accuracy; calibration services; measurement measurement techniques; radio frequency; uncertainties measurement.

This volume is a collection of diagrams, tables, and te material, which has been assembled to show the interrelatio ships between various radio frequency measurements made the Institute for Basic Standards (IBS). In particular, the me surements are those which lead to services provided to the pub or to other government agencies. These services include not on calibrations made for fees, but the broadcast services of the fo NBS radio stations. Measurements made as part of the IE research and development program are not included.

The information included is designed to give the users a potential users of the radio frequency services a clearer u derstanding of the origins of the measurement output of IBS this field.

TN374. **Incipient and developed cavitation in liquid cryogens,** K. Edmonds and J. Hord, Nat. Bur. Stand. (U.S.), Tech. No 374, 31 pages (Feb. 1969).

Key words: Cavitation; cryogens; incipience.

Cavitation characteristics of liquid hydrogen and liqu nitrogen flowing in a transparent plastic venturi have been dete mined and conventional cavitation-inception-parameter curv are given. Representative developed-cavitation data, consistir of pressure and temperature measurements within full developed cavities, are also given; measured temperatures a pressures within the cavities were generally not in the modynamic equilibrium. Existing theory was used to obta equations which correlate the experimental data for develop cavities in liquid hydrogen or liquid nitrogen. The theory is e tended to include the effect of cavity thickness and the expe mental data are used to evaluate the results. Some recommend tions for future work are given.

4375. **Tables of bias functions, B_1 and B_2, for variances based on finite samples of processes with power law spectral densities,** J. A. Barnes, Nat. Bur. Stand. (U.S.), Tech. Note 375, 39 pages Jan. 1969).

Key words: Spectral density; statistics; unbiased estimate; variance.

D. W. Allan showed that if y(t) is a sample function of a ran- m noise process with a power law spectral density (i.e., $S_y(f)$ $\eta|f|^\alpha$), then there is generally bias to the estimated variance of defined as

$$\sigma_y^2(N,T,\tau) = 1/N - 1 \sum_{n=1}^{N} (\bar{y}_n - \langle \bar{y} \rangle)^2,$$

here N is the number of samples, y_n is the average value of y(t) er the n-th interval of duration τ, I is the time between the ginnings of any two successive sample intervals, and

$$\langle \bar{y} \rangle \equiv 1/N \sum_{n=1}^{N} \bar{y}_n.$$

lan also showed that, under these conditions, the expectation lue of the estimated variance is proportional to $\tau\mu$ where μ is constant related to α, the exponent in the spectral density; i.e.,

$$E[\sigma_y^2(N,T,\tau)] \propto \tau^\mu.$$

ased on this work one may define the two bias functions

$$B_1(N,r,\mu) \equiv \frac{E[\sigma_y^2(N,T,\tau)]}{E[\sigma_y^2(2,T,\tau)]}$$

nd

$$B_2(r,\mu) \equiv \frac{E[\sigma_y^2(2,T,\tau)]}{E[\sigma_y^2(2,T,\tau)']}.$$

here $r \equiv T/\tau$ and the B's are functions of μ through their depen- ence on y(t).

If one has a sample variance, $\sigma_y^2(N_1, T_1, \tau_1)$, the bias functions llow one to give an unbiased estimate for $\sigma_y^2(N_2, T_2, \tau_2)$ pro- ided the spectral type is known (i.e., μ is known).

The tables give values of $B_1(N,r,\mu)$ and $B_2(r,\mu)$ accurate to our significant figures for the following values of N,r,μ:

$$\mu = -2.0 \text{ to } 2.0 \text{ in steps of } 0.2;$$

$$N = 4, 8, 16, 32, 64, 128, 256, 512, 1024, \infty;$$

$$= 0.001, 0.003, 0.01, 0.03, 0.1, 0.2, 0.4, 0.8, 1, 1.01, 1.1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, \infty.$$

TN376. **Unassigned.**

TN377. **Slush hydrogen fluid characterization and instrumentation,** C. F. Sindt, P. R. Ludtke, and D. E. Daney, Nat. Bur. Stand. (U.S.), Tech. Note 377, 69 pages (Feb. 1969).

Key words: Cryogenic; flow restrictions; friction angle; gel; liquid-solid mixtures; particle size; plug flow; slurry flow; slush hydrogen.

Areas of the slush hydrogen fluid characterization program covered are production, transfer, and storage of liquid-solid mixtures.

An experiment has been performed in which a second component was added to liquid hydrogen to determine the effect on the size of the solid particles produced by the freeze-thaw method. Also, an experiment performed with 4.4 percent oxygen in nitrogen resulted in particles an order of magnitude smaller in size than those normally observed in freeze-thaw production of pure nitrogen slush.

The friction angle of settled solids of slush hydrogen on several metals was determined for surface finishes ranging from 2 to 110 micro inches rms. The angle at which solids slide from the surface was found to be a function of the surface finish.

Data were taken in the flow loop over a range of velocities from 1.5 to 40 ft/sec (0.46 to 12.2 m/s). The friction losses determined from the flow data are compared to losses predicted for Newtonian fluids. Losses with slush of solid fractions from 0.1 to 0.4 were found to be lower than with triple-point liquid hydrogen at the higher Reynolds numbers.

Liquid-solid mixtures of hydrogen with solid fraction of 0.5 were transferred through three types of flow restrictions. The restrictions were a globe valve, an orifice, and a venturi. Losses through the restrictions were essentially the same with the high solid fraction slush as with triple-point liquid.

A brief review of the pumping characteristics of slush hydrogen is presented. A comparison of developed head, efficiency, cavitation constant, and net positive suction head is discussed.

Gelling of slush hydrogen with pyrogenic silica was accomplished with solid fractions from 0 to 0.2. The amount of gelling agent required to gel slush was found to be proportional to the liquid volume of the slush.

TN378. **Preparation and characterization of slush hydrogen and nitrogen gels,** A. S. Rapial and D. E. Daney, Nat. Bur. Stand. (U.S.), Tech. Note 378, 43 pages (May 1969).

Key words: Gels; liquid hydrogen gels; liquid nitrogen gels; liquid-solid hydrogen mixtures; rocket propellants; slush hydrogen; slush hydrogen gels; slush nitrogen gels.

An experimental apparatus has been developed for the gelation of slush hydrogen, and slush hydrogen was gelled for the first time. Measurements of the weight-bearing capacity of the gel as a function of mass percent gelant were made for liquid and slush nitrogen and hydrogen. These measurements verify the simple models discussed here for gelled liquid and slush within the experimental accuracy; the models predict a reduction in gelant concentration from 38 mass percent to 25 mass percent in going from the Normal Boiling Point liquid hydrogen to slush hydrogen of 0.40 solid fraction for the silica gelant used in this work. Reduction in the mass percent gelant for other gelants should be similar.

TN379. **Standard time and frequency: its generation, control, and dissemination from the National Bureau of Standards time and frequency division,** J. B. Milton, Nat. Bur. Stand. (U.S.), Tech. Note 379, 27 pages (Aug. 1969).

Key words: Clock synchronization; frequency and time dissemination; primary frequency standard; standard frequency broadcasts; time interval; time scales.

The Time and Frequency Division of the National Bureau of Standards produces the NBS time scales, AT(NBS), SAT(NBS), and UTC(NBS). These time scales are developed by utilizing the properties of the NBS frequency standard, NBS-III. The main byproduct of these time scales is the operational clock systems. These operational clock systems are used, among other things, to calibrate the clocks and secondary standards necessary for the operation of the NBS radio stations, WWV, WWVB, WWVL, and WWVH. These stations transmit SAT(NBS), UTC(NBS), and various tones, alerts, and corrections for time-of-day information.

TN379-1. **Standard time and frequency: its generation, control, and dissemination from the National Bureau of Standards Time and Frequency Division,** J. B. Milton, Nat. Bur. Stand. (U.S.), Tech. Note 379-1, 26 pages (June 1972).

Key words: Clock synchronization; frequency and time dissemination; primary frequency standard; standard frequency broadcasts; time interval; time scales.

The Time and Frequency Division of the National Bureau of Standards produces the NBS time scales, AT(NBS) and UTC(NBS). These time scales are developed by utilizing the properties of the NBS frequency standard, NBSFS. The main byproduct of these time scales is the operational clock systems. These operational clock systems are used, among other things, to calibrate the clocks and secondary standards necessary for the operation of the NBS radio stations, WWV, WWVB, WWVL, and WWVH. These stations transmit UTC(NBS), and various tones, alerts, and corrections for time-of-day information.

TN381. **Some applications of the Josephson effect,** R. A. Kamper, L. O. Mullen, and D. B. Sullivan, Nat. Bur. Stand. (U.S.), Tech. Note 381, 63 pages (Oct. 1969).

Key words: Josephson effect; superconductivity; thermometry; tunnel junctions.

We describe techniques for fabricating permanent Josephson junctions between thin films of niobium and lead, and for absolute noise thermometry at very low temperatures using the Josephson effect. We discuss the possible benefits of applying superconductivity to nuclear magnetic resonance detection, and review other applications of the Josephson effect.

TN382. **Laser power and energy measurements,** D. A. Jennings, E. D. West, K. M. Evenson, A. L. Rasmussen, and W. R. Simmons, Nat. Bur. Stand. (U.S.), Tech. Note 382, 64 pages (Oct. 1969).

Key words: Calorimetry; laser; laser calorimetry; laser energy; laser power.

Most laser calorimeters operate in a constant temperature environment. The calorimeters can be used as deflection devices or the data can be analyzed by extrapolation or integration. Consideration of the heat flow problem common to all of these methods points up the underlying assumptions and the possible errors involved.

Calorimeters for measuring the output energy of pulsed ruby and neodymium glass lasers have been built and calibrated. The absorbing medium is an aqueous solution of $CuSO_4$. Calibration of laser energy detectors has an estimated uncertainty of ± 2 percent for input energies of 0.1J to 100J. Comparisons of absorption cell calorimeters with metal plate calorimeters agree within 1 percent.

Instrumentation is described that is used for the calibration of CW laser power meters. The calibration unit employs an absorption cell calorimeter to calibrate the output of a photovoltaic cell transfer detector. The power meter to be calibrated is then compared to the calibrated output of the transfer detector. The calibrations are within an accuracy of 4 percent.

A discussion and description is also given of several types of calorimeters that have been used to measure the output of a 100 watt CO_2 laser. The most recent design provides for measurement from 1 watt to 5 kilowatts with a measured accuracy of better than 3 percent.

TN383. **A bibliography of thermophysical properties of air from 0 to 300 K,** L. A. Hall, Nat. Bur. Stand. (U.S.), Tech. Note 383, 121 pages (Oct. 1969).

Key words: Air; bibliography; equation of state; low ter perature; mechanical properties; thermodynamic prope ties; transport properties.

References together with an abbreviated abstract a presented for mechanical, thermodynamic, and transport prope ties of air from 0 to 300 K published up to December 1968. total of 610 articles have been indexed. Each article has be reviewed and coded with regard to properties studied, type of a ticle (i.e., experimental, theoretical, etc.), and method of prese tation of data. The temperature and pressure ranges for each pr perty under consideration are also given. An index has be prepared according to property with four sub-categories: soli liquid, gas up to 200 K, and gas above 200 K.

TN384. **Thermophysical properties of oxygen from the freezi liquid line to 600 R for pressures to 5000 psia,** R. D. McCar and L. A. Weber, Nat. Bur. Stand. (U.S.), Tech. Note 38 189 pages (July 1971).

Key words: Density; dielectric constant; enthalpy; entrop equation of state; fixed points; heat transfer coefficient index of refraction; Joule-Thomson; latent heat; melti point; oxygen; Prandtl number; specific heat; speed sound; surface tension; thermal conductivity; thermal d fusivity; vapor pressure; viscosity; volume.

Tables of thermophysical properties of oxygen are present for temperatures from the melting line to 600 R for pressures 5000 psia. The tables include, entropy, enthalpy, internal energ density, volume, speed of sound, specific heat, thermal condu tivity, viscosity, thermal diffusivity, Prandtl number and t dielectric constant for 79 isobars. Also included in the isobar tables are quantities of special utility in heat transfer calcul tions: $(\partial P/\partial V)_T$, $(\partial P/\partial T)_\rho$, $V(\partial H/\partial V)_P$, $V(\partial P/\partial U)_V$, $-V(\partial P/\partial V$ $I/V(\partial V/\partial T)_P$.

In addition to the isobaric tables, tables for the saturated vap and liquid are given which include all of the above propertie plus the surface tension. Tables for the P-T of the freezing liqui index of refraction and the derived Joule-Thomson inversi curve are also presented. The specific heat of the saturated liqu is given in graphical form. A temperature-entropy chart and Mollier diagram are also included.

TN385. **Thermal conductance at the interface of a solid and he um II (Kapitza conductance),** N. S. Snyder, Nat. Bur. Stan (U.S.), Tech. Note 385, 90 pages (Dec. 1969).

Key words: Heat transfer; helium II; Kapitza conductanc

A review is presented of the experimental and theoretic work on Kapitza conductance, including a compilation of t available data on conductance to helium II. A short derivation the phonon radiation limit indicates the reason for the appro mate T^3 temperature dependence and the small size of the Kap za conductance for most solids. Considerable qualitative a quantitative correspondence of the data with this limit is foun From the limited evidence available, the role of surface con tions, and of bulk parameters such as the Debye temperature determining the conductance are considered empirical Theoretical knowledge of the Kapitza conductance is seen give an inadequate explanation of the data. In addition, t phenomena which occur when the heat flux is high enough th properties of the bulk liquid are also involved in the measur conductance are described briefly.

TN386. **A precision, high frequency calibration facility for coaxi capacitance standards,** R. N. Jones and L. E. Huntley, Na Bur. Stand. (U.S.), Tech. Note 386, 27 pages (Mar. 1970).

Key words: Calibration; capacitance; capacitance, measur ment; coaxial capacitance standards; impedance, measur

ments, capacitance; standards; statistical control.

Using high frequency impedance standards which are fitted h precision coaxial connectors, and limiting calibrations to cific frequencies and impedance values, can contribute atly toward improving measurement agreement and stan- dization. These advantages have been utilized in the develop- nt of a new and much improved calibration service for pacitance in the high frequency region. The service is for pacitances of 50, 100, 200, 500 and 1000 picofarads at 100 z, 1 MHz, and 10 MHz. This paper describes the instrumen- ion used in the measurements and the method of data ndling, and gives a detailed breakdown of the measurement certainties.

N387. **Hydrogen spin exchange frequency shifts,** H. Hellwig, Nat. Bur. Stand. (U.S.), Tech. Note 387, 13 pages (Mar. 1970).

Key words: Frequency pulling; hydrogen beam tube; hydrogen maser; maser tuning; spin exchange.

Frequency shifts due to hydrogen spin exchange collisions are scussed for the hydrogen maser and the hydrogen storage am tube. The combined effects of spin exchange and cavity lling in the hydrogen maser are evaluated with emphasis on equency errors introduced by standard tuning procedures. It is und that an automatic cavity tuning system based on a varia- on of the linewidth does not introduce a frequency error. In ntrast, manual tuning procedures based on an interpolation of easurements at different cavity settings do not yield a perfect mpensation of spin exchange effects. However, the frequency ror becomes only significant at unnecessarily large cavity off- ts.

The smallness of the spin exchange shifts and the near absence cavity pulling in a hydrogen storage beam tube are expected to ermit a determination of spin exchange shifts by varying the eam intensity with a precision adequate for stability and accura- y figures of 10^{-14} or better.

N389. **Quantifying hazardous electromagnetic fields: Practical considerations,** R. R. Bowman, Nat. Bur. Stand. (U.S.), Tech. Note 389, 15 pages (Apr. 1970).

Key words: Electromagnetic fields; field parameters; hazards; instrumentation; quantifying.

The usefulness of power density to express the hazard poten- al of electromagnetic fields is limited to simple fields that are pproximately uniform and plane wave. For fields that are com- licated by having reactive components or by having multipath nterference patterns, power density is not a suitable parameter or quantifying the potential hazards because: (a) such fields can e very strong even though the power density is small, and (b) he power density in such fields is very difficult to measure. Since some of the most important hazardous fields can involve ery complicated field configurations (for instance, fields near eaking cracks in microwave ovens), it is important to establish more rational measure for hazardous fields. A qualitative liscussion is given of the many issues involved in selecting a uitable field parameter for quantifying hazardous electromag- netic fields in general. It is concluded that the total energy densi- y of the field is the best parameter, but in many instances the electric energy density alone will be adequate. Some general liscussion is given concerning "ideal" instrumentation for quan- ifying hazardous fields.

TN390. **Far infrared absorption in liquefied gases,** M. C. Jones, Nat. Bur. Stand. (U.S.), Tech. Note 390, 39 pages (Apr. 1970).

Key words: Absorption coefficient; argon; carbon monoxide; far infrared; hydrogen; liquefied gases; methane; nitrogen; oxygen.

Experimental results are given for the absorption coefficient of the liquids hydrogen (three para concentrations), nitrogen, oxygen, carbon monoxide, methane and argon in the wave number range 20-250 cm^{-1} (40-500 μm). In addition, data for liquid hydrogen are given at wave numbers up to 600 cm^{-1} (16.7 μm). The results are discussed in terms of the induced dipole, and, in the case of carbon monoxide, the permanent dipole. An indication of the way in which the data may be employed in calculations of thermal radiative transfer is made by calculation of the modified Planck mean absorption coefficient.

TN391. **Quantifying hazardous microwave fields: analysis,** P. F. Wacker, Nat. Bur. Stand. (U.S.), Tech. Note 391, 19 pages (Apr. 1970).

Key words: Electromagnetic radiation; energy density; hazards; measurement; microwave radiation; probe; radiation; standards.

The familiar power density radiation hazard standards are quite satisfactory for a field consisting of a single infinite traveling plane wave. However, for microwave and lower-frequency fields, hazards occur primarily in near fields which cannot be approximated as the aforementioned plane wave. Further, power density can be quite misleading or even meaningless as a measure of hazard in a near field. Thus, power density in a standing wave can be precisely zero, yet the hazard of such a field can be arbitrarily large. Similarly, a reactive field may present a considerable hazard, yet have zero time-average power density.

The major hazard from microwave and lower frequency radiation is believed to arise from dielectric heating of body tissues, and the heating of an isotropic medium is proportional to the sum of the squares of the absolute values of the electric field components $|E_x|^2 + |E_y|^2 + |E_z|^2$. Hence, electric field energy density is proposed for a radiation hazard standard.

Analytical limitations of various types of probes are considered and the advantages of a spherically-symmetric probe of lossy dielectric are discussed. For a rather general spherically-symmetric probe in an arbitrary field, both exact and approximate treatments are given for the calibration constant with full correction for the perturbation of the field by the probe. Conditions for a constant factor are also given.

TN392. (Revised September 1973). **Thermodynamic properties of compressed gaseous and liquid fluorine,** R. Prydz and G. C. Straty, Nat. Bur. Stand. (U.S.), Tech. Note 392, 197 pages (Sept. 1974) $1.50, SD Catalog No. C13.46:392 (Rev. 1973).

Key words: Density; enthalpy; entropy; fixed points (PVT); fluorine; Joule-Thomson; latent heat; melting curve; PVT measurements; saturation densities; specific heats; vapor pressure; velocity of sound; virial coefficients.

An apparatus has been constructed and used successfully to measure vapor pressure and PVT data of fluorine from the triple point to 300 K at pressures to about 24 MN/m^2. Material problems caused by the toxic and corrosive nature of fluorine were solved. A network of isotherm and isochore polynomials and a truncated virial equation were used to represent all PVT data. These equations represent the data with an average standard deviation of about 0.02 percent in density, the corresponding accuracy being estimated at 0.1 percent. Equations for the saturated liquid and vapor densities, the vapor pressure curve, the melting line, and the ideal gas properties are also presented. Comparisons are given to published values of the second virial coefficients, vapor pressures, and saturation densities. Additional comparisons are also made to measured specific heats and latent heats of vaporization. New values are reported for the triple point and critical point parameters together with the temperature and saturation densities at the normal boiling point. Finally,

extensive tables of thermodynamic properties of fluorine are given which include pressure, temperature, density, isotherm and isochore derivatives, internal energy, enthalpy, entropy, specific heats at constant pressure and volume and velocity of sound. Some erroneous values for the internal energy and enthalpy of the compressed liquid below 135 K, published previously, have been corrected in this revision. Supersedes Technical Note 392, Oct. 1970 Ed.

TN393. **A method for designing multi-screw waveguide tuners,** M. P. Weidman and E. Campbell, Nat. Bur. Stand. (U.S.), Tech. Note 393, 20 pages (Oct. 1970).

Key words: Capacitive screw tuner; impedance transformer; waveguide tuner.

Capacitive screw, waveguide tuners are commonly used in microwave measurement systems and as devices for adjusting the impedance of various waveguide terminations. The design of a broadband tuner of this type has been a problem in the past.

This paper describes a method for designing tuners which will work effectively for relatively wide ranges of frequencies.

TN394. **Characterization of frequency stability,** J. A. Barnes, A. R. Chi, L. S. Cutler, D. J. Healey, D. B. Leeson, T. E. McGunigal, J. A. Mullen, W. L. Smith, R. Sydnor, R. F. C. Vessot, and G. M. R. Winkler, Nat. Bur. Stand. (U.S.), Tech. Note 394, 50 pages (Oct. 1970).

Key words: Allan variance; frequency; frequency stability; sample variance; spectral density; variance.

Consider a single generator whose instantaneous output voltage $V(t)$ may be written as

$$V(t)=[V_0+\epsilon(t)]\sin[2\pi\nu_0 t+\phi(t)]$$

where V_0 and ν_0 are the nominal amplitude and frequency respectively of the output. Provided that $\epsilon(t)$ and $\phi(t)=d\phi/dt$ are sufficiently small for all time t, one may define the fractional instantaneous frequency deviation from nominal by the relation

$$y(t)\equiv\frac{\dot{\phi}(t)}{2\pi\nu_0}.$$

A proposed definition for the measure of frequency stability is the spectral density $S_y(f)$ of the function $y(t)$ where the spectrum is considered to be one-sided on a per hertz basis.

An alternative definition for the measure of stability is the infinite time average of the sample variance of two adjacent averages of $y(t)$; that is, if

$$\bar{y}_k=\frac{1}{\tau}\int_{t_k}^{t_k+\tau}y(t)dt,$$

where τ is the averaging period, $t_{k+1}=t_k+T$, $k=0, 1, 2\ldots$, t_0 is arbitrary, and T is the time interval between the beginnings of two successive measurements of average frequency; then the second measure of stability is

$$\sigma_y^2(\tau)\equiv\left\langle\frac{(\bar{y}_{k+1}-\bar{y}_k)^2}{2}\right\rangle,$$

where $\langle\ \rangle$ denotes infinite time average and where $T=\tau$.

In practice, data records are of finite length and the infinite time averages implied in the definitions are normally not available; thus estimates for the two measures must be used. Estimates of $S_y(f)$ would be obtained from suitable averages either in the time domain or the frequency domain. An obvious estimate for $\sigma_y^2(\tau)$ is

$$\sigma_y^2(\tau)\approx\frac{1}{m}\sum_{k=1}^{m}\frac{(\bar{y}_{k+1}-\bar{y}_k)^2}{2}.$$

Parameters of the measuring system and estimating procedu are of critical importance in the specification of frequency stab ty. In practice, one should experimentally establish confiden limits for an estimate of frequency stability by repeated trials.

TN395. **Design for a variable-output-coupling far-infrar Michelson laser,** J. S. Wells, K. M. Evenson, L. M. Matarre D. A. Jennings, and G. L. Wichman, Nat. Bur. Stand. (U.S Tech. Note 395, 23 pages (Jan. 1971).

Key words: HCN Lasers; H_2O lasers; infrared lasers; var ble coupling lasers.

A technique for varying the coupling of power from far- frared gas lasers and the design and construction of these lase are described. The coupling method is based on Michelson's i terferometric principle and permits a continuously variat coupling of the available power from the laser. The present las design is the result of evolution over the last year and a half.

TN396. **Data analysis for isoperibol laser calorimetry,** E. West, Nat. Bur. Stand. (U.S.), Tech. Note 396, 34 pages (Fe 1971).

Key words: Calorimetry; laser; laser calorimetry; las energy; laser power.

Isoperibol calorimeters (those operating in a constant-tei perature environment) are used to measure the power and ener in laser beams relative to electrical standards. The derivation the basic formula is reviewed. Two methods are presented f analyzing the data taken at equal time intervals: (1) An appro mate manual method with criteria for avoiding significant erro of approximation and (2) A least squares method for use with a tomatic digital computers.

TN397. **Tabulated values of cavitation B-factor for helium, H_2, F_2, O_2, refrigerant 114, and H_2O,** J. Hord and R. O. Voth, N Bur. Stand. (U.S.), Tech. Note 397, 116 pages (Feb. 1971).

Key words: Cavitation; cryogenics; pumps.

A brief history is given on the development of the B-fact concept and its application to the design of liquid pumps. Ada tation of the "quasi-static" vaporization model to the cavitati process is discussed; previous methods of computing B-fact are reviewed and a simplified, more precise computation, co sistent with the "quasi-static" model, is established. Merits the different computational techniques are discussed and two the methods are graphically compared. The best available pr perty data are used to compute B-factors for several fluids ov a wide range of temperatures. The results are tabulated reference data; they are useful in the application of the B-fact concept to the prediction of performance in cavitating liqu pumps.

TN398. **Power and energy measurement of repetitively pulse lasers,** D. A. Jennings, Nat. Bur. Stand. (U.S.), Tech. No 398, 10 pages (Mar. 1971).

Key words: Average power; energy per pulse; laser; pea power; repetitively pulsed lasers.

The problem of measuring average power, energy per puls and peak power of some of the more common repetitively pulse lasers is discussed. The techniques which have been used at th National Bureau of Standards are mentioned along with some the accuracies obtained. Accuracies of 3 to 10 percent can b achieved, depending on the laser source and the parameter of i terest.

TN399. **The physical basis of atomic frequency standards,** A. Risley, Nat. Bur. Stand. (U.S.), Tech. Note 399, 54 page (Apr. 1971).

Key words: Atomic frequency standards; cesium beam; energy levels; hydrogen maser; hyperfine interaction; rubidium gas cell; transition probability.

A tutorial discussion of the physical basis of atomic frequency ndards is given. These principles are then related to the condi- ns under which an atom can be used as the working substance a stable and accurate frequency standard. The three primary amples of atomic frequency standards—the hydrogen maser, e cesium beam, and the rubidium gas cell—are then discussed terms of these principles and conditions. The functions of the ndamental parts of each device become apparent through this velopment.

N400. **Electrochemical analysis: Studies of acids, bases, and salts by Emf, conductance, optical, and kinetic methods, July 1965 to June 1966,** Edited by R. G. Bates, NBS Tech. Note 400 (Sept. 6, 1966).

Key words: Acidity; analytical chemistry; conductance; deuterium oxide; dissociation processes; electrochemistry; electrolytes; Emf; indicators; isopiestic; vapor pressure; methanol-water solvents; thermodynamics.

This survey of the activities of the Electrochemical Analysis ction, Analytical Chemistry Division, covers the period July 65 to June 1966. An attempt is made to summarize a year's ogress on the technical projects of the Section in such a way as stress the program and capabilities of the organizational unit a whole. A description of facilities and equipment is esented and the directions of new programs are indicated. ief summaries of the several lines of work now under way are ven. The main areas include the study of acidity measurement water, deuterium oxide, and methanol-water solvents, along ith the development and certification of standard reference aterials with which acidity scales in these media can be efined. Solvent effects and isotope effects are being studied, nd equilibrium data for certain systems of analytical interest ave been obtained. Progress on a conductometric method for etermining traces of water is reported, and the thermodynamic roperties of some salt mixtures have been measured by a vapor ressure method. Kinetic methods for trace analysis have been xamined, and a new lot of potassium hydrogen phthalate Standard Reference Material 84h) has been certified for use as n acidimetric standard. The survey concludes with lists of the embers of the Section staff, publications and manuscripts roduced during the year, talks given by the staff, and committee ssignments.

N401. **Activities of the NBS Spectrochemical Analysis Section, July 1965 to June 1966,** Edited by B. F. Scribner, NBS Tech. Note 401 (Sept. 30, 1966).

Key words: Analysis; arc temperature; atomic absorption spectrometry; analog computer; bibliography; computer; electrodeposition; electron back scatter; electron probe microanalyzer; emission spectroscopy; laser probe; mass spectroscopy; photographic photometry; plasma jet; preconcentration; pulse height analyzer; spectrochemical analysis; spectroscopy; standard reference materials; time-shared computer; x-ray spectroscopy.

A summary is given of the activities of the NBS Spectrochemical Analysis Section for the period from July, 1965 hrough June, 1966, during which the move into the new facilities t Gaithersburg, Md. was made. Activities in optical pectrometry included development of programs for calculations n a time-sharing computer, measurement of arc temperatures, pplications of the laser probe and the plasma jet, and studies on tomic absorption spectrometry. In x-ray spectroscopy, there ave been some modifications of equipment, improvements in computation methods, and several applications. Improvements and additions were made to the electron probe analyzer, along with studies on measurement techniques, including non-dispersive analysis and computation procedures. The spark-source mass spectrometer has also been modified, and a new analog computer has been built and tested for reduction of photographic plate data; applications of this instrument to analyses of pure materials are described. Enrichment methods are being studied for the analysis of pure materials by emission spectroscopy, particularly with an electrodeposition technique. Homogeneity studies and analyses have been performed in the development of standard reference materials. Other activities included analyses of samples to assist other NBS groups and government agencies, and literature surveys. Listings are given of 20 publications and 26 talks by members of the Section during the year.

TN402. **Analytical coordination chemistry: Titrimetry, gravimetry, flame photometry, spectrophotometry, gas evaluation and isotopic preparations, July 1965 to June 1966,** Edited by O. Menis, NBS Tech. Note 402 (July 21, 1967).

Key words: Spectrophotometric titration; controlled potential coulometric; molybdenum; homogeneous precipitation; aluminum; beryllium; thermoanalytical standards; tricalcium silicate; spectrophotometry; antimony; high precision determination of nickel; simultaneous determination copper; cobalt; "releasing agents" in flame emission and atomic absorption; magnesium; ferrous SRMs; stoichiometric mixtures uranium oxide; isotope ratio determination.

Studies in four areas of analytical chemistry: titrimetry, gravimetry, flame emission and atomic absorption, and solution spectrophotometry, are described from the standpoint of analytical coordination chemistry and applications to NBS standard reference materials. In the first two competences these investigations dealt with spectrophotometric titrations and homogeneous precipitation methods. Advances are described in the latter two areas through the unique applications of ternary complexes, displacement reactions in metal-ligand systems and the use of complexing media as "releasing agents". This approach is described for the determination of nanogram quantities of Sb, Cu, Ni and Au in very high purity zinc by both spectrophotometric and flame procedures. Also in flame emission and atomic absorption a current table is presented for the detection limits of 70 elements. Progress of a new method is reported for the simultaneous determination of Ni, Cu and Co by the dimethylglyoxime method. Descriptive tables of results are also given for ferrous, non-ferrous and ceramic materials which were analyzed by one of the four competences. In another analytical area dealing with the analysis of gases in metals results of homogeneity and precision studies lead to certification of three new ferrous SRM's for their oxygen content. Also reported are the initial investigations of pyrohydrolytic separations of fluoride, nitrides and borons, separations of molybdenum from tungsten, controlled potential coulometric titration of molybdenum, and a description of improved instrumentation in flame emission and atomic absorption. Finally data are given on the preparation of stoichiometric mixtures of uranium oxide of varied isotopic composition and a list describing the variety of special analyses is included.

TN403. **Microchemical Analysis Section: Summary of activities, July 1965 to June 1966,** Edited by J. K. Taylor, NBS Tech. Note 403 (Sept. 1, 1966).

Key words: Atomic weights; coulometric analysis; gas analysis; mass spectrometric gas analysis; microchemical analysis; polarographic analysis; standard reference materials, analysis of; stoichiometry.

This report describes the scientific programs and research activities of the Microchemical Analysis Section of the Analytical Chemistry Division of the NBS Institute for Materials Research during the period July 1965 to June 1966. General activities are reported in the areas of gas analysis by mass spectrometry, polarography, coulometry, stoichiometry, and classical microchemical analysis. Research accomplishments described in some detail include: improvements in the sensitivity of gas analysis using high-pressure mass spectrometry; analysis of deuterated compounds by mass spectrometry; comparative polarographic analysis of high precision; polarographic methods for trace and ultra-trace determination of a number of elements; highly accurate coulometric iodimetric titration; a highly precise method for determination of magnesium based on its final weighing as magnesium sulfate; and a number of microchemical procedures for the analysis of a variety of materials.

TN404. **Radiochemical analysis: Activation analysis, instrumentation, radiation techniques, and radioisotope techniques, July 1965 to June 1966,** Edited by J. R. DeVoe, NBS Tech. Note 404 (Sept. 30, 1966).

Key words: NBS reactor; NBS Linac; Cockroft-Walton generator; digital computers; activation analysis; standard reference materials; photo-neutron reactions; flux monitors; Cu, Se, Al, V in irons and steels; homogeneity testing; pneumatic rabbit sensor; Mossbauer spectroscopy; tin standard for chemical shift; PARLORS program for Mössbauer spectra; Mössbauer instrumentation; Mössbauer laboratories; radiometric trace chromatography; radioisotope dilution; substoichiometry by controlled potential coulometry; radiochemical separations; theoretical detection limits for activation analysis; CLSQ program for multicomponent decay; solid state detectors; electronic data handling.

This is the third summary of progress of radiochemical analysis which encompasses the work of both the Radiochemical Analysis and Activation Analysis Sections of the Analytical Chemistry Division at the National Bureau of Standards.

Pertinent information on the irradiation facilities of the nuclear reactor, Linac, and Cockroft-Walton generator are described. A number of analyses of standard reference materials by activation analysis are described (e.g., Cu in cast iron, SRM 82b; Se in selenium steel, SRM 1170; Al in steel, SRM 14e; and V in stainless steel, SRM 73c). Various aspects of the technical problems in activation analysis such as its use for homogeneity testing, production of suitable flux monitors, and experimental design with respect to increasing selectivity (such as by using variable neutron energy) and reducing systematic and random errors, are presented. A realistic procedure for estimating sensitivity and for designing the analysis to optimize the detection limit is described. A computer program that resolves complex decay curves utilizes parameter changes convenient for the conversational aspect of "time sharing" digital computers. A highly specific radiochemical separation for copper using a type of amalgam exchange is described.

Description of specialized data handling equipment as well as information on a fast rise preamplifier, solid state detector system, and other special instruments such as a pneumatic transport system rabbit sensor, are presented.

A description of the laboratories used in Mossbauer spectroscopy is presented. Special problems in radiation detection for use in a spectrometer are also described. The Standard Reference Material Program for chemical shift in Mossbauer spectroscopy is discussed with particular reference to the search for a tin standard. The computer program, "Parlors M," that is used for resolving complex Mossbauer spectra i presented in its entirety in Appendix II.

The use of thin layer chromatography in conjunction wit radioactive reagent analysis for trace elements is describe Substoichiometric radioisotope dilution continues to be studie by evaluating systematic and random errors, as well as b developing the technique from physio-chemical principles suc as controlled potential coulometry.

TN405. **Organic Chemistry Section: Air pollution studies; kineti behavior of sugars in solution carbon-14- and tritium-labele carbohydrates; characterization of chemical structure phenylhydrazono-phenylazo tautomerism; synthesis of researc materials, cyclopentitols and related substances; novel researc materials; standard reference materials (organic), July 196 through June 1966,** Edited by H. S. Isbell, NBS Tech Not 405 (Sept. 30, 1966).

Key words: Air-pollution studies; oxidation of polycycli aromatic hydrocarbons; sugars in solution; conformationa analysis; carbon-14- and tritium-labeled carbohydrates large-scale paper chromatography; phenylhydrazon phenylazo tautomerism; cyclopentitols and relate substances; unsaturated alditols; infrared spectra c acylamido derivatives; carbohydrate reference materials metallo-organic standard reference materials.

This report describes work in progress in the Organi Chemistry Section of the Analytical Chemistry Division of th NBS Institute for Materials Research. It includes certai historical material, presented to give perspective to the overa program. The following research areas are discussed: ai pollution studies, kinetic behavior of sugars in solution, carbor 14- and tritium-labeled carbohydrates, characterization c chemical structure; phenylhydrazonophenylazo tautomerism synthesis of research materials: Cyclopentitols and relate substances, novel research materials, and standard referenc materials.

TN406. **X-ray wavelength conversion tables and graphs fo qualitative electron probe microanalysis,** K. F. J. Heinrich an M. A. M. Giles, NBS Tech. Note 406 (Sept. 25, 1967).

Key words: Electron probe microanalyzer; wavelengths; x ray emission; x-ray spectrometers.

Tables and graphs have been constructed for electron probe x ray spectrometers equipped with crystal changers and calibrate for LiF crystals in angstroms. These tables indicate th equivalent reading for the lines which can be normally expecte to appear in wavelength scans using the following crystals: LiF EDDT, ADP, KAP, and Pb stearate (LSD). The readings wer extracted from the tables of E. W. White, et al. The tables ar arranged by the atomic numbers of the emitting elements; th graphs show the readings for observable lines as a function c atomic number for each of the aforementioned crystals. A suggested method for using the tables and graphs is included.

TN407. **Applications of a time-sharing computer in a spec trochemistry laboratory: optical emission and x-ra fluorescence,** S. D. Rasberry, M. Margoshes, and B. F Scribner, Nat. Bur. Stand. (U.S.), Tech. Note 407, 58 page (Feb. 1968).

Key words: Analytical chemistry; calculations; computer emission spectroscopy; programming; spectrochemic analysis; time-sharing computer; x-ray spectroscopy.

A time-sharing computer system employing the Dartmou College Basic compiler has been in use in this laboratory fo more than two years, and it has been applied to both routine ar non-routine calculations. Descriptions are given of the comput

tem and its associated programming language and commands. pical applications and advantages and disadvantages of the tem are discussed. An appendix contains descriptions of 13 grams thought to be of interest to other optical and x-ray ctrochemistry laboratories. Examples of input and output are en with each of these programs.

N408. Superseded by Technical Note 24.

N409. **Fortran programs for the calculation of Wigner 3j, 6j, and 9j coefficients for angular momenta ≤ 80,** R. S. Caswell and L. C. Maximon, NBS Tech. Note 409 (Nov. 15, 1966).

Key words: Fortran program; Wigner coefficients; quantum theory of angular momentum; 3j coefficient; 6j coefficient; 9j coefficient; Clebsch-Gordan coefficients.

Fortran II and Fortran IV programs are given for the lculation of Wigner 3j, 6j and 9j coefficients containing dividual angular momenta less than or equal to 80. The large mbers, resulting from the factorials which appear in the pressions for these coefficients, are handled by taking garithms and performing most of the pertinent arithmetic with e logarithms. The alternating series involved in the pressions for the 3j and 6j coefficients are summed ithmetically in double precision. We present two versions of e basic program for the calculation of these coefficients (each rsion being given both in Fortran II and in Fortran IV). All rograms are called as single-precision Fortran functions. The fference between Versions I and II is in the internal structure these programs. In Version I, only the series summation is in uble precision, resulting in a faster program which occupies ss memory in the computer, the computation time being of the rder of 0.001 to 0.01 sec per 6j and 0.1 to 1 sec per 9j. Version I, being entirely in double precision internally, is much more curate (the errors being of the order of one percent of the rrors in Version I), but the computation time for a given efficient is approximately 50% greater than in Version I. nformation relative to the accuracy and memory requirements f the two versions of the program is provided, and Fortran II nd IV lists of the programs and calling instructions are given.

N410. **Improved Fortran program for single particle energy levels and wave functions in nuclear structure calculations,** R. S. Caswell, NBS Tech. Note 410 (Sept. 30, 1966).

Key words: Eigenvalues; eigenfunctions; energy levels; wave functions; single particle shell model.

An improved program has been developed for numerical alculations of single particle energy levels and wave functions or Woods-Saxon or other real potential wells. The program is lesigned to be used as a subroutine of a larger program for uclear structure calculation but may be used separately if lesired. Improvements over the previous program include: (1) or bound states the wave function is calculated by integrating outward from zero radius and inward from a maximum radius beyond the nuclear potential well with matching at an ntermediate radius; (2) a first order correction has been made to he starting conditions at small radius for the integration of the wave function; (3) a large step size is used until the calculation has nearly converged on the eigenvalue; then a small step size is used to provide maximum accuracy; (4) the correction of a small error in the Kutta-Runge integration procedure has been made. As a result of the changes the program is approximately five times faster than the previous version. Checks with harmonic oscillator potentials give an accuracy of .01% in the energy level values. Listings of Fortran II and Fortran IV versions are given.

TN411. **Methods for performance-testing of electro-mechanical pressure transducers,** P. S. Lederer, NBS Tech. Note 411 (Feb. 9, 1967).

Key words: Electro-mechanical; pressure; transducer; calibration; performance; test method; dynamic calibration and telemetering.

This publication describes methods in one particular program at NBS for the performance-testing of electro-mechanical pressure transducers (such as telemetering transducers used in aerospace testing). It covers static and dynamic calibration procedures in detail, delineates environmental and other tests, and describes the test equipment used. Examples of dynamic calibration results are interpreted.

TN412. **Quantum mechanical calculations of the second virial coefficients for hydrogen,** M. E. Boyd and S. Y. Larsen, NBS Tech. Note 412 (Apr. 10, 1967).

Key words: Second virial coefficient; quantum mechanics; hydrogen; equation of state; statistical mechanics; intermolecular potential.

Quantum mechanical second virial coefficients of dilute ortho and para hydrogen have been calculated for the case of a Lennard-Jones potential. These computations cover the temperature range from 0 °K to 80 °K. Special attention is paid to the behavior of the Boltzmann and exchange contributions. The purely statistical contribution to the ortho-para difference is shown to vanish to three decimal places by about 10.5 °K. Comparison with experimental data indicates that considerable improvement in the potential function and inclusion of non-spherical terms will be required at the low temperatures considered here.

TN413. **The solid system. II. Numeric compression,** P. A. D. deMaine, K. Kloss, and B. A. Marron; and **The solid system. III. Alphanumeric compression,** P. A. D. deMaine, B. A. Marron, and K. Kloss, NBS Tech. Note 413 (Aug. 15, 1967).

Part I.

Key words: Numeric compression; information handling; high-speed information transmission; information storage and retrieval; systems analysis.

This part of NBS Technical Note 413 describes the general NUMERIC COMPRESSOR (NUPAK) Algorithm for automatically compressing (encoding) or decoding compressed numerical information, which may of course have come from graphical information. The amount of compression achieved is determined by the "lowest limit of significance," the range, and the sequential patterns of the data to be stored. The encoded information can be stored in memory or on external storage devices in a small fraction of the space normally required, and can be expanded (decoded) item-by-item whenever needed by the system.

Part II.

Key words: Alphanumeric compression; information handling; high-speed information transmission; information storage and retrieval; systems analysis.

An algorithm for compressing alphanumeric information is described. Unlike other methods which depend upon frequency of occurrence of words in a particular class of publications, this scheme is language and content independent since the information for compression is obtained from the text itself. The compressed bit stream is preceded by sufficient information for automatic reconstruction of the original bit stream whenever the system requires it. Even with this additional information required for expansion, compression rates approaching 40% have been achieved. Because this ALPHANUMERIC

COMPRESSOR (ANPAK) is fully automatic and self-organizing, it can operate on information which has already been compressed via the NUMERIC COMPRESSOR (NUPAK).

TN414. **Quantitative methods for management,** G. Suzuki, NBS Tech. Note 414 (May 23, 1967).

Key words: Operations research; quantitative analysis; management; decision-making; education.

An elementary treatment of some of the better known and widely used analytical methods in operations research/systems analysis. The material is presented in a manner which attempts to indicate why quantitative methods are useful in managerial decision-making situations. Some basic references are provided.

TN415. **Thermal radiation property measurement techniques,** S. T. Dunn, J. C. Geist, D. G. Moore, H. E. Clark, and J. C. Richmond, NBS Tech. Note 415 (Apr. 27, 1967).

Key words: Averaging spheres; diffuse reflectance; emissivity; emittance; flux averaging devices; infrared reflectance; spectral reflectance; spectral emittance; specular reflectance.

This is an annual summary report of work completed on NASA Contract R-09-022-032. The work comprised (1) completion of the development and calibration of a rotating cylinder procedure for measuring normal spectral emittance of non-conducting materials at temperatures in the range of 1200 to 1600 °K, (2) analysis and calibration of an ellipsoidal mirror reflectometer, and (3) a study of the relation between surface roughness and geometric distribution of flux reflected from a surface.

TN416. **Study of a Halpern-type 4π neutron detector,** H. M. Gerstenberg and E. G. Fuller, NBS Tech. Note 416 (June 12, 1967).

Key words: Detector; efficiency; four-pi; Halpern; neutron; photoneutron; response; yields.

The response to various neutron spectra of a 2-inch diameter BF_3 proportional counter in a Halpern-type geometry has been studied as a function of moderator thickness. Neutron sources used were a calibrated RaDBe(α,n) source and a series of photoneutron sources using a number of bremsstrahlung spectra. The reactions used were $^{16}O(\gamma,n)$, $^{31}P(\gamma,n)$ and $d(\gamma,n)$. For these sources absolute neutron yields were determined either from the residual $\beta+$ activity or from the known cross section and the absolute bremsstrahlung intensity. Using these empirical data a final detector with 13 BF_3 counters was constructed. Over the spectral range covered by the above sources the measured efficiency for counting neutrons of the final detector was 9.6 percent with an estimated uncertainty of ± 0.5 percent, independent of spectrum. The detector was used to measure the neutron yields from Pb, Au, Ta, Ho, Ag, Cu, Co, Ca, P, Al, O and C for a series of bremsstrahlung energies between 12.0 and 29.0 MeV. These yields were compared with those calculated from previously published neutron yield cross sections. The data indicate that previously reported discrepancies in neutron yield data can probably be traced to the determination of neutron detector efficiencies.

TN417. **Spectral emission properties of NBS standard phosphor samples under photo-excitation,** C. F. Shelton, Nat. Bur. Stand. (U.S.), Tech. Note 417, 31 pages (Mar. 1968).

Key words: Phosphors; photo-excitation; photoluminescence; spectral emission; spectral radiometry; standard phosphor samples.

The photo-excitation spectral emission properties of 10 of the 14 NBS standard phosphor samples have been determined. Pressed tablets of the phosphors were excited by radiation from a mercury arc lamp, passing through a narrow band-pass filter to obtain either 2537Å or 3650Å excitation. The measurement system is described, correction of the data is discussed, and the spectral emission data are presented. Relative quantum efficiencies were calculated. The results are compared with measurements reported by two other laboratories.

Among the items treated are: pushbutton word generators providing automatic typing of often used programming instructions; and option switches for full or half-duplex operation, for inserting the sixth bit for lower case letters, and the eighth bit for parity compatibility.

TN418. **Radiometric methods for measuring laser output,** D. A. McSparron, C. A. Douglas, and H. L. Badger, NBS Tech. Note 418 (Nov. 1967).

Key words: Laser; laser energy measurement; optical attenuator; photoelectric photometry; radiometric calibration; radiometry.

The output of pulsed lasers may be measured with reasonable accuracy by modifications of established radiometric methods. The receiver, thermopile or phototube, is used ballistically. It is calibrated by an incandescent-lamp standard of spectral irradiance. The laser beam is attenuated to make its irradiation on the receiver comparable to that from the calibrating source. Attenuation is accomplished by intercepting the entire laser beam on a diffusely reflecting surface. The attenuation factor is determined from direct measurement of the reflectance of this diffusing surface and the geometric constants of the system. The accuracy of the measurement of laser output is dependent upon the accuracy of calibration of the standard of spectral irradiance and the accuracy with which the spectral sensitivity of the receiver, the spectral transmittance of the band-pass filters, and the reflectance of the diffuser can be determined. Measurements made with different photoelectric receivers agree to about 1.5% using a 1/4-joule pulsed ruby laser as a source. Total uncertainty is estimated to be about 5%. Measurements made using these radiometric methods have been compared with calorimetric measurements and a discrepancy of 9% was observed.

TN419. **Accessory equipment and teletypewriter modifications for remote computer consoles,** C. H. Popenoe and R. C. Thompson, Nat. Bur. Stand. (U.S.), Tech. Note 419, 22 pages (Feb. 1968).

Key words: Remote access; teletype; time-sharing.

Equipment auxiliary to, and simple modifications of a teletypewriter are described which enable it to be used more efficiently as a remote console of a computer. The descriptions and drawings are sufficiently detailed to enable one to duplicate the modifications or construct the auxiliary equipment with little or no design effort.

TN420. **Drawings of micrometer U-tube manometers for the ranges up to 100 mm of mercury,** A. M. Thomas and J. L. Cross, NBS Tech. Note 420 (Aug. 26, 1967).

Key words: Manometer; micrometer; u-tube; vacuum; medium-vacuum measurements.

Drawings with sufficient detail are presented so that micrometer U-tube manometers for use with mercury, oil, and water may be constructed. Measurements made with the oil manometer have an uncertainty of about 4×10^{-4} mm of Hg plus one part in 10^4 of the reading. Measurements made with the mercury manometer have an uncertainty of about 4×10^{-3} mm of Hg plus eight parts in 10^5 of the reading. The operation and an error analysis are described elsewhere.

N421. **Radiochemical analysis: Nuclear instrumentation, radiation techniques, nuclear chemistry, radioisotope techniques July 1966 through June 1967,** Edited by J. R. DeVoe, NBS Tech. Note 421 (Nov. 1967).

Key words: Computers; cross sections; detection limits for analysis; flux monitors; Mossbauer instrumentation; Mossbauer spectroscopy; NBS Linac; nickel-61; PARLORS program for Mossbauer spectra; photoneutron reaction; solid state detectors; standard reference materials; tin standard for chemical shift.

This is the fourth summary of progress of the Radiochemical nalysis Section of the Analytical Chemistry Division at the ational Bureau of Standards.

The section's effort comprises four major areas: Mossbauer ectroscopy, nuclear chemistry, nuclear instrumentation, and e application of statistics in nuclear and analytical chemistry.

A new design of transducer which is more compact than the evious design has been made so that low temperature periments can be more easily performed. A method of multaneously measuring two spectra with a single transducer s been devised. A single line nickel-61 source has been made d the magnetic moment of the excited 5/2 state has been easured with this source. Efforts have continued on the terpretation of the spectral parameters and their relation to ructure analysis. Studies are continuing on the production of a andard for chemical shift of tin compounds.

Equipment is in the final state of assembly and initial testing r measuring cross sections of reactions such as $(\gamma,^3He)$ or $(\gamma,^4He)$ by mass spectrometry of the reaction products.

The precision of an analytical method must be carefully used hen expressing a detection limit. In addition, care must be aken to be definitive about the meaning of a limit of detection. A suggested procedure for uniformity in reporting these often sed terms is presented in this report.

The practical operation of Ge(Li) and Si(Li) detectors has een evaluated. It is found that careful control of the reamplifier noise and response is required for optimum erformance.

A study of the precision and accuracy of gamma-ray excited x-ay fluorescence was made. Using as a basis the analysis of ertified Standard Reference Materials, an improvement of a actor of two in precision was measured. The major advantage oncluded from this work is that if rapid analysis requiring ortability is desired, the radioisotopic source approach is useful.

TN422. **Activities of the NBS Spectrochemical Analysis Section July 1966 to June 1967,** B. F. Scribner, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 422, 84 pages (Jan. 1968).

Key words: Computing; digital readout; electron probe; gold analysis; isotope dilution method; laser probe; liquid Q-switch; mass attenuation coefficients; microphotometer; optical spectrometry; plasma torch; platinum analysis; preconcentration; selenium analysis; spark source mass spectrometry; spectrochemical analysis; standard reference materials; sulfur analysis; time-shared computer; x-ray absorption coefficients; x-ray fluorescence analysis; vacuum spectrometer.

A summary is given of activities of the NBS Spectrochemical Analysis Section for the year July 1966 through June 1967. In optical spectrometry, studies were made of (1) the effectiveness of a liquid Q-switch for laser pulse control and (2) the applicability of the high-frequency plasma torch in atomic emission and absorption spectroscopy. Two papers on laser probe spectrochemical analysis were published. In electron probe microanalysis an alignment procedure was developed for the x-ray spectrometer, data on x-ray mass absorption coefficients were collected and critically evaluated, and a review of techniques for scanning microprobe analysis was published. The factors entering into quantitative electron probe analysis are being investigated. In x-ray spectrometry studies were made of interferences especially in the analysis of complex alloys. A combination of techniques involving enrichment by electrodeposition, stable isotope dilution, and determination by the spark source mass spectrometer has provided an accurate method for trace analysis. Improvements in the Section's equipment, including digital readout devices, and developments in computer applications are also discussed. Listings are given of 15 publications and 23 talks by members of the Section during the year.

TN423. **Electrochemical Analysis Section: Summary of activities, July 1966 to June 1967,** Edited by R. G. Bates, NBS Tech. Note 423 (Oct. 1967).

Key words: Acidity; analysis; conductance measurements; electrochemical analysis; electrochemistry of solutions; glass electrodes; medium effects; pH measurements.

This survey of the activities of the Electrochemical Analysis Section, Analytical Chemistry Division, covers the period July 1966 to June 1967. An attempt is made to summarize a year's progress on the technical projects of the Section in such a way as to stress the program and capabilities of the organizational unit as a whole. A description of facilities and equipment is presented, and the directions of the programs are indicated. Brief summaries of several lines of work now under way are given. The main areas include the measurement of acidity with progress toward the establishment of standards for pH, pH*, and pD being reported. Studies of the behavior of glass electrodes in deuterium oxide are described and solvent effects on ionic processes are discussed. Equilibrium data for certain ionic systems have been obtained, modifications of a precision conductance bridge are described, and a method for titrating hydrogen fluoride in dimethylformamide is outlined. The survey concludes with lists of the members of the Section staff, publications and manuscripts produced during the year, talks given by the staff, and committee assignments.

TN424. **Analytical coordination chemistry: Titrimetry, gravimetry, flame photometry, spectrophotometry, and gas evolution July 1966 to June 1967,** O. Menis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 424, 106 pages (Jan. 1968).

Key words: Absorption and fluorescence spectrophotometry; arsenic; atomic absorption; beryllium; DTA studies; dysprosium in a glass; flame emission; gases in metals; gravimetry; homogeneous precipitation; impurities in zinc and selenium; Li_2O in glass; nitrogen; oxygen in titanium; titrimetry.

In the related areas of gravimetry, titrimetry, flame emission and atomic absorption spectroscopy, absorption and fluorescence spectrophotometry, and gases in metals, the versatile aspects of coordination chemistry have, in several instances, been uniquely exploited to yield either more precise and accurate results or lower detection limits. Fivefold improvement in the gravimetric analysis for beryllium has been obtained by means of an incomplete homogeneous precipitation followed by a selective spectrophotometric examination of the filtrate. In the field of thermal analysis a survey of fifteen compounds has revealed several promising, future standards for DTA studies covering the range of 75 to 900 °C. In the section on titrimetry highly precise procedures are described for the determination of boron and beryllium. Various instrumental parameters have been investigated in flame emission and atomic absorption spectroscopy in order to optimize such variables as nebulizer-burner and oxidant-fuel systems, elimination of interferences, and source difficulties. The use of chelate extraction systems has led to the

extension of detection limits to the submicrogram level for impurities in zinc and selenium, while modified electronics has permitted the precise determination of 10 percent Li_2O in glass with a relative standard deviation of better than 0.2 percent. In absorption and fluorescence spectrophotometry the research aspect of ternary complexes or mixed chelates are described together with their potential use at the nanogram-picogram level. In the same area improvement in accuracy has been obtained by controlled dissolution of samples in closed systems with particular attention being given to the determination of arsenic in cast iron. Also described in this section is the differential spectrophotometric determination of dysprosium in a glass to be used as a neutron flux monitor, in which case the relative error was reduced to less than 0.25 percent. Finally, in the area of high vacuum fusion a new standard was certified for oxygen in titanium and in two titanium alloys. In addition, research in the use of the same technique for the determination of nitrogen has apparently eliminated the problem of low values that have in the past so frequently plagued the analyst.

TN425. **Microchemical Analysis Section: Summary of activities, July 1966 to June 1967,** Edited by J. K. Taylor, NBS Tech Note 425 (Oct. 1967).

Key words: Coulometric analysis; gas analysis; mass spectrometric gas analysis; microchemical analysis; null-point potentiometry; polarographic analysis; standard reference materials, analysis.

This report describes the research activities and scientific programs of the Microchemical Analysis Section of the Analytical Chemistry Division of the NBS Institute for Materials Research during the period July 1966 to June 1967. General activities are reported in the areas of gas analysis, polarography, potentiometry, coulometry, chemical microscopy, and classical microchemical analysis. Research accomplishments described in some detail include the following: high pressure mass spectrometry; high precision differential polarography; an improved coulometric technique for titration of halides; developments in micro null-point potentiometry; techniques for the accurate weighing of small liquid samples. A number of microchemical procedures which have been developed for the analysis of a variety of materials are also included.

TN426. **Analytical Mass Spectrometry Section: Summary of activities, July 1966 to June 1967,** Edited by W. R. Shields, NBS Tech. Note 426 (Sept. 15, 1967).

Key words: Instrumentation; isotopic analyses; mass spectrometry; procedures.

This report describes the advances in instrumentation and the research activities of the Analytical Mass Spectrometry Section during the period July 1966 to June 1967.

Advances in instrumentation include the construction of a multi-stage mass spectrometer, a high vacuum beam valve, a Z focussing lens, a re-designed collector, a filament degas chamber, and new equipment for sample drying. The new facilities at Gaithersburg are described.

Elements studied during this period include: B, Cr, Pb, Rb, U, and Pu. Chemical procedures are given for B, Cr, Pb, and Pu; mass spectrometric procedures are given for B, Cr, Pb, Pu, Rb, and U.

TN427. **Organic Chemistry Section: Air pollution studies; characterization of chemical structures; synthesis of research materials; novel research materials; isotopic methods for analysis of carbohydrates; occurrence, preparation, and properties of naturally occurring monosaccharides (including 6-deoxy sugars); standard reference materials (organic), July 1966 through June 1967,** Edited by R. Schaffer, NBS Tech. No 427 (Oct. 1967).

Key words: Air pollution studies; characterization chemical structures; disaccharide of d-lyxofuranos infrared absorption methods for analysis of carbohydrate naturally occurring monosaccharides and 6-deoxy sugar oxidation of polycyclic aromatic hydrocarbon phenylhydrazono-phenylazo tautomerism; quebrachitc levo-inositol; standard reference materials; 1,2-(isopropylidene-β-L-idofuranose; 2,3-0-isoptropylidene-β-(threo-pentulofuranose.

This report describes work in progress in the Organ Chemistry Section of the Analytical Chemistry Division of th NBS Institute for Materials Research. The following researc areas are discussed: air pollution studies; characterization chemical structures; synthesis of research materials; disaccharide of d-lyxofuranose; novel research material isotopic methods for analysis of carbohydrates; occurrenc preparation, and properties of naturally occurrir monosaccharides, including 6-deoxy sugars; and standa reference materials.

TN428. **Activation analysis: Cockcroft-Walton generator, nucle reactor, Linac, July 1966 through June 1967,** Edited by J. DeVoe, NBS Tech. Note 428 (Nov. 1967).

Key words: Activation analysis; biological; botanic samples; carbon in sodium; Cockroft-Walton generato digital computers; flux monitors; high precision 14 Me neutron activation; homogeneity testing; instrumentatio NBS Linac; NBS reactor; photoneutron reactions; se absorption corrections; standard reference material vanadium in irons and steels.

This is the first separate (not combined with that Radiochemical Analysis) summary of progress for th Activation Analysis Section of the Analytical Chemist Division of the National Bureau of Standards.

Pertinent information on the irradiation facilities of the nucle reactor, Linac and Cockcroft-Walton generator are describe The initial installation of pneumatic transfer tubes is complete Of great significance is the completion of a clean room that used for pre-irradiation chemical separation for high sensitivi activation analysis.

A dual-sample biaxial rotating 14 MeV neutron-irradiatic assembly has been tested. This assembly is part of a system th is controlled by a relay type of programmer to automate thos irradiation steps that adversely affect precision of the analysi This system was used to improve greatly the precision analysis for oxygen and fluorine.

As a result of improved precision with the 14 MeV neutr irradiation, a study of systematic errors is now possible. Effor to establish a reproducible correction factor for neutron ar gamm-ray absorption between different matrices within th sample have shown considerable promise.

Standard Reference Material (SRM) steel chip Nos. 3b, 3 and 30f have been analyzed for vanadium. Preliminary analys of high purity platinum (a potential SRM) showed silver, coppe gold, palladium, and iridium at the ppm level. Future biologic SRM's, (tree leaves, and beef liver) were tested for homogenei and found satisfactory.

A variety of service analyses were performed. In particula very pure aluminum was found to contain fractions of a ppm chromium and scandium.

Additional efforts are being made to monitor reactor neutr fluxes. Additional nuclear instrumentation is being assembled improve the versatility of the analysis technique.

Performance of the bremsstrahlung target, used with the linear ectron accelerator, has been evaluated. Photon intensity istribution and stability was found to be within usable range. nalyses using the (γ,n) or (γ,p) reactions have been developed r magnesium in steels, and carbon in sodium metal.

N429. **Separation and Purification Section: summary of initial activities February 1966 through June 1967,** D. H. Freeman, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 429, 48 pages (Feb. 1968).

Key words: Ion exchange; purification; reagents; zone refining.

This report describes the initial growth and research activities f the Separation and Purification Section since its formal or- anization in February 1966.

A research capability for the study and refined adaptation of n exchange materials is described. There are new activities re- orted for the areas of extreme purification, chemical reagents, rganic chemicals, including the use of crystallization for the chievement, protection, and measurement of chemical purity. pecific studies have been conducted in the purification of ineral acids, nitrobenzene, and the development of zone refin- ng methods.

TN430. **Designs for surveillance of the volt maintained by a small group of saturated standard cells,** W. G. Eicke and J. M. Cameron, NBS Tech. Note 430 (Oct. 9, 1967).

Key words: Control charts; experiment design; saturated standard cells; standard cells calibration; statistics; voltage standard.

This technical note describes a procedure for maintaining urveillance over a small group of saturated standard cells. The neasurement process is briefly discussed and the principle of eft-right balance as a means of eliminating certain systematic errors is developed. Specific designs and their analysis for ntercomparing 3, 4, 5 and 6 cells in a single temperature ontrolled environment are given. Procedures for setting up ontrol charts on the appropriate parameters are given, and a echnique is described for detecting certain types of systematic errors.

TN431. **Second breakdown in semiconductor devices - A bibliography,** H. A. Schafft, NBS Tech. Note 431 (Oct. 1967).

Key words: Bibliography; device reliability; diodes; failure mechanisms; failure modes; second breakdown; semiconductor devices; thermal breakdown; transistors.

Almost 200 references with appropriate key words are listed which provide, it is believed, a comprehensive coverage of the iterature of second breakdown in transistors and other semiconductor devices from 1958 through much of 1967. A representative list of earlier papers dealing with what appears to e second breakdown in point-contact and p-n junction diodes is lso included. The indexes consist of an author index and an ndex to subject matter with reference tabulations and with key word assignments.

TN432. **Connection tables from Wiswesser chemical structure notation—a partial algorithm,** G. F. Fraction, J. C. Walker, and S. J. Tauber, Nat. Bur. Stand. (U.S.), Tech. Note 432, 63 pages (Sept. 1968).

Key words: Acyclic; benzene; chemical structure notations; connection tables; contractions; ring system; syntax analysis; transformation algorithm; Wiswesser.

An algorithm has been developed for transforming certain types of Wiswesser organic structure notations into connection tables. Acyclic and benzene structures are treated, and provision has been made for all of the types of contractions used by the Wiswesser notation system. A separate algorithm is presented for treating linearly fused ring aggregates. A syntax has been developed to describe those portions of Wiswesser notations which refer to non-benzene ring systems.

TN433. **Input/output packages for the systems 360 assembly language processor,** P. A. D. deMaine, Nat. Bur. Stand. (U.S.), Tech. Note 433, 14 pages (Sept. 1968).

Key words: Assembly language; card punch; card read; input/output; on-line print; system 360.

Three input-output (I/O) software packages for use with the Assembly Language Processor (ALP) of the Systems 360 are described. They are for card read, on-line-print and card punch operations. A single pseudo-operation statement, which contains all required formats and addresses, suffices for the execution of each input-output package. Printed error and guide messages aid in program debugging. In addition to the conventional formats (A, I, F and E), Systems 360 column binary (X) and hexadecimal (J and B) are permitted. With a single pseudo-operation these I/O packages can handle up to eight individual items or arrays of any length in a single or mixed format.

TN434. **"Life cycling" test on several strain gage pressure transducers,** P. S. Lederer, NBS Tech. Note 434 (Oct. 1967).

Key words: Life cycling; life testing; pressure cycling; pressure transducer; strain gage.

This publication reports the effects of many thousands of pressure cycles on the performance characteristics of several types of strain gage pressure transducers. The results obtained indicate permanent changes in zero pressure output and sensitivity. Most of these changes tend to occur during the first few thousands of cycles. The equipment and procedures used to obtain the data are described.

TN435. **The hyperbolic character of certain experimental results which tend toward limiting values,** A. F. Kirstein, NBS Tech. Note 435 (Nov. 1967).

Key words: Experimental; graphical solution; hyperbolic character; limiting values.

The hyperbolic character of certain experimental data obtained from structural and mechanical testing provides an extremely simple graphical method for use in approximating the limiting values associated with the data. The method, developed by Southwell to explain the behavior of eccentrically loaded thin elastic struts, is shown to have much wider application. A limited number of illustrations are given to describe the method and to show how it might be used as a research tool.

TN436. **Studies of calibration procedures for load cells and proving rings as weighing devices,** G. B. Anderson and R. C. Raybold, Nat. Bur. Stand. (U.S.), Tech. Note 436, 22 pages (Jan. 1969).

Key words: Calibration; force; load cells; proving rings; transducers; uncertainty; weighing.

Elastic devices such as load cells and proving rings, when used with comparison measurement techniques, yield uncertainties orders of magnitude smaller than generally accepted. Their use, in direct reading application, is affected by numerous characteristics of materials, as well as the techniques of application and interpretation of data. This paper is intended to present progress made in the evaluation of calibration techniques, to the end that such transducers may be used with a predictable uncertainty in direct reading applications. Attempts are being made to formulate calibration procedures which are consistent with application procedures. The confusion existing in the derivation and application of practical force units is considered sufficient justification

for a brief discussion of forces derived from mass standards and gravitational acceleration.

TN437. **Disclosures on: Autosort, an automatic collating and sorting machine; optical heterodyne refractometer; liquid metering pump; stable wideband relaxation oscillator using three inverting amplifiers; and seat belt webbing abrasion resistance testing machine,** Editors, D. Robbins and A. J. Englert, NBS Tech. Note 437 (Nov. 1967).

Key words: Abrasion resistance testing; automatic document distribution; flexible tubing pump; inverting amplifiers; laser beam phase shift; laser heterodyning; liquid metering pump; optical refractive index; programmed document distribution; relaxation oscillator; rotatable document bin array; seat belt webbing abrasion.

This Note presents descriptions and drawings of five devices that embody interesting and unusual solutions to problems frequently encountered in their respective fields. The devices are: autosort, an automatic collating and sorting machine, optical heterodyne refractometer, liquid metering pump, stable wideband relaxation oscillator using three inverting amplifiers, and seat belt webbing abrasion resistance testing machine.

Other disclosures on various subjects may be found in NBS Technical Notes 237, 253, 263, 282, 287, and 295.

TN438. **Compendium of *ab initio* calculations of molecular energies and properties,** M. Krauss, NBS Tech. Note 438 (Dec. 1967).

Key words: *Ab initio* electronic calculation; dipole moment; dissociation energy; electron affinity; energy; field gradient; magnetic constants; molecular electronic structure; orbital energy; polarizability; quadrupole moment; spectroscopic constants.

The number of *ab initio* molecular electronic calculations has increased dramatically in the last few years. Both the practitioners and other interested students of the results of the calculations have found it increasingly difficult to determine the present status of these calculations. This compendium references the work from 1960 to the present and abstracts from the mass of data the best values for several observable properties including the total energy, dissociation energy, electron affinity, spectroscopic constants, electric moments, field gradients, polarizabilities, and magnetic constants. In order to provide and insight into molecular electronic structure tables of orbital energies are also included.

These tables are meant to direct attention to the successes and failures of the calculations by compiling a large percentage of the best results in a reasonably compact form. Its usefulness will be limited in time by rapid advance in the field.

TN439. **A laser-source integrating sphere reflectometer,** G. J. Kneissel and J. C. Richmond, Nat. Bur. Stand. (U.S.), Tech. Note 439, 70 pages (Feb. 1968).

Key words: Diffuse reflectance; graphite; high temperature reflectance; infrared reflectance; integrating sphere reflectometer; laser; reflectance; sodium chloride coating; synchronous amplification; thoria; tungsten.

A reflectometer was developed for measuring the absolute spectral reflectance of materials at temperatures up to 2500 °K. The equipment included (1) a helium-neon laser as the source, capable of operation at 0.6328, 1.15 or 3.39μm, (2) a 35 cm diameter integrating sphere coated with sodium chloride, (3) a lead sulfide detector, and (4) a radio frequency generator for heating the specimen by induction. A spike filter transmitting at the laser wavelength in front of the detector absorbed most of the background radiation from the hot specimen, and a chopped incident beam together with synchronous amplification of the signal from the detector was used to eliminate the effect of the remaining background radiation. The integrating sphere could be evacuated, or operated under a slight positive pressure of purified helium. An error analysis showed that the measured absolute reflectances are in error by less than one percent. Preliminary data are presented for thoria, tungsten and graphite. Graphite was found to be stable in reflectance on heating to 2150 °K in vacuum. Both thoria and tungsten were somewhat unstable in reflectance on heating in vacuum.

TN440. **Disclosure on: Autoeditor — a semi-automatic copy-editing apparatus,** D. Robbins, Editor, Nat. Bur. Stand. (U.S.), Tech Note 440, 49 pages (Apr. 1968).

Key words: Automatic capitalization; automatic deletions; automatic stop for revision; editorial mark sensing; manual additions; narrative text editing; punched paper tape typewriter.

This note is a disclosure on a semi-automatic apparatus for incorporating editorial revisions in narrative text using punched paper tape combined with mark-sensing techniques. Pencil marks placed on the original draft by the editor are sensed and arranged to automatically capitalize the first letter of a word, to capitalize an entire word, or stop the apparatus at the point where a change is to be made. Addition of text is entered manually with an electric typewriter; deletion of text is accomplished by activating a "mark skip" key which advances the tape without typing until the next control mark is sensed.

TN441. **Tabulation of published data on Soviet electron devices through October 1967,** C. P. Marsden, Nat. Bur. Stand. (U.S.), Tech. Note 441, 98 pages (July 1968).

Key words: Electron devices; electron tubes; Soviet electron devices; semiconductors.

This tabulation includes published data on Soviet electron devices as collected from publications, mostly handbooks, published by the various ministries and institutes of the USSR. Information is given on all active devices ranging from receiving to microwave devices, semiconductor devices, and miscellaneous devices such as, for example, photographic flash tubes and thermistors. (Supersedes NBS Tech. Note 265).

TN442. **An empirical formula for the coherent scattering cross section of gamma rays,** A. Nath and A. M. Chose. Nat. Bur. Stand. (U.S.), Tech. Note 442, 16 pages (Apr. 1968).

Key words: Coherent scattering; Delbrück; empirical formula; gamma rays; nuclear Thomson; Rayleigh.

An empirical formula has been developed for estimating coherent scattering cross sections of γ-rays of energies below 1 MeV and in the range of 0 — 2.5mc units of momentum transfer. The formula has been compared with the experimental data available in the literature in the case of Pb, Sn and Cu scattered for different photon energies between 0.279 — 1.33 MeV. Experimental data, in general, have been found to be in good agreement with the results of the empirical formula, the deviation being within $\pm$10 percent in most of the cases. The empirical formula has also been compared with the form factor results of Nelms and Oppenheim and with the accurate theoretical data of the Birmingham group. The latter is in excellent agreement with the empirical formula.

TN443. **A computer oriented single-fingerprint identification system,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 443, 28 pages (Mar. 1968).

Key words: Classification; computer; descriptor; file; fingerprint; identification; pattern-recognition.

A procedure is described for computing a set of numeric

criptors that identify a single fingerprint. The procedure rts with the X and Y coordinates and the individual directions the minutiae (ridge endings and bifurcations) of a fingerprint pression. Sets of descriptors are computed corresponding to ups or constellations of these minutiae. Descriptors corponding to various fingerprint impressions are stored on magic tape. A fragment of a fingerprint impression such as occurs a latent fingerprint may also be used.

A second computer program reads the descriptors correspondto two different fingerprint impressions from magnetic tape. score is computed that indicates how well the two impressions tch. Preliminary experimental results suggest that this cedure might be suitable as a basis for a single-fingerprint ssification system.

N444. **Reform: a general-purpose program for manipulating formatted data files,** R. McClenon and J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 444, 28 pages (Aug. 1968).

Key words: File editor; fixed-field file editor; Fortran program; insert program; packing program; reformatting; report generator; unpacking program.

A program listing and description is given of REFORM, an inpendent program with which it is possible to manipulate and it files containing as many as nine different fixed-field card forats. It can select or abridge information from any of the cards d print that information, or reformat new cards in any desired der or arrangement. Provision is made for introducing as many twenty-six arbitrary strings of characters, each of which may up to seventy-nine characters in length, thereby permitting the sertion of labels, headings, or comments into the file. The proam, which operates on the 1108 computer at NBS, is written ASA FORTRAN, and care has been taken to reduce to a inimum the program changes required to make the program run other computers.

N445. **A bibliography on methods for the measurement of inhomogeneities in semiconductors (1953-1967),** H. A. Schafft and S. G. Needham, Nat. Bur. Stand. (U.S.), Tech. Note 445, 47 pages (May 1968).

Key words: Bibliography; electron voltaic; measurement methods; photoconductivity; photovoltaic; point potential probe; semiconductor material inhomogeneities; spreading resistance; voltage breakdown.

About 130 papers which deal with the measurement chniques useful in detecting the type and location of various inomogeneities, primarily in germanium and silicon, are listed ith key words. The types of inhomogeneities considered are ose in impurity concentration, resistivity, mobility, diffusion ngth, lifetime, surface conditions, crystal perfection, and p-n nctions. Some of the twenty-two effects or methods used to dect these inhomogeneities are: photovoltaic, electron-voltaic, notoconductivity, one-, two- and four-point probe, spreading sistance, and voltage breakdown. There are three indexes: a ference tabulation according to key words, a reference tabulaon according to methods or effects used to detect an inomogeneity, and an author index.

N446. **PRECISE: A multiple precision version of Omnitab,** A. E. Bean and J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 446, 84 pages (June 1968).

Key words: Double precision; elementary functions; equation solver; linear equation solver; magnetic tape utility program; multiple-precision computing; multiple-precision programming; PRECISE; triple-precision; user's manual.

This users manual describes PRECISE—a completely assemled interpretive program for the IBM 7090/7094 which enables he user to carry out arithmetic operations and function generation in multiple precision (accuracy to 28 significant figures). PRECISE operates as a sub-monitor under the IBSYS or DC-IBSYS monitor systems. Appendixes describe how jobs are set up to be run under the PRECISE sub-monitor, and how the system may be expanded to include new subroutines. The program, which responds to instructions in the form of plain English sentences or contractions thereof, has provision for handling numbers out of the normal 7090/7094 range. It handles numbers as large as 10 to the 10 to the 9 power. Other features of the program include: free-field input; a work-sheet of 7,500 cells (3 × 2500 computer words) which can be dimensioned by the user at run time (75 rows by 100 columns, 300 rows by 25 columns, etc.); solution of systems of linear equations in as many as 85 unknowns; flexible formatting; tape handling facility; and row and column sums. A description of the UOM Multiple Precision Package (SHARE Dist. No. 3081) is included as an appendix.

TN447. **Research on high temperature materials at the National Bureau of Standards,** E. Passaglia, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 447, 19 pages (July 1968).

Key words: High temperature materials; materials properties.

The National Bureau of Standards, with support from the Advanced Research Projects Agency of the Department of Defense, has begun a program on High Temperature Materials. This program includes projects on properties of high temperature materials, projects on their preparation, and others designed to explain basic phenomena limiting the use of materials at high temperatures. A summary of the progress in this program is given here.

TN448. **Status report. National standard reference data system, April 1, 1968,** E. L. Brady, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 448, 132 pages (June 1968).

Key words: Atomic and molecular data; chemical kinetics; colloid and surface properties; data systems design and development; information services; mechanical properties; nuclear data; solid state data; standard reference data; thermodynamic and transport properties.

This report summarizes the status of activities of the NBS Office of Standard Reference Data as of April 1968. It provides a detailed review of the data compilation activities within the seven broad categories of the technical scope of the program: (1) nuclear data, (2) atomic and molecular data, (3) solid state data, (4) thermodynamic and transport data, (5) chemical kinetics, (6) colloid and surface properties, and (7) mechanical properties. Progress in data systems design and development and in information services are reviewed. Certain problem areas of the program are identified. The appendix includes: (1) a listing of information and data centers associated with the Office of Standard Reference Data, (2) publications of the National Standard Reference Data System, and (3) a listing of organizations, groups, or individuals compiling or evaluating data.

TN449. **Research on laser standards and materials at the National Bureau of Standards,** K. G. Kessler, E. Passaglia, and N. N. Winogradoff, Editors, Nat. Bur. Stand. (U.S), Tech. Note 449, 32 pages (June 1968).

Key words: Holography; laser energy; laser materials; laser power; laser radiometry; laser standards; laser transitions; modulation of lasers; near and far field patterns; optical properties.

A brief report is presented on research in the areas of laser standards and laser materials now in progress at the National Bureau of Standards. Included are the measurement of the power and energy output of lasers, their near and far field patterns and their optical properties. The physical and chemical properties of laser materials are studied in an attempt to relate such properties to the operating characteristics of lasers.

TN450. **Unassigned.**

TN451. **Radiochemical Analysis Section: summary of activities July 1967 to June 1968,** J. R. DeVoe, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 451, 131 pages (Jan. 1969).

Key words: Backscatter geometry; computer programs for Mössbauer spectrometry; computers; corrosion products; counting statistics; cross sections; detection limits for analysis; electric field gradient tensors; flux monitors; interferometric Mössbauer spectrometer; Mössbauer instrumentation; Mössbauer spectrometry, NBS Linac; nickel-61; nuclear recoil; overflow counter; photonuclear reactions; proportional counter; quantitative Mössbauer spectrometry; standard reference materials.

This is the fifth summary of progress of the Radiochemical Analysis Section of the Analytical Chemistry Division at the National Bureau of Standards.

The sections' effort comprises four major areas: Mössbauer spectrometry, nuclear chemistry, nuclear instrumentation and the application of statistics in nuclear and analytical chemistry.

Studies in nuclear reactions have centered around measurement by time of flight mass spectrometry of helium-4 produced from reactions such as $^{7}Li(\gamma,\alpha)^{3}H$.

Statistical methods have been applied to the measurement of peaks in radiation spectra, to reporting trace amounts of radioactivity, to the calibration of Standard Reference materials, and to the reporting of detection limits of a system of measurement.

A procedure for cooling a moving absorber with a stationary source for Mössbauer spectrometry is described. A system for taking spectra using the scattering mode is described along with a large "pancake" shaped proportional counter that is used in the system. Theoretical interpretations of Mössbauer spectra of nickel compounds are given. Computer programs which incorporate constraints such as field intensity and quadrupole moments have been written. Several applications of Mössbauer spectrometry, such as surface corrosion studies are described. Preliminary data are given on the charge states of ^{119m}Sn after nuclear recoil. A technique for resolving some of the difficulties in quantitative analysis of chemical structures is also described.

An overflow counter for collecting more counts than the memory capacity of a pluse height analyzer is described. A sequential scanner for a frequency synthesizer has adapted the NBS Optical Interferometric Mössbauer Spectrometer from a constant velocity to a constant acceleration mode.

TN452. **Activities of the NBS Spectrochemical Analysis Section July 1967 through June 1968,** B. F. Scribner, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 452, 80 pages (Sept. 1968).

Key words: Computing; digital readout; electron probe; emulsion calibration; emulsion sensitivity; gold analysis; isotope dilution method; microprobe grid scanner; optical spectrometry; plasma torch; platinum analysis; preconcentration; silicon detector; spark source mass spectrometry; spectrochemical analysis; standard reference materials; time-shared computer; x-ray absorption coefficients; x-ray fluorescence analysis; x-ray mass attenuation coefficients; zinc analysis.

A summary is given of activities of the NBS Spectrochemical Analysis Section for the year July 1967 through June 1968. This covers research activities, improvement in equipment, and applications in analysis including the certification of standard reference materials. In optical spectrometry studies were completed on the plasma torch as a means of excitation of solutions, and on computer programs for the calibration of photographic emulsions. In electron probe microanalysis a matrix scanner for automatic point-by-point grid scans was tested a a lithium-drifted silicon detector was installed for non-diffracti x-ray dispersion. A study was made of color composites for co bining the information of three x-ray area scans. In quantitati probe analysis, measurements were made of x-ray mass atten tion coefficients, and a study of atomic corrections is underwa In x-ray fluorescence considerable improvement was realized replacement of electronics by solid state circuitry, and metho are being studied for corrections of interelement effects, utilizi the digital computer. Spark source mass spectrometry was a plied, by means of chemical separations and by isotope diluti techniques, to the accurate determination of impurities in zi platinum, and gold. A critical study was made of the uniform of response of ion-sensitive emulsions over the area of the pla used in the mass spectrometry. Improvements in the Sectio equipment and further developments in computer applicatic are also discussed. Listings are given of 23 publications and talks by members of the Section during the year.

TN453. **Electrochemical Analysis Section: summary of activit July 1967 to June 1968,** R. G. Bates, Editor, Nat. Bur. Sta (U.S.), Tech. Note 453, 88 pages (July 1968).

Key words: Acidity; analysis; conductance measuremer electrochemical analysis; electrochemistry of solutio ionic activity; ion-selective electrodes; pD measuremer pH measurements; medium effects; solvent effects.

This survey of the activities of the Electrochemical Analy Section, Analytical Chemistry Division, covers the period J 1967 to June 1968. An attempt is made to summarize a yea progress on the technical projects of the Section in such a wa to stress the program and capabilities of the organizational u as a whole. Brief summaries of several lines of work under v are given. The review describes briefly new equipment and fa ties acquired during the year. A major effort devoted to aci measurements has led to new pH standards and new refere solutions for pD in heavy water. Solvent effects on acid-b phenomena in mixed solvents have shed some light on the f tors, including solvent structure, governing ion-solvent inte tions. A start was made on the study of ion-specific electro and the establishment of standard scales for ionic activ Equilibrium data for hydrochloric acid in 92.41 wt. per ethanol and for the ionization of carbonic acid in heavy w have been obtained. The establishment of conductance st dards for oceanographic research was begun. The survey c cludes with lists of the members of the Section staff, publicati and manuscripts produced during the year, talks given by staff, and committee assignments.

TN454. **Analytical Coordination Chemistry Section: summar activities July 1967 to June 1968,** O. Menis, Editor, Nat. B Stand. (U.S.), Tech. Note 454, 92 pages (July 1968).

Key words: Atomic absorption and atomic fluoresce spectrometry; differential thermal analysis; flame emissi gases in metals; gravimetry and titrimetry; sp trophotometry and spectrofluorometry; standard refere materials.

This annual report outlines the progress made in titrime gravimetry, flame emission, atomic absorption and fluoresce spectrophotometry, spectrofluorometry and the determina of gases in metals in conjunction with the analysis of Stand Reference Materials. It describes recent developments in ins mentation and in sample dissolution techniques and discus some unique applications of coordination systems and ter complexes.

In flame spectroscopy considerable progress was made in development and testing of electrodeless discharge lamps,

arc continuum sources, a.c. scanning systems, resonance detectors and improved nebulizer-burner combinations. The relative merits of flame emission, atomic absorption and atomic fluorescence were evaluated from theoretical and practical standpoints. Specialized instrumentation was also developed for use in thermal analysis studies and in spectrofluorometry. In the area of gases in metals, a new inert gas fusion apparatus having a unique sampling valve and gas flow system was constructed and coupled to a high sensitivity gas chromatograph. In addition, a new commerical inert gas fusion apparatus was tested and a vacuum fusion unit modified to permit more readily the successive determination of oxygen and nitrogen.

Studies were made of the dissolution of refractory materials containing volatile or easily hydrolizable components. Sealed Teflon-lined bombs and quartz tubes were successfully applied to the determination of trace nitrides in steels and niobium alloys and of antimony at the 10-50 ppm level in ferrous alloys. The latter was prerequisite to the provision of standards for correlating the presence of trace antimony in rotor blades with power turbine failures. Teflon-lined bombs were also used for the dissolution of clays prior to the determination of trace components.

The formation and extraction of ternary complex systems were investigated to provide enhanced spectrophotometric and spectrofluorometric sensitivity for trace metal determination. Improvement in the detection limits of existing procedures were effected by the use of micro-volume techniques. Also, the utilization of recently developed spectrofluorometric chelating agents have yielded significant improvement in sensitivity. Beryllium, for example, was readily determined in resin beads at the 50 picogram level.

Finally, a large number of Standard Reference Materials and potential standards were certified for their major, minor and trace constituents. These included clays, tungsten-molybdenum compacts, neutron flux glasses, aluminum alloys, organo-metallic compounds, ferrous alloys, solder, and high-purity and doped zinc, platinum and gold. Many of the values obtained were confirmed by independent methods.

TN455. **Microchemical Analysis Section: summary of activities July 1967 to June 1968,** J. K. Taylor, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 455, 145 pages (Oct. 1968).

Key words: Coulometric analysis; gas analysis; methods of chemical analysis; microchemical analysis; microscopic analysis; polarographic analysis; specific ion electrodes.

This report describes the research activities and scientific programs of the Microchemical Analysis Section of the Analytical Chemistry Division of the NBS Institute for Materials Research during the period July 1967 to June 1968. General activities are reported in the areas of gas analysis, polarography, potentiometry, coulometry, chemical microscopy, and classical microchemical analysis. Research activities described in some detail include: determination of trace amounts of oxygen in gases, development of a coulometric method for precise analysis of boric acid, improvements in microdetermination of silver and fluorine by null-point potentiometry, the electrochemical generation of fluoride ion, preparation of resin-bead particle standards, and determination of trace elements by the nuclear track technique. A number of microchemical procedures which have been developed for the analysis of a variety of materials are also included.

TN456. **Analytical Mass Spectrometry Section: summary of activities July 1967 to June 1968,** W. R. Shields, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 456, 54 pages (Nov. 1968).

Key words: Instrumentation; isotopic analyses; mass spectrometry; procedures.

This report describes the advances in instrumentation and the research activities of the Analytical Mass Spectrometry Section during the period July 1967 to June 1968.

Advances in instrumentation include the construction of the electronic interface automating both the control of the multistage instrument, and the digital readout and data reduction. A new and improved beam valve is also described.

Elements studied during this period include: B, Ni, Pb, Li, U, and Pu. Chemical procedures are given for B, Pb, CaF_2, U, and Pu; mass spectrometric procedures are given for B.

TN457. **Organic Chemistry Section: summary of activities July 1967 to June 1968,** R. Schaffer, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 457, 127 pages (Sept. 1968).

Key words: Acetylation; analysis of corn syrups; carbohydrate structure and characterization; cholesterol; clinical chemistry; creatinine; di-*O*-isopropylidene-D-*erythro*-pentulofuranose; D-psicose, dextrose; n.m.r. spectroscopy; nicotinic acid; 1,2:3-4-metallo-organic standard reference materials; periodic acid; polycyclic air-pollutants; polyhydroxy cyclic compounds; standard reference materials; sucrose; sulfonic Ka measurements; urea; uric acid.

This report describes work in progress in the organic Chemistry Section of the Analytical Chemistry Division of the NBS Institute for Materials Research. The following research areas are discussed:

Carbohydrate Synthesis, Structure, and Characterization: Novel Research Materials and Model Compounds. The reaction of sulfonic esters of D-mannitol with methoxide has been examined, and a new dianhydrohexitol has been isolated, and identified as 2,3:4,5-dianhydro-D-iditol. Methods for the esterification of tetrahydroxy-*p*-benzoquinone and benzenepentol, and the disproportionation of the former compound during acetylation have been studied. A novel method for acetylation in 100 percent phosphoric acid has been developed. The usefulness of bromine for oxidizing cyclohexanehexols into inososes and diketoinositols was investigated. Acetylations of certain inosose phenylhydrazones was proved to provide arylazocyclohexene derivatives, whereas previous workers had reported otherwise. NMR spectroscopy was used to determine the conformations of several bi- and tri-cyclic carbohydrate derivatives in solution, and the influence of substituents and of dipolar interactions on conformation was analyzed. The factors that determine the rates of reaction of the cyclic disulfones that are intermediates in the MacDonald-Fischer degradation of sugars were evaluated by pKa measurements and NMR analysis. Syntheses of "D-ribulose" and D-psicose have been carried out.

Clinical Chemistry. Extensive examinations of the properties of high-purity samples of creatinine, uric acid, and urea have been made, as a preliminary stage in the development of Standard Reference Materials for these compounds. The application of phase solubility analysis and differential scanning calorimetry has been studied where appropriate for evaluations of purity. The properties and methods for determining the purity of SRM cholesterol were studied.

Properties of Polycyclic Air-Pollutants. The oxidation of a variety of polycyclic, aromatic compounds by periodic acid was studied and found to proceed by (1) a free-radical mechanism that gives rise to coupling products, or (2) a two-equivalent oxidation mechanism that leads to quinonoid derivatives, or both. On treatment with periodic acid, azulene, a non-benzenoid, aromatic compound, gave a free-radical-containing, polymeric material having ionic properties.

Analytical Chemistry of Corn Sugars and Related Products. As a preliminary but basic step in a program for developing relationships between the compositions and physical properties of

corn syrups prepared by various processes, a variety of methods have been explored for assaying the water content in syrups.

In order to describe experimental procedures adequately, it has occasionally been necessary to identify commercial materials and equipment in this report. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

TN458. **Activation Analysis Section: summary of activities July 1967 to June 1968,** P. D. LaFleur, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 458, 109 pages (Mar. 1969).

Key words: Activation analysis; Cockcroft-Walton neutron generator; computer literature searching; extraction; group separations; homogeneity testing; hydrogen bis(2-ethylhexyl) phosphate; matrix effect; molybdenum; NBS LINAC; NBS reactor; photon activation analysis sensitivities; standard reference materials; zinc.

The facilities used by the reactor, LINAC and neutron generator groups for activation analysis are described. Proposed installation of four new irradiation terminals and a new pneumatic transfer tube system are outlined.

A new 2.5-mA neutron generator has been installed and the biological shield, pneumatic transfer system and the detector assembly modified. Studies of blank problems for oxygen determination and self-absorption corrections in photopeak analysis have resulted in greatly improved precision for Standard Reference Materials. Halide in photographic emulsions, using 14-MeV and 2.6-MeV neutrons, have been determined.

Considerable emphasis has been placed on the development of group radiochemical separations, SRM steel and high purity zinc samples have been analyzed using this technique.

Eighteen different SRMs were analyzed for a variety of elements and a variety of service analyses were performed.

The self-absorption effects of the matrix on irradiation photons were studied and calculations of sensitivities for photon activation analysis were made. Carbon in sulfur, yttrium in rare earth oxides and oxygen in sodium were determined by photon activation.

The extraction of metals by bis(2-ethylhexyl) orthophosphoric acid has been studied, and distribution coefficients are given for many of the transition metals. The results indicate enhanced applicability of this reagent for radiochemical separations.

Updated keys for computer literature searching and a sample output are included.

TN459. **Separation and Purification Section: summary of activities July 1967 to June 1968,** D. H. Freeman, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 459, 56 pages (Dec. 1968).

Key words: Analytical distillation; clinical standards; crystallization; divinylbenzene; EDTA; ion exchange resins; microstandards; particulate matter; reagents; resin structure; ultra-pure reagents; urea; uric acid.

The research activities of the Separation and Purification Section are described, including their significance to the program of the Office of Standard Reference Materials. The work involves basic developments to characterize ion exchange resins using infrared spectrophotometry, stoichiometric analysis of resin structure, and the study of chain scission. The availability of spherical particles of homogeneous ion exchange resin has been exploited with the recently developed microstandards. Analytical gas chromatography has been developed with emphasis given to the specialized needs of measuring trace contaminants in purified organic compounds including divinylbenzene, EDTA, and clinical standards such as uric acid and urea. Purification capabilities involving the use of crystallization, analytical distillation, and of the newly installed low temperature (−30 °C) laboratory are described. The activities of the ultra-pure reagents project, including work on the laser light scattering measurement of traces of liquid borne particulate matter, on reagent preparation, and methods of reagent storage are described.

TN460. **Unassigned.**

TN461. **Tables of solutions to Bragg's equation for copper, cobalt, iron, and chromium Kᾱ radiation and small diffraction angles,** J. P. Colson and E. S. Clark, Nat. Bur. Stand. (U.S.), Tech. Note 461, 75 pages (Aug. 1968).

Key words: Bragg's equation; Co; Cr; Cu; Fe; Kᾱ radiation; small angle.

Tables of solutions to Bragg's equation are presented for the Kᾱ radiation of Cu(1.541838 Å*), Co(1.790260 Å*), Fe(1.937355 Å*), and Cr(2.291002 Å*). The value of 2θ is increased in increments of 0.001 degree from 0.001 to 2.999 degrees and in increments of 0.00001 radian from 0.00002 to 0.04999 radian. The solutions are rounded off to five digits.

TN462. **Nonnumeric data processing in Europe: a field trip report,** M. E. Stevens, Nat. Bur. Stand. (U.S.), Tech. Note 462, 66 pages (Nov. 1968).

Key words: Artificial intelligence; automatic abstracting; automatic indexing; computational linguistics; computer centers; documentation; information storage; library automation; optical character recognition; pattern recognition; programming languages; selection and retrieval; speech and speaker recognition.

A number of nonnumeric data processing projects in the United Kingdom, Belgium, the Netherlands, Italy, Sweden, the Federal Republic of Germany, and the U.S.S.R. have been visited. Topics covered include character and pattern recognition; speech analysis, synthesis, and recognition; artificial intelligence; mechanized documentation and library automation; linguistic data processing, and computing and programming theory.

TN463. **Mössbauer effect study of magnetic ordering in copper-rich Cu-Ni-Fe alloys,** L. J. Schwartzendruber, Nat. Bur. Stand. (U.S.), Tech. Note 463, 138 pages (Aug. 1968).

Key words; Alloys; copper; gold; iron; magnetism; Mössbauer effect; nickel.

The ^{57}Fe Mössbauer effect has been observed in a series of copper rich Cu-Ni-Fe alloys, and for two samples of gold rich Au-Fe. At low temperatures most of these alloys order magnetically and the Mössbauer effect spectra develop typical six-line hyperfine field structure. For dissolved Fe the room temperature Cu-Fe and Au-Fe spectra consist of a doublet superimposed on a central line. In Cu-Ni-Fe the spectra at room temperature consist of a doublet with no evidence of a central line when the Ni concentration is above 10 atomic percent. The doublet separations at room temperature (and their estimated uncertainties) are 0.69 ± 0.02, 0.58 ± 0.02 and 0.22 ± 0.04 mm/sec in Au-Fe, Cu-Fe, and Cu-Ni-Fe respectively. By observation of the spectra in a magnetic field the doublet structure is shown to be due to magnetic interactions between Fe and other Fe or Ni atoms. Isomer shifts, metallurgy in Cu-Ni-Fe alloys, sample preparation techniques, and the Mössbauer effect equipment developed are also discussed.

TN464. **The NBS Alloy Data Center: function, bibliographic system, related data centers, and reference books,** G. C. Carter, L. H. Bennett, J. R. Cuthill, and D. J. Kahn, Nat. Bur. Stand. (U.S), Tech. Note 464, 199 pages (Aug. 1968).

Key words: Alloys; annotation; automated; bibliography; data; indexing; information; Knight shifts; metals; NMR

soft x-ray spectroscopy.

The Alloy Data Center, part of the National Standard Reference Data System, has two primary functions. One is to stimulate cooperation and coordination among the existing data centers in the area of the physical properties of well characterized alloys. The final data generated by these centers for publication should be consistent with one another where correlation or possible overlap exists. The other purpose is the collection (from publications as well as private communications), evaluation, and publication of data in some areas where special competence exists in the Alloy Physics Section. Of interest to the center are metals, semimetals, intermetallic compounds, and alloys. Excluded are those materials which have ill-defined constitutions and heat treatments. An automated system has been developed to meet the bibliographic needs of the center. This system will be described as well as the specific properties of interest. The system presently contains a complete annotated file on papers dealing with NMR Knight shift measurements. The soft x-ray spectroscopy compilation is being kept up-to-date with the same system.

TN465. **Measurement of carrier lifetime in semiconductors—an annotated bibliography covering the period 1949-1967,** W. M. Bullis, Nat. Bur. Stand. (U.S.), Tech. Note 465, 64 pages (Nov. 1968).

Key words: Bibliography; diffusion length; diode recovery; excess carrier lifetime; measurement methods; photoconductive decay; photoconductivity; photomagnetoelectric effect; recombination of excess carriers; semiconductors; surface photovoltage.

About 300 papers concerned with the measurement and interpretation of carrier lifetime in semiconductors are listed together with key words and a brief comment for each. Eight types of entries are included: Description of Methods, Analysis of Results, Standard Methods, Experimental Results, Theoretical Models, Auxiliary Procedures and Data, Reviews, and Books. Emphasis is placed on methods of carrying out measurements of carrier lifetime. Hence complete coverage was attempted and nearly two thirds of the entries appear in the first three categories. A large fraction of the papers listed describe the photoconductivity or photoconductive decay methods. The other most popular methods are based on diode characteristics or the photomagnetoelectric effect. In all, 35 methods for measuring carrier lifetime are represented by entries. In addition, representative papers which describe various models for recombination are included together with a number of papers which discuss the influence of surface recombination and trapping phenomena. Auxiliary procedures such as surface preparation, formation of ohmic contacts, control of temperature, and the like are described in some of the entries. Two indexes, a Key Word Index and an Author Index, are provided together with a classification of the various methods for measuring carrier lifetime.

TN466. **Matching fingerprints by computer,** J. H. Wegstein, J. F. Rafferty, and W. J. Pencak, Nat. Bur. Stand. (U.S.), Tech. Note 466, 17 pages (July 1968).

Key words: Computerized-fingerprint-identification; fingerprints; pattern-recognition.

A procedure is described for determining whether two fingerprint impressions were made by the same finger. The procedure uses the X and Y coordinates and the individual directions of the minutiae (ridge endings and bifurcations). The identity of two impressions is established by matching a constellation or group of minutiae in one impression with a corresponding constellation in the other impression in terms of the relative distances and relative angles of the minutiae.

TN467. **Activation analysis: a bibliography through 1971,** G. J. Lutz, R. J. Boreni, R. S. Maddock, and J. Wing, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 467, 892 pages (Aug. 1972).

Key words: Activation analysis; bibliography; element determined; literature file; matrix analyzed; technique used.

References to papers published in the open literature which describe work using activation analysis are printed from a computer based storage and retrieval system. Published as a two-part volume, part 1 is a listing of references according to accession numbers (approximately 6200) while part 2 is composed of four appendices. Appendix I is an index for the element determined, Appendix II is an index of the matrix analyzed, Appendix III is an index of the technique used, Appendix IV is an author index. The two parts when used together, permit a literature search defined by the several indices. Supersedes NBS TN467, Parts 1 and 2 issued May 1971.

TN468. **Unassigned.**

TN469. **NBS interagency transducer project,** P. S. Lederer, Nat. Bur. Stand. (U.S.), Tech. Note 469, 23 pages (Oct. 1968).

Key words: Dynamic calibration; evaluation; InterAgency Transducer Project; performance characteristics; telemetry; transducer.

For a number of years, the National Bureau of Standards has been engaged in a continuing project to study the performance of transducers, primarily those used in telemetry. This project has been supported by agencies of the Defense Department and NASA. This report provides a brief description of the background and history of the project, of its objectives, of some of the specialized facilities developed and used, and of some of the publications that have issued from the project.

TN470. **EDPAC: utility programs for computer-assited editing, copy production, and data retrieval,** C. G. Messina and J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 470, 80 pages (Jan. 1969).

Key words: Alphanumeric data files; computer-assisted text preparation; data retrieval; FORTRAN programs; free field text files; mechanized text editing.

A description and listings are given of EDPAC, a package of five related utility computer programs: SCRAMBLE, SUBSTITUTE, SEARCH, BLOCKSEARCH, JUSTIFY, and their subroutines. These programs perform transformations on alphanumeric data. The programs have been written in FORTRAN, with care taken to make them as system and machine-independent as possible, permitting their use on many different computers.

SCRAMBLE scans an input file for specified characters, which it replaces by different characters. SUBSTITUTE similarly replaces strings of characters by other strings. SEARCH and BLOCKSEARCH scan for the occurrence of certain strings and list the lines or blocks, respectively, in which they occur. JUSTIFY produces text, for printing on a card-controlled typewriter or on an extended character printer, which has been left- and right-justified between specified margins.

Some applications of the EDPAC programs are discussed. Emphasis is placed on computer-assisted text preparation.

TN472. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report July 1 to September 30, 1968,** W. M. Bullis, Editor, Nat Bur. Stand. (U.S.), Tech. Note 472, 45 pages (Dec. 1968).

Key words: Carrier lifetime; electrical properties; germanium; methods of measurement; microelectronics; resistivity; semiconductor devices; semiconductor materials; semicon-

ductor process control; silicon; thermal properties; wire bonds.

This quarterly progress report describes NBS activities relating to: measurement of resistivity, carrier lifetime, inhomogeneities, and Hall effect in semiconductor crystals; study of infrared measurement methods, properties of deep-lying impurities (in InSb), and high field effects; establishment of a processing facility; evaluation of wire bonds; review of NASA measurement methods; and measurement of second breakdown in transistors, thermal properties of devices, and noise in microwave diodes. Projects on silicon nuclear radiation detectors and specification of germanium are also described. Supplementary data concerning staff, committee activities, technical and information services, and publications are included as appendixes. A list of ASTM Standards relevant to integrated circuit processing is also included.

TN473. **Laboratory-field comparison of built-up roofing membranes,** T. H. Boone, L. F. Skoda, and W. C. Cullen, Nat. Bur. Stand. (U.S.), Tech. Note 473, 15 pages (Dec. 1968).

Key words: Bituminous adhesive; bituminous built-up membranes; engineering properties; laboratory-field comparison; strength-thickness.

The values of breaking load, elongation and thermal expansion of nine bituminous built-up membranes prepared by roofing contractors under field conditions and by technicians in the laboratory were measured at subfreezing temperatures. The data indicated that the field-prepared specimens agreed favorably with laboratory-prepared specimens, although the samples from the field frequently reflected higher values for thermal-shock resistance than did their laboratory-prepared counterparts. The higher values were attributed to the smaller amounts of bitumen used between the plies of the field specimens. The results appeared to support the validity of the application of the "strength-thickness rule" to bituminous built-up membranes.

TN474. **Critically evaluated transition probabilities for Ba I and II,** B. M. Miles and W. L. Wiese, Nat. Bur. Stand. (U.S.), Tech. Note 474, 22 pages (Jan. 1969).

Key words: Ba I; Ba II; line strengths; oscillator strengths; transition probabilities.

Critically evaluated transition probabilities, in order of increasing quantum numbers, are compiled for Ba I and II from available literature sources.

TN475. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report October 1 to December 31, 1968,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 475, 38 pages (Feb. 1969).

Key words: Carrier lifetime; die attachment; electrical properties; germanium; metallization; methods of measurement; microelectronics; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; wire bonds.

This second quarterly progress report in this series describes NBS activities relating to: measurement of resistivity, carrier lifetime, inhomogeneities, and Hall effect in semiconductor crystals; study of infrared measurement methods, properties of deep-lying impurities (in InSb), and high field effects; establishment of a processing facility; evaluation of aluminum metallization, wire bonds, and wafer die attachment; review of NASA measurement methods; and measurement of second breakdown in transistors, thermal properties of devices, and noise in microwave diodes. Projects on silicon nuclear radiation detectors and specification of germanium are also described. Supplementary data concerning staff, committee activities, technical services, and publications are included as appendixes.

TN476. **Line emission sources for concentration measurements and photochemistry,** W. Braun and T. Carrington, Nat. Bur. Stand. (U.S.), Tech. Note 476, 23 pages (Mar. 1969).

Key words: Absorption; analysis; gas; photochemistry; spectroscopy; vacuum ultraviolet.

When a resonance line is absorbed in its own gas, measurements of this absorption can be used to derive a value of the product, nf, of concentration of the absorber and f value of the transition. This line absorption process is also important in the study of fluorescence and photochemistry, where it is possible to produce atoms or molecules in a single quantum state without otherwise disturbing the system. The interpretation and success of these applications of line absorption depend critically on the shape of the line emitted by the light source. This is strongly influenced by the optical depth in the emitting region, and by the inevitable presence of a reversing layer through which the light must travel on its way out of the lamp. This paper presents a simple model which can be used to estimate the effects of these properties of the light source on the threshold and sensitivity of measurements of nf, and on the power which can be delivered to absorbing atoms outside the lamp. Emphasis is on the general principles of lamp design and diagnosis, rather than on accurate description of a particular lamp.

TN477. **The performance of roofing made with Asplund felts,** S. H. Greenfeld, Nat. Bur. Stand. (U.S.), Tech. Note 477, 27 pages (Mar. 1969).

Key words: Asphalt; Asplund; felt; mineral-surfaced roll roofing; shingles; wood fibers.

A study of the durability of roofing made with Asplund wood fibers was conducted from 1942 to 1967. Concentrations of 0 to 60 percent wood fibers (oak or pine) prepared by three variations of the Asplund process were evaluated. All the mineral-surfaced roll roofings and shingles were performing well after 25 years with only four specimens showing more deterioration than the controls (only rags and paper in their felts). No differences in performance could be related to the felt composition.

TN478. **Some evolving conventions and standards for character information coded in six, seven, and eight bits,** J. L. Little, Nat. Bur. Stand. (U.S.), Tech. Note 478, 30 pages (May 1969).

Key words: ASCII; character codes; code extension; code character sets; collating sequence; computer codes; data transmission codes; information code structure; international information code; Russian code standard; standard information codes; USASCII.

This Technical Note describes some of the properties of the USA Standard Code for Information Interchange, widely known as ASCII or USASCII. It also relates this code to similar international codes and presents the national code for Russia as an example of the worldwide acceptance of this code, which is comprised of seven information bits representing 128 coded characters. Some of the conventions which are evolving to relate these seven bit codes to six and eight bit computer codes are given, and conventions for extending the code to represent an unlimited repertoire of concepts is also given. Two alternate arrangements of the code table are shown to facilitate an understanding of its structure and application.

TN479. **A Fortran program for analysis of ellipsometer measurements,** F. L. McCrackin, Nat. Bur. Stand. (U.S.), Tech. Note 479, 82 pages (Apr. 1969).

Key words: Computer programs; ellipsometry; Fortran program; multiple films; optical constants; reflection coefficients; thin films.

A general Fortran program is given that performs the calculations required to analyze ellipsometer measurements. This pro-

gram replaces the program given in NBS Technical Note 242, entitled "A Fortran Program for Analysis of Ellipsometer Measurements and Calculation of Reflection Coefficients From Thin Films." The main changes from the previous program are: (1) the new program is in Fortran IV and V rather than Fortran II; (2) the relative transmission of the wave plate is considered in analyzing ellipsometer readings; (3) an improved method is used for calculating the refractive index of a film; (4) the form of the input data is improved; (5) a method for calculating and correcting for tilt of the reflecting surface is given; (6) an improved method of calculating confidence limits for the calculated values of thickness and refractive index of a film is used; and (7) a method for calculating the optical constants of an adsorbing film of given thickness is included.

TN480. **Misalinement detector for axial loading fatigue machines,** D. C. Robinson, Nat. Bur. Stand. (U.S), Tech. Note 480, 15 pages (Apr. 1969).

Key words: Axial loading; fatigue machine; misalinement; test fixtures.

A strain gage device for measuring changes in alinement between the test fixtures of axial loading fatigue machines is described. Variations in fixture orientation are determined by measurement of the bending induced in a compliant beam clamped in parallel mounts attached to the test fixtures. Changes in bending with applied tension loads are an indication of alterations in the alinement between the load transmitting members of a machine. An approximately linear relationship was found to exist between changes in bending determined by the detector and the fatigue life of high strength fasteners for various levels of misalinement induced in a fatigue machine.

TN481. **A semi-automated single fingerprint identification system,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 481, 21 pages (Apr. 1969).

Key words: Computerized-fingerprint identification; fingerprints; pattern-recognition.

A system is described in which a fingerprint is manually coded by tracing certain ridges and noting events such as ridge endings and ridge beginnings. This code is sent by teleprinter to a central file where a computer identifies the fingerprint by comparing the code with codes previously entered in the file. The scheme for comparing codes is given along with some preliminary test results using typical fingerprints.

TN482, Superseded by Technical Note 724.

TN483. **Construction and operation of a simple high-precision copper-point blackbody and furnace,** R. D. Lee, Nat. Bur. Stand. (U.S.), Tech. Note 483, 16 pages (May 1969).

Key words: Blackbody; optical pyrometry; radiometry.

Detailed instructions for the construction and operation of an inexpensive copper-point blackbody and furnace are presented. Such a source may be expected to realize the radiance temperature of 1083.3 °C (Int. 48) with an uncertainty of 0.2 °C and a variation in successive use of less than 0.033 °C. The furnace requires no inert gas or vacuum and utilizes only 225 watts to reach a melt in about an hour after turn on. Melts and freezes last about five minutes each and at least fifty melts and freezes are expected during the lifetime of the furnace.

TN484. **A review of rate constants of selected reactions of interest in re-entry flow fields in the atmosphere,** M. H. Bortner, Nat. Bur. Stand. (U.S.), Tech. Note 484, 62 pages (May 1969).

Key words: Attachment-detachment reaction; charge exchange reaction; collisional ionization reaction; evaluated rate constants; flow field kinetics; O_2-N_2 systems.

The major reactions normally encountered in flow field reentry calculations for the oxygen nitrogen system are reviewed and a rate constant value for each reaction is recommended. Collisional ionization processes, charge exchange reactions and attachment-detachment reactions are included. Rate constant coefficients to fit the equation $k = aT^b e^{-c/T}$ are reported in tabular form for the selected rate constant. The data are also graphed as log k vs T(K). In all, over twenty forward and reverse reactions are reviewed. Additionally, a large number of rate constant values for reactions which also effect flow field calculations are given.

TN485. **An evaluation of certain methods for the chemical analysis of styrene-butadiene rubber,** E. J. Parks and F. J. Linnig, Nat. Bur. Stand. (U.S.), Tech. Note 485, 27 pages (July 1969).

Key words: Bound styrene; carbon black; chemical analysis; latexes; oil; organic acid; serums; soap; stabilizer; styrene-butadiene rubber (SBR); washes.

The applicability of available methods for the analysis of unvulcanized styrene-butadiene rubber (SBR, formerly GR-S) for organic acid and soap is influenced by the type of coagulation (alum or salt-acid), the type of acid present (fatty acid, rosin acid, or mixed acids), and the presence of carbon black or oil. No single method is universally applicable for the analysis of organic acid and soap, but reasonably unbiased results can be attained by proper selection of the available procedures.

The complete-solution procedure for alum-coagulated (AC) SBR has given reasonably good results for organic acid in samples containing mixed acids, while the extraction procedure using aqueous isopropanol-toluene azeotrope (ITA) gives good results for AC samples containing fatty acid only.

The complete-solution procedure for SBR coagulated with salt and acid gives less biased results for organic acid and soap than the aqueous ITA extraction procedure, but the latter should be used for all SBR containing carbon black and for estimating oil in oil-rubber masterbatches. Both complete-solution procedures and the ITA extraction procedure can be adapted for the determination of stabilizer and bound styrene. The present ASTM extraction procedure using ethanol-toluene azeotrope is less satisfactory than the other procedures.

TN486. **Some problems in measuring tread wear of tires,** S. Spinner and F. W. Barton, Nat. Bur. Stand. (U.S.), Tech. Note 486, 27 pages (Aug. 1969).

Key words: Statistics; tires; tread wear testing.

Some problems in tread wear testing of tires are discussed and methods for dealing with these problems are presented. Experimental data are shown to illustrate these methods. Finally some recommendations are made, based primarily on this information, in order to achieve greater uniformity and a statistically valid approach to tread wear testing.

TN487. **Considerations in computing the useful frequency range of piezoelectric accelerometers,** N. Newman, Nat. Bur. Stand. (U.S.), Tech. Note 487, 20 pages (June 1969).

Key words: Electrical excitation; lowest resonant frequency; mechanical excitation; piezoelectric accelerometer; usable frequency range.

This paper analyzes two lumped-parameter models for computing the usable frequency range of piezoelectric accelerometers. The analyses indicate why application of an electrical excitation to the piezoelectric element of a mounted pickup does

not, in general, give the same result as application of a mechanical acceleration to the structure on which the pickup is mounted. Tabular results of the computations for various sets of parameters indicate those cases for which the electrical drive will give resonant frequency values within 2 percent of those for the pickup mounted on a vibrating structure. For these parameter sets, the electrical drive can be used as a reliable substitute.

TN488. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report January 1 to March 31, 1969,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 488, 44 pages (July 1969).

Key words: Carrier lifetime; die attachment; electrical properties; gamma detectors; germanium; gold-doped silicon; indium antimonide; metallization; methods of measurement; microelectronics; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; wire bonds.

This quarterly progress report, third of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconducting crystals; evaluation of wire bonds; and measurement of thermal properties of semiconductor devices. Other tasks involve: study of infrared measurement methods, deep-lying impurities in InSb, gold in silicon, and high field effects; establishment of a processing facility; evaluation of aluminum metallization and wafer die attachment; review of NASA measurement methods; and measurement of Hall effect in semiconductor crystals, second breakdown in transistors, and noise in microwave diodes. Related projects on silicon nuclear radiation detectors and specification of germanium are also described. Supplementary data concerning staff, committee activities, technical services, and publications are included as appendixes.

TN489. **Tables of response functions for silicon electron detectors,** M. J. Berger, S. M. Seltzer, S. E. Chappell, J. C. Humphreys, and J. W. Motz, Nat. Bur. Stand. (U.S.), Tech. Note 489, 62 pages (Aug. 1969).

Key words: Detector response function; electron back-scattering; electron energy absorption; electron transmission; silicon detectors.

Calculated response functions are presented which describe the pulse-height distributions produced by monoenergetic electrons incident on silicon detectors. It is assumed that the direction of incidence is perpendicular, and that the detectors are wide enough so that lateral leakage of energy is insignificant. The validity of the calculations has been confirmed experimentally for incident energies between 0.25 MeV and 1.0 MeV and detectors with thicknesses between 0.061 mm and 3.0 mm. The calculated response functions cover a wider range of conditions, including fourteen energies between 0.15 MeV and 5.0 MeV and ten detector thicknesses between 0.05 and 10.0 mm. At energies $\geq$ 1 MeV, response functions are given not only for bare detectors but also for an arrangement in which the detectors are shielded on the transmission side by another detector operating in anti-coincidence.

TN490. **Thermal gradient effects on thirteen flush mounted pressure transducers,** L. Horn, Nat. Bur. Stand. (U.S.), Tech. Note 490, 23 pages (Aug. 1969).

Key words: Pressure measurement errors; pressure transducers; response; temperature; thermal gradients; zero shift.

Thirteen different flush mounted pressure transducers of seven manufacturers were tested by creating a thermal gradient in them and recording the resultant zero shifts. Photographs of typical outputs are shown and the results are compared. A typical recording shows these general characteristics; (1) a very rapid change in output reaching a peak in a second or less, (2) a more gradual shift which reaches a peak in a time which may be a few seconds or more than a minute, and (3) a shift in reading which remains as long as the gradient is maintained. Examples were found in which each of these were positive or negative. The magnitude in a few cases was small, in many was a large fraction of its range, and in one case well in excess of the full scale range.

TN491. **Gravity measurements and the standards laboratory,** D. R. Tate, Nat. Bur. Stand. (U.S.), Tech. Note 491, 10 pages (Aug. 1969).

Key words: Absolute gravity; deadweight; force; geodetic pendulum; gravity; gravity meter; Potsdam system; standard gravity; units of force.

The local value of the acceleration due to gravity is a fundamental datum for almost every standards laboratory as it, together with accurate standards of mass, is the basis for the standards involving force. Instruments used as standards in this area include precise deadweight piston gages, deadweight calibrators for force transducers, liquid manometers, and earth field accelerometer calibrators. The practical realization of the absolute ampere and the absolute volt require a knowledge of force. This paper presents the basic information about how gravity measurements are made and outlines procedures for obtaining a suitable value for a given location. It also gives a brief discussion of the background and meaning of the term "standard gravity," and its application in the computation of forces in units of the pound-force and the kilogram-force.

TN492. **Component combination and frame-embedding in Chinese character grammars,** K. Rankin and J. L. Tan, Nat. Bur. Stand. (U.S.), Tech. Note 492, 36 pages (Feb. 1970).

Key words: Blocking; Chinese characters; component combination; frame-embedding; generative grammar; grammar; linguistics.

Chinese characters can be almost completely described from the point of view that each character is composed of a number of components and that each component is composed of a number of strokes. This note offers a grammatical treatment of component combination. It is concerned with the three most productive processes of component arrangement. This grammar differs from previous grammars in that the constraints on recursion have been minimized and great lexical economy has been achieved.

TN494. **ARPA-NBS program of research on high temperature materials,** A. D. Franklin, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 494, 28 pages (Sept. 1969).

Key words: Copper; creep; crystal growth; diffusion; enthalpy; evaporation; fracture; glass band structure; high temperature materials; mass transport; materials properties; mechanical relaxation; oxides; polymers; pyrolytic graphite; transition metal borides.

Brief reviews are given of work performed during the period of July 1 to December 31, 1968, on a number of projects concerning High Temperature Materials. Topics include the optical constants of titanium, diffusion of oxygen in oxides, growth of Al_2O_3 bicrystals by chemical vapor deposition, high temperature creep in copper, fracture in glass, the electronic structure of transition metal borides and related compounds, the enthalpy of pyrolytic graphite at high temperatures, the mechanism of volatilization of polymers, and the interaction between mechanical relaxation and annealing in polymers.

TN495. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly Report April 1 to June 30, 1969,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 495, 45 pages (Sept. 1969).

Key words: Carrier lifetime; die attachment; electrical properties; gamma detectors; germanium; gold-doped silicon; indium antimonide; metallization; methods of measurement; microelectronics; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; wire bonds.

This quarterly progress report, fourth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; evaluation of wire bonds; and measurement of thermal properties of semiconductor devices. Other tasks involve study of infrared measurement methods, deep-lying impurities in InSb, gold in silicon; and high field effects; establishment of a processing facility; evaluation of aluminum metallization and wafer die attachment; review of NASA measurement methods; and measurement of Hall effect in semiconductor crystals, second breakdown in transistors, and noise in microwave diodes. Related projects on silicon nuclear radiation detectors and specification of germanium are also described. Supplementary data concerning staff, committee activities, technical services, and publications are included as appendixes.

TN496. **Rare gas resonance lamps,** R. Gorden, Jr., R. E. Rebbert and P. Ausloos, Nat. Bur. Stand. (U.S.), Tech. Note 496, 55 pages (Oct. 1969).

Key words: Aluminum window; extinction coefficients; ionization quantum yield; photochemistry; photoionization; rare gases; resonance lamps; saturation ion current.

Rare gas resonance lamps having high spectral purity, high intensity, and long lifetimes have successfully been manufactured. The design and filling procedure for these lamps is described in detail. Particular operational characteristics of the xenon, krypton, argon, neon, and helium resonance lamps are also given. Windows suitable for use with each of these lamps are described, with particular emphasis given to the procedure for fabricating thin aluminum windows for use with neon and helium lamps. In addition, a method for determining extinction coefficients and ionization quantum yields based on the measurement of saturation ion currents is described.

TN497. **The effects of extended high-temperature storage on the performance characteristics of several strain gage pressure transducers,** R. Williams, Nat. Bur. Stand. (U.S.), Tech. Note 497, 22 pages (Oct. 1969).

Key words: Life testing; pressure transducer; sensitivity shift; strain gage; temperature cycling; temperature storage; zero shift.

This publication reports the results of a test program to evaluate the effects of high-temperature storage on the performance characteristics of several types of commercial strain gage pressure transducers. The results obtained indicate shifts in the zero pressure output and the sensitivity, some of which are permanent. The equipment used and the procedure followed are described.

TN498. **Bibliographies on fabric flammability. Part 1. Wearing apparel. Part 2. Fabrics used on beds. Part 3. Carpets and rugs,** S. H. Greenfeld, E. R. Warner, and H. W. Reinhart, Nat. Bur. Stand. (U.S.), Tech. Note 498, 36 pages (Feb. 1970).

Key words: Apparel; bedding; beds; blankets; carpets; clothing; fabrics; fibers; fire; flame; flammability; flammable; floor coverings; mattresses; pillow cases; pillows; rugs; sheets; springs; wearing apparel.

As recognition of the urgency of the flammable fabrics problem, the Flammable Fabrics Act of 1953 was amended in 1967 to include all items of wearing apparel and interior furnishings. In order to facilitate research and assist in the development of new standards and test methods in these areas, a series of bibliographies is being prepared by the NBS Office of Flammable Fabrics. The first three, on wearing apparel, bed fabrics and carpets and rugs, are included in this Technical Note.

TN498-1. **Bibliographies on fabric flammability. Part 4. Interior furnishings,** S. H. Greenfeld, E. R. Warner, and H. W. Reinhart, Nat. Bur. Stand. (U.S.), Tech. Note 498-1, 24 pages (June 1970).

Key words: Bedding; beds; blankets; carpets; curtains; drapes; fabrics; fibers; fire; flames; flammability; flammable; floor coverings; furnishings; furniture; interior furnishings; mattresses; pads; pillow cases; pillows; plastics; rugs; sheets; springs; upholstered furniture; upholstery.

As recognition of the urgency of the flammable fabrics problem, the Flammable Fabrics Act of 1953 was amended in 1967 to include all items of wearing apparel and interior furnishings. In order to facilitate research and assist in the development of new standards and test methods in these areas, a series of bibliographies is being prepared by the NBS Office of Flammable Fabrics in cooperation with the NBS Library. The first three bibliographies, on wearing apparel, fabrics used on beds, and carpets and rugs, were published in NBS Technical Note 498. This one is on interior furnishings. It includes all of the references on bed fabrics and carpets and rugs that appeared in TN498, along with those on upholstered furniture, draperies, curtains, and materials that are used in interior furnishings.

TN498-2. **Bibliographies on fabric flammability. Part 5. Testing and test methods,** S. H. Greenfeld, E. R. Warner, and H. W. Reinhart, Nat. Bur. Stand. (U.S.), Tech. Note 498-2, 39 pages (Sept. 1970).

Key words: Bibliography of test methods; burning; burning rate; combustion; fire; fire retardant; flame; flame spread; gases; ignition; smoke.

This, the fifth of a series of bibliographies on fabric flammability, relates to test methods and testing of fabrics and products made from fabrics and related materials. Unlike the earlier bibliographies, which cited references to flammability of categories of fabric products, this one cuts across product lines and covers all of the products within the ranges defined in the 1967 amendment to the Flammable Fabrics Act. Approximately 300 citations are included.

TN499. **Multiple scattering corrections for the associated-particle neutron time-of-flight technique,** A. C. B. Richardson, Nat. Bur. Stand. (U.S.), Tech. Note 499, 68 pages (Oct. 1969).

Key words: Associated-particle; cross-section; Monte Carlo; multiple scattering; neutron; time-of-flight.

The computer code, MAGGIE, for the calculation of multiple scattering and sample attenuation in neutron differential cross-section measurements, has been revised and corrected. The particular case of the scattering geometry required by the associated-particle time-of-flight is considered in detail.

TN500. **Edit-insertion programs for automatic typesetting of computer printout,** C. G. Messina, J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 500, 50 pages (Apr. 1970).

Key words: Applications, computers; computer-assisted typesetting; FORTRAN programs; KWIC index; phototypesetting; printing.

SETLST and KWIND are FORTRAN programs which accept a card deck or Fortran records on magnetic tape and insert the appropriate flags and shift symbols required by many of the "standard" typesetting programs associated with phototypesetting devices. The programs are specialized to the particular application; the typesetting device and associated programs; and to the desired typeface, by means of control cards and substitution tables supplied at run time. Examples are shown of applications to program listings, KWIC indexes, and normal computer output. When the input is in tabular form, the program permits more sophisticated operations including rearrangement, removal of trailing blanks, typeface changes between columns, etc. These programs can handle any records which can be read by a FORTRAN READ statement under an "A" format control.

TN501. **Radiochemical analysis: Mössbauer effect, nuclear chemistry, nuclear instrumentation, statistical analysis and radioisotope techniques, July 1968 to June 1969,** J. R. DeVoe, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 501, 149 pages (Feb. 1970).

Key words: Calculations; conversion electrons; counting statistics; cross sections; cryostats; electric field gradient tensor; electronics; gas analysis; heterogeneity; interferometric; internal magnetic field; iron; molybdenum; Mössbauer spectrometer; Mössbauer spectrometry; nickel-61; proportional detector; radiochemistry; radioisotope dilution; rutile; self-consistent crystal field; standard reference materials; structure analysis.

This is the sixth summary of progress of the Radiochemical Analysis Section of the Analytical Chemistry Division at the National Bureau of Standards.

The section's effort comprises five major areas: Mössbauer spectroscopy, nuclear chemistry, nuclear instrumentation, radioisotope tracer techniques and the application of statistics in nuclear and analytical chemistry.

Low temperature devices for Mössbauer spectroscopy are a subject of continuing interest, and this year's effort is centered around the design of variable temperature devices. A high temperature device is also described.

Preliminary data on the detection of conversion electrons show the potential for Mössbauer spectroscopy in the field of chemical bonding in surfaces.

Further exploration of the potential of Mössbauer spectroscopy for the measure of structural parameters of nickel compounds have been made.

Preliminary data are presented on the structure of iron doped rutile (TiO_2) which is of significance to the determination of mineral structures found on the moon. Theoretical predictions of Mössbauer spectra resulting from electric field gradients due to crystal field interactions are presented. Evaluation of the basic integrals using the self-consistent Hartree-Fock method is given for ions of the first row of transition elements.

Precautions to be taken in the analysis of gamma-ray spectra are presented when model errors exist and when a gain shift is detected.

A system for gas analysis which utilizes gas chromatography is described. Its application to nuclear cross section studies is also presented. A method for setting limits on sample heterogeneity using a specific analysis method provides a useful indicator for evaluation of the adequacy of standard reference materials.

An interesting presentation of detection and measurement in the femtogram region is given.

The complete circuitry for the optical interferometric Mössbauer spectrometer is presented in this report.

Quantitative analysis for molybdenum and iron using radioisotope dilution to a precision that rivals most other techniques is described.

TN502. **Activities of the NBS Spectrochemical Analysis Section, July 1968 through June 1969,** B. F. Scribner, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 502, 108 pages (Dec. 1969).

Key words: Analytical curve functions; color composite; computer programs; electron probe; gold analysis; isotope dilution method; laser probe; metal foil analysis; microanalysis; non-diffractive x-ray spectra; optical spectrometry; platinum analysis; preconcentration techniques; spark source mass spectrometry; spectrochemical analysis; spectrograph; standard reference materials; steel analysis; target current scanning; trace analysis; x-ray absorptiometry; x-ray fluorescence analysis; x-ray scans.

Spectrochemical research activities, improvements in equipment, and applications are summarized. In optical emission spectrometry micro methods were investigated and computer programs were completed for fitting analytical curves. In electron probe microanalysis studies of corrections for quantitative analysis and new gains in non-diffractive analysis and target current scanning were made. X-ray absorptiometry was applied to the analysis of thin metal foils and computer programs were improved for correction of x-ray fluorescence analysis. Chemical pre-concentration of impurities combined with isotope dilution spark source mass spectrometry found increased application in accurate trace analysis. Resolution of the mass spectrometer was improved and the behavior of ion samples was studied. Extensive involvement in the standard reference materials program contributed to certification of several SRM's including high purity Zn and Au, two sets of wires, Au-Ag and Au-Cu, for microprobe analysis, and electronic and magnetic alloys. Listings are given of 21 publications and 29 talks by members of the Section during the year.

TN503. **Electrochemical Analysis Section: summary of activities July 1968 to June 1969,** R. G. Bates, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 503, 99 pages (Aug. 1969).

Key words: Acidity; analysis; conductivity; electrochemical analysis; electrochemistry of solutions; ionic activity; ion-selective electrodes; pD measurements; pH measurements; medium effects; solvent effects; standard reference materials.

This survey of the activities of the Electrochemical Analysis Section, Analytical Chemistry Division, covers the period July 1968 to June 1969. An attempt is made to summarize a year's progress on the technical projects of the Section, to indicate the composition and capabilities of the unit as a whole, and to stress the Section's role in the mission of the Institute. Brief summaries of several lines of work under way are given. The concept of a broad program on acidity measurements is outlined, and new efforts to provide assistance in clinical acid-base measurements are summarized. Progress toward reference standards for the calibration of ion-selective electrodes is reported. Equilibrium data for phosphoric acid in heavy water, for piperazinium ion in 50 wt percent methanol-water, and for hydrochloric acid in a solvent composed of 2-methoxyethanol (80 wt percent) and water (20 wt percent) have been obtained. Considerable effort has been devoted to the development of new standard reference materials, including standards for conductivity measurements. Lists of publications, talks, and committee assignments of staff members are given.

504. **Analytical Coordination Chemistry Section: summary of activities July 1968 to June 1969,** O. Menis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 504, 120 pages (Oct. 1969).

Key words: Certification of standard reference materials; differential thermal analysis; flame emission and atomic absorption; gases in metals; spectrofluorimetry; spectrophotometry.

Research developments are described in flame emission and omic absorption spectrometry, spectrophotometry, spectofluorometry, differential thermal analysis and the analysis and rtification of Standard Reference Materials. The application of wavelength scanning and second derivative measurements of ectral line intensities serve to overcome broad-band and conuum interferences of matrices in flame emission analysis. It so provides for the analysis of samples as small as 50 μl. In omic absorption studies of arsenic, basic corrections for specal interferences are given.

New spectrophotometric methods have been developed for e analysis of multicomponent systems. These include the multaneous determinations of cobalt, nickel and copper with ,3-quinoxalinedithiol and of vanadium and iron with β-isopropyltropolone. The extraction of ternary ion association comlexes initially containing non-colored or non-fluorescent oranic cations, followed by displacement of these groups by ighly colored or highly fluorescent dye cations directly in the rganic phase, has provided a means of simultaneously improvng sensitivity and selectivity in absorption and fluorescence pectrophotometry. The determinations of gold and uranium are escribed to illustrate the approach. Spectrofluorometric studies f the determination of rare earth elements in synthetic borate lass are also presented.

Instrument modifications and temperature measurement echniques now provide a tenfold increase in the precision of neasurements of phase transition temperatures of quartz and otassium nitrate on differential thermal analysis standards.

Procedures, analytical data and background information are resented for Standard Reference Materials of steels, cast and nodular irons, ferrosilicon, high-purity materials, neutron flux monitor wire, organo-metallic compounds, glasses, and clays. These descriptions include atomic absorption methods for copper in steel, magnesium in nodular iron, impurities in calcium carbonate, high precision spectrophotometric methods for cobalt in aluminum wire, molybdenum and tungsten in microprobe standard, traces of iron and copper in high purity gold and methods for the determination of silica and aluminum in clays.

TN505. **Microchemical Analysis Section: summary of activities July 1968 to June 1969,** J. K. Taylor, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 505. 140 pages (Oct. 1969).

Key words: Chemical analysis; coulometric analysis; gas analysis; ionic equilibria; ion-selective electrodes; microchemical analysis; microscopic analysis; polarographic analysis.

This report describes the research activities and scientific programs of the Microchemical Analysis Section of the Analytical Chemistry Division of the NBS Institute for Materials Research during the period July 1968 to June 1969. General activities are reported in the areas of gas analysis, polarography, potentiometry, coulometry, chemical microscopy, and classical microchemical analysis. Research activities described in some detail include: gravimetric preparation of gas analysis standards; polarographic determination of trace elements in glass; fabrication and performance of a microfluorine electrode; elucidation of the boric acid-borate-mannitol system; investigation of the relation between the equilibrium point and inflection point in acidimetric titrimetry; coulometric determination of trace quantities of chromium; and determination of trace elements by nuclear track measurements. A number of procedures which have been developed for the analysis of a variety of materials, utilizing the techniques mentioned above, are also included.

TN506. **Analytical Mass Spectrometry Section: Summary of activities, July 1968 to June 1969,** W. R. Shields, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 506, 55 pages (May 1970).

Key words: Instrumentation; isotope dilution; isotopic analyses; mass spectrometry; procedures.

This report describes the advances in instrumentation and the research activities of the Analytical Mass Spectrometry Section during the period July 1968 to June 1969.

Chemical and mass spectrometric procedures are described for the determinations of the absolute isotopic abundance ratios of natural rubidium, boron in a natural boric acid and a ^{10}B enriched boric acid, and of uranium in six SRMs.

Procedures are also described for the determination of trace amounts of copper and lead in steel, and silver, copper, boron and uranium in glass by isotope dilution mass spectrometry.

TN507. **Organic Chemistry Section: summary of activities July 1968 to June 1969,** R. Schaffer, Editor, Nat. Bur. Stand. (U.S.). Tech. Note 507, 145 pages (Oct. 1969).

Key words: Bilirubin analysis; calcium carbonate SRM; conformations by NMR; corn syrup analysis; creatinine SRM; D-glucose (clinical SRM); organic trace analysis; SRM's for clinical analysis; urea SRM; uric acid SRM; 6-amino-6-dexoy-D-glucose-6-^{15}N.

This report by the Organic Chemistry Section of the National Bureau of Standards' Institute for Materials Research summarizes a year's scientific activities; consequently, it covers both work that was completed and some that is still in progress. It reports new work on carbohydrates and polyhydroxy cyclic compounds, and analytical studies leading to (*a*) the development of Standard Reference Materials for clinical chemistry, (*b*) characterizations of trace quantities of organic compounds, and (*c*) understanding the properties of starch hydrolyzates.

In research on carbohydrates, rules on selective hydrolysis of certain ketose acetals, a new crystalline derivative of potential use as an SRM for "D-ribulose," conformations of compounds having *m*- and *p*-dioxane rings, and a synthesis of ^{15}N-labeled "6-amino-D-glucose" are described.

Work on polyhydroxy cyclic compounds has shown that (*a*) phenylosotriazoles of diketoinositols favor a half-chair conformation, (*b*) mercuric acetate is a superior reagent for preparing these osotriazoles, (*c*) acetylation in 100 percent phosphoric acid gives an octaacetoxydibenzo-*p*-dioxin from 4,6/5-trihydroxy-1,2,3-cyclohexanetrione, whereas acetylation in pyridine had been shown to produce aromatized products, (*s*) periodic acid oxidizes phenylhydrazino to phenylazo derivatives, and (*e*) phenylformazans and bis(phenylhydrazones) form highly colored salts with strong acids.

In examining a variety of commercial samples of bilirubin in the course of developing an SRM for clinical analysis, data have been obtained by several techniques, including thin-layer chromatography and thermogravimetric analysis. Visible spectrophotometry gave data on the stability of bilirubin dissolved in a variety of solvents. Measurements were made by the diazo assay. A materials-balance analysis of bilirubin samples was developed.

Various chromatographic procedures, used to examine a

supply of D-glucose as an SRM, are described. Measurements of optical rotation in water and methyl sulfoxide, and other analytical data, are also given. Some of the work pertaining to the creatinine, urea, calcium carbonate, uric acid, and cholesterol SRM's that have been issued are presented.

Finally, work on the detection and identification of trace quantities of a few organic compounds is summarized, and the description and statistical evaluations of several methods developed for the characterization of the properties of corn starch hydrolyzates are summarized.

TN508. **Activation Analysis Section: Summary of activities, July 1968 to June 1969,** Nat. Bur. Stand. (U.S.), Tech. Note 508, 147 pages (July 1970).

Key words: Activation analysis; ancient stained glass; carbon; Cockcroft-Walton neutron generator; coincidence spectrometer; group separations; homogeneity testing; hydrated antimony pentoxide; NBS LINAC; NBS Reactor; neutron flux measurements; photofission; standard reference materials; tetracycline.

The design and installation of irradiation facilities for the NBS Reactor are described, and studies of the operating characteristics of the pneumatic tube facilities are reported. Procedures have been developed for determining molybdenum in the presence of large amounts of tungsten and for the determination of uranium. Methods for determining a contamination-free blank for application to liquid samples, and a study of the application of neutron activation to the analysis of stained glass were begun. The application of thermal and fast neutron activation analysis and photonuclear activation analysis to the NBS Standard Reference Material program is discussed. Studies have been made of the application of 3-MeV neutrons from a Cockcroft-Walton neutron generator to activation analysis and of the 3-MeV neutron buildup in 14-MeV neutron activation analysis. The determination of carbon by photonuclear activation has been extended to several metals other than sodium; thallium has been determined in glass samples by photon bombardment, and the photofission of thallium, bismuth and lead has been studied. Hydrated antimony pentoxide has been used to separate sodium from glass samples for subsequent instrumental activation analysis, and the antibiotic, tetracycline, has been applied to radiochemical separations.

TN509. **Separation and Purification Section: Summary of activities, July 1968 to June 1969,** D. H. Freeman and W. L. Zielinski, Jr., Editors, Nat. Bur. Stand. (U.S.), Tech. Note 509, 73 pages (Feb. 1970).

Key words: Gas chromatography; infrared analysis; ion exchange; liquid chromatography; purification; separation; styrene/divinylbenzene; ultrapure reagents.

This is the annual progress report on the Separation and Purification Section activities. The major task of developing a certified ion exchange microstandard as a Standard Reference Material is presented in terms of the preparative and characterizational work involved. Fundamental studies of ion exchange substrates includes the application of quantitative analytical infrared spectrophotometry to measure crosslinking in the copolymer network, and to determine the degree of sulfonation. Optical microscopy is applied to the study of swelling kinetics for single copolymer particles. Analytical gas chromatography is applied to the isomers of divinylbenzene. The recently acquired quadrupole mass spectrometer is described. Liquid chromatography at high pressures and with high resolution has been begun recently. The activities of a project dealing exclusively with ultrapure reagents is described including the problems of contamination free storage.

TN510. **Use of a time-shared computer system to control a Hall e fect experiment,** W. M. Bullis, W. R. Thurber, T. N. Pyke, Jr F. H. Ulmer, and A. L. Koenig, Nat. Bur. Stand. (U.S.), Tecl Note 510, 46 pages (Oct. 1969).

Key words: Computer-controlled experiment; data acquis tion system; digital scanner; experiment-computer inte face; Hall effect; system control module; teletypewriter ir terface; time-shared computer.

An experimental time-shared computer system has been use to control and collect data from a Hall effect experiment. In add tion to selection of the voltage sequence and control of specime current and magnetic flux directions, the computer exerts pos tive control over the specimen temperature in accordance wit a series of thermocouple voltages entered by the operator at th beginning of the run. The interface circuitry is constructed fro four general purpose modules and a single special purpose uni Details of the interface system and the programs used to contr the experiment and to perform intermediate calculations a given. It was found that the time-shared system was well-suite to control an experiment of this type. The demands on the con puter were essentially similar to those required by a human us interacting in a conversational mode. Substantial savings in tim over manual data collection and reduction were realized; a ten perature run with 38 to 40 data points between 10 and 320 could be completed in less than 4 hours.

TN511. **Measurement methods for the semiconductor devi industry—a summary of NBS activity,** W. M. Bullis. Na Bur. Stand. (U.S.). Tech. Note 511. 24 pages (Decemb 1969).

Key words: Carrier lifetime; germanium; lithium-drift gamma-ray detectors; resistivity; resistivity inhom geneities; second breakdown; silicon.

Work at NBS which led to the development of a broad pr gram on Methods of Measurement for Semiconductor Material Process Control, and Devices is described. Initial work w concentrated on resistivity of silicon wafers and second breal down in transistors. In the first case, the basis for a significa improvement in the method for measuring resistivity of silic wafers was established. and in the second. concepts were d veloped which formed the basis of a new type of specificatic for operating conditions free from second breakdown. Wo was extended to include other projects, including studies germanium for gamma-ray detectors. carrier lifetime. a resistivity inhomogeneities which are still in progress. Form tion of the broad program in response to increased interest improved measurement methods is described.

TN512. **The accuracy of air tower pressure gages in suburb Washington, D.C.,** B. G. Simson and R. W. Radlinski, Na Bur. Stand. (U.S.), Tech. Note 512, 10 pages (Dec. 1969).

Key words: Air towers; tire pressure.

A survey of 50 air tower pressure gages in service stations suburban Washington, D.C., was performed. Results show that a motorist using these towers has only a 20 percent chan of inflating his tires within ±1 psi of the pressure indicated by t tower's gage. It is shown that a calibration of the tower gag would reduce the standard deviation of the obtained pressure 0.5 psi.

TN513. **Hydrogen fluoride and the thermochemistry of fluorin** G. T. Armstrong, Nat. Bur. Stand. (U.S.), Tech. Note 51 21 pages (Feb. 1970).

Key words: Fluorides; fluorine dissociation energy; fl orine thermochemistry; heats of formation; hydrofluo acid; hydrogen fluoride.

The thermochemistry of hydrogen fluoride is reviewed. The principal emphasis is on the experimental basis of the heats of formation of HF(g) and of HF(aq). Data from flame calorimetry in which HF(g) and HF(aq) are formed, evidence from processes involving other fluorine compounds, and some evidence from spectroscopic and photodissociation studies are brought together.

TN514. **ARPA-NBS program of research on high temperature materials and laser materials, January 1-June 30, 1969,** A. D. Franklin and H. S. Bennett, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 514, 98 pages (Jan. 1970).

Key words: Band structure; chemical analysis; copper; creep; crystal defects; crystal growth; diffusion; evaporation; fracture; glass; high temperature materials; inhomogeneities in glass; laser damage; laser glass; lasers; mass transport; materials properties; mechanical relaxation; metal borides; optical properties; opto-elastic properties; oxides; polymers; ruby; titanium; transition.

Brief reviews are given of work performed during the period January 1 to June 30, 1969, on a number of projects concerned with High Temperature Materials and with Laser Materials. Under the High Temperature Materials heading, topics include diffusion of oxygen in oxides, growth of Al_2O_3 crystals by chemical vapor deposition, the electronic structure of transition metal borides and related compounds, the optical constants of titanium, high temperature creep in copper, fracture in glass, the mechanism of volatilization of polymers and long-chain compounds, and the interaction between mechanical relaxation and annealing in polymers. Work on Laser Materials includes measurement of bulk optical and elastic properties of laser materials, a study of the "orange" degradation of ruby, measurements of sub-crystal misalignment in ruby, damage in glass induced by high-energy laser pulses, chemical analyses for ruby and Nd-doped laser glasses, and preliminary studies on detection of submicroscopic inhomogeneities in glass.

TN515. **Use of an on-line computer in neutron time-of-flight measurements,** H. T. Heaton, II, Nat. Bur. Stand (U.S.), Tech. Note 515, 31 pages (Jan. 1970).

Key words: Data handling system; interruptable computer; neutron time-of-flight; neutron total cross section; on-line computer; Program Selector Board.

This paper describes the on-line data handling system at the NBS Electron Linear Accelerator facility as it is used for measuring neutron total cross sections by time-of-flight techniques.

TN516. **A selective roll-to-roll printer for producing duplicate microfilm copies, "Selectaframe" Printer,** J. N. Strohlein and T. C. Bagg, Nat. Bur. Stand. (U.S.), Tech. Note 516, 9 pages (Feb. 1970).

Key words: Information retrieval device; microcopier; microfilm duplicator; reader-printer; selective copier.

The "Selectaframe" printer, a convenient device for copying onto roll film selected frames from other rolls of film for subsequent automatic enlargement printing is described in detail.

TN517. **Accelerometer calibration with the earth's field dynamic calibrator,** J. S. Hilten, Nat. Bur. Stand. (U.S.). Tech. Note 517, 30 pages (Mar. 1970).

Key words: Accelerometer; air bearings; calibrator; accelerometer; dynamic; earth's field; interAgency transducer project; low frequency; rotational frequency response; transducer.

This paper describes a simple device for the precise dynamic calibration of certain accelerometers at low frequencies. Calibration of an accelerometer is achieved by rotating the instrument in the earth's gravitational field at a number of constant rotational speeds.

TN518. **Tabulation of data on semiconductor amplifiers and oscillators at microwave frequencies,** C. P. Marsden and R. Y. Cowan, Nat. Bur. Stand. (U.S.), Tech. Note 518, 66 pages (Feb. 1970)

Key words: Amplifiers; basic characteristics; microwave; oscillators; solid-state.

This tabulation includes some of the basic characteristics of semiconductor microwave devices, specifically amplifiers and oscillators of foreign and domestic origin.

TN519. **Forensic Science: A bibliography of activation analysis papers,** G. J. Lutz, Editor, Nat. Bur. Stand. (U.S), Tech. Note 519, 47 pages (Mar. 1970).

Key words: Activation analysis in forensic science; forensic science.

References to Activation Analysis in Forensic Science are indexed into 32 categories for precise literature searching by the Forensic Scientist. An Author index is included.

TN520. **Methods of measurement for semiconductor materials, process control, and devices, Quarterly Report, July 1 to September 30, 1969,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 520, 69 pages (Mar. 1970).

Key words: Alpha detectors; aluminum wire; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma detectors; germanium; gold-doped silicon; indium antimonide; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic microphone; wire bonds.

This quarterly progress report, fifth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; evaluation of wire bonds; and measurement of thermal properties of semiconductor devices. Other tasks involve study of infrared measurement methods, deep-lying impurities in InSb, and gold in silicon; establishment of a processing facility; evaluation of aluminum metallization and wafer die attachment; review of NASA measurement methods; and measurement of Hall effect in semiconductor crystals, second breakdown in transistors, and properties of microwave devices. Related projects on silicon nuclear radiation detectors and specification of germanium are also described. Supplementary data concerning staff, committee activities, technical services, and publications are included as appendixes. Laboratory procedures for use and calibration of a capacitor microphone to measure vibration amplitude of the tool tip of an ultrasonic wire bonder are also described in a separate appendix.

TN521, Superseded by Technical Note 719.

TN522. **Beam handling techniques for electron linear accelerators,** S. Penner, Nat. Bur. Stand. (U.S.), Tech. Note 522, 21 pages (Apr. 1970).

Key words: Beam handling; beam optics; beam transport; electron linear accelerator; instrumentation for electron beams; linac.

The design of beam transport systems for electron linear accelerators intended for nuclear physics research is discussed. The subjects covered include beam optics, diagnostics and control of electron beams, and problems of handling high power beams.

TN523. **Experimental techniques for electron scattering investigations,** S. Penner, Nat. Bur. Stand. (U.S.), Tech. Note 523, 46 pages (Apr. 1970).

Key words: Background; current monitoring; detector ladders; electron scattering; experimental techniques; lineshape fitting; on-line computer systems; radiative tails; resolution; spectrometer design.

Modern experimental techniques for high energy electron scattering are discussed. Subjects included are: high resolution spectrometer design, the energy loss spectrometer concept, detector ladder systems, beam current monitoring techniques, suppression and measurement of background, the use of on-line computer systems, theoretical considerations and the analysis of data, and 180° scattering.

TN524. **Determination of the light elements in metals: A bibliography of activation analysis papers,** G. J. Lutz, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 524, 70 pages (May 1970).

Key words: Boron; carbon; light elements; metals; nitrogen; oxygen; phosphorous; silicon; sulfur.

References to the Determination of the Light Elements in Metals using Activation Analysis are indexed according to the elements boron, carbon, nitrogen, oxygen, phosphorous, silicon and sulfur. The indexes are arranged by Element Determined and subdivided according to Matrices and Nuclear Reactions involved. An Author Index is included.

TN525. **The flammable fabrics program 1968-1969. U.S. Department of Commerce report of activities under the Flammable Fabrics Act 1968-1969,** Nat. Bur. Stand. (U.S.), Tech. Note 525, 84 pages (Apr. 1970).

Key words: Flammable fabrics; Flammable Fabrics Act of 1953; flammable fabrics program 1968-1969; reducing flammability; research authorized.

The 90th Congress amended the Flammable Fabrics Act of 1953 to authorize the Secretary of Commerce to conduct research on the flammability of fabrics, related materials, and products; to conduct studies on the feasibility of reducing their flammability; to develop test methods and devices; and to offer training in the use of these devices. In this publication, the National Bureau of Standards, to which responsibility for these activities was delegated, reports to Congress of the work done under this program from October 1968, when funds first were made available, to the end of 1969. Future reports will be issued annually.

The new action by Congress gives recognition to the fact that although many thousands of persons have been injured or killed as a result of the burning of flammable fabrics, adequate details have not been available on the causes of the accidents, the frequency of ignition of different kinds of garments and interior furnishings, the nature, extent, and severity of injury, and the nature of the hazards to which the public is exposed from burning fabrics. Much of the emphasis in the research summed up in this report has been on identifying these hazards and obtaining quantitative information about them. Some of the studies are being made by outside organizations, and these are reported as well as the in-house research at NBS.

TN526, Superseded by Technical Note 715.

TN527. **Methods of measurement for semiconductor materials, process control, and devices, Quarterly Report, October 1 to December 31, 1969,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 527, 60 pages (May 1970).

Key words: Alpha detectors; aluminum wire; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma detectors; germanium; gold-doped silicon; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, sixth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; evaluation of wire bonds, metallization adhesion, and die attachment; and measurement of thermal properties of semiconductor devices and electrical properties of microwave devices. Work on related projects on silicon nuclear radiation detectors and specification of germanium for gamma-ray detectors is also described. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN528. **Tire use survey. The physical condition, use, and performance of passenger car tires in the United States of America,** J. L. Harvey and F. C. Brenner, Nat. Bur. Stand. (U.S.), Tech. Note 528, 59 pages (May 1970).

Key words: Accident; review; survey; tire disablement; tire inflation; tire loading; tire pressure gages; tire use; tread wear.

This review summarizes the results of two surveys of the physical condition and use of passenger car tires in the continental U.S.A., conducted under contract for the Office of Vehicle Systems Research (OVSR) of the National Bureau of Standards (NBS) during the period June 1967 through May 1968.

Data and results are compared with those in four related reports recently published by the Traffic Institute of Northwestern University. The latter reports cover studies on the use, condition, and performance of passenger car tires on the Illinois Tollway during the period September 1966 through August 1967. Pertinent information from various other sources is also included.

Based on the compiled evidence, some conclusions are drawn concerning the physical condition, use, and abuse of passenger car tires in service during these years, particularly with regard to tread depth, inflation pressures, and degree of overloading. The various estimates of tire disablement rates are compared, and contributions of tires to motor vehicle accidents explored.

The authors make several recommendations directed toward upgrading the level of quality of passenger car tires in service and reducing their abuse, with the hope and expectation that service performance will be improved, and contributions of tires to highway accidents reduced.

TN529. **Determination of oxygen concentration in silicon and germanium by infrared absorption,** W. R. Thurber, Nat. Bur. Stand. (U.S.), Tech. Note 529, 21 pages (May 1970).

Key words: Absorption coefficient; infrared absorption; germanium; methods of measurement; oxygen in germanium; oxygen in silicon; silicon.

Infrared absorption measurements were made at room temperature, 80 K, and 20 K to determine the absorption coefficien

oxygen in silicon and germanium single crystals. A study was one to compare the results of four experimental methods, which volved both absolute and difference procedures. Sources of ror were identified, including that due to calculating the ab-rption coefficient with an approximate equation which eglects multiple internal reflections. Measurements made on e same specimen at several temperatures give additional data n the relation of oxygen concentration to absorption coefficient low temperatures.

N530. **Systems analysis of inland consolidation centers for marine cargo,** R. H. Jordan, M. C. Stark, C. O. Bunn, J. L. Donaldson, W. J. Obright, H. R. Millie, J. Gilsinn, A. J. Goldman, W. A. Horn, Nat. Bur. Stand. (U.S.), Tech. Note 530, 162 pages (Nov. 1970).

Key words: Containerization; maritime, cargo; mathematical models; optimal locations; systems analysis; transportation.

This Technical Note documents a study, carried out for the U.S. Maritime Administration and completed by interested Bureau staff, to develop analytical techniques to optimize the locations and characteristics of inland consolidation centers for marine cargo. Such centers would consolidate less-than-container lots of cargo into "full" container loads for export, and would unload and distribute containerized import cargo.

After discussing the nature and scope of the study problem and outlining the functions and operations of the centers, the paper reports the fact-finding phase of the analysis. Successive chapters present and analyze data on: initial and operating costs for centers, current demand for their services as derived from a recent survey by the Delaware River Port Authority of its hinterland, and relevant (ground) transportation rates for containerized and uncontainerized material.

Reported next is the development of a mathematical model for estimating good locations and sizes for the consolidation centers. The selective implementation of this model as a computer program is described in sufficient detail to guide prospective users. A final chapter describes the illustrative application of this program to the data at hand, with results quite encouraging for the "inland center" concept.

TN531. **ARPA-NBS program of research on high temperature materials and laser materials, Reporting Period 1 July to 31 Dec., 1969,** High Temperature Materials Reports edited by A. D. Franklin, Laser Materials Reports edited by H. S. Bennett, Nat. Bur. Stand. (U.S.), Tech. Note 531, 75 pages (June 1970).

Key words: Band structure; chemical analysis; copper; creep; crystal defects; crystal growth; diffusion; evaporation; glass; high temperature materials; inhomogeneities in glass; laser damage; laser glass; lasers; mass transport; materials properties; metal properties; optical properties; opto-elastic properties; oxides; polymers; ruby; titanium; transition.

Brief reviews are given of work performed during the period July 1 to December 31, 1969, on a number of projects concerned with High Temperature Materials and with Laser Materials. Under the High Temperature Materials heading, topics include diffusion of oxygen in oxides, growth of Al_2O_3 crystals by chemical vapor deposition, the electronic structure of transition metal borides and related compounds, the optical constants of titanium, high temperature creep in copper, and the mechanism of volatilization of polymers and long-chain compounds. Work on Laser Materials includes measurement of bulk optical and elastic properties of laser materials, a study of the "orange" degradation of ruby, measurements of sub-crystal misalignment in ruby, damage in glass induced by high-energy laser pulses, chemical analyses for ruby and Nd-doped laser glasses, and preliminary studies on detection of submicroscopic inhomogeneities in glass.

TN532. **Pollution analysis: A bibliography of the literature of activation analysis,** G. J. Lutz, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 532, 32 pages (June 1970).

Key words: Activation analysis; element determined; matrix analyzed; pollution analysis; technique used.

The literature of the use of activation analysis of pollution samples is reindexed in detail with respect to Element Determined, Matrix Analyzed and Technique Used for precise literature searching. An author index is included.

TN533. **14-MeV neutron generators in activation analysis: A bibliography,** G. J. Lutz, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 533, 91 pages (June 1970).

Key words: Activation analysis; element determined; matrix analyzed; technique used; 14-MeV neutron generators.

The literature of 14-MeV neutron generators in activation analysis is reindexed in detail with respect to Element Determined, Matrix Analyzed and Technique Used for precise literature searching. An author index is included.

TN534. **Oceanography: A bibliography of selected activation analysis literature,** G. J. Lutz, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 534, 36 pages (June 1970).

Key words: Activation analysis; element determined; matrix analyzed; oceanography; technique used.

The literature of oceanography in activation analysis is reindexed in detail with respect to Element Determined, Matrix Analyzed and Technique Used for precise literature searching. An author index is included.

TN535. **Compilation and use of criminal court data in relation to pre-trial release of defendants. Pilot study,** J. W. Locke, R. Penn, J. Rick, E. Bunten, and G. Hare, Nat. Bur. Stand. (U.S.), Tech. Note 535, 242 pages (Aug. 1970).

Key words: Bail; criminal court data; criminal justice system; dangerousness; data collection problems and procedures; District of Columbia; judicial system; prediction research; pre-trial release; preventive detention; recidivism; statistical relationships.

A number of Pre-Trial Release studies which have been conducted during the past several years show that various measures of criminal activity while on release vary from 7.9 percent (reindictment for those indicted on felony charges) to 70 percent (rearrest of those originally arrested on a robbery charge). Little actual sentence data were available for or presented in these studies, and no personal data on the defendants or facts about the crimes themselves were shown. This document describes a pilot study of a very thorough analysis of criminal cases, including both felonies and misdemeanors, in a four week sample of cases in the District of Columbia during the first half of 1968. The method of data collection is described, together with attendant problems. Possible techniques of data presentation are shown along with criteria and relevant factors pertinent in quantifying "dangerousness." The potential for developing "dangerousness" prediction methods as a basis for decisions on pre-trial release is analyzed, with the conclusion that much work needs to be done before an effective prediction device based on a "dangerousness" criterion can be formulated.

Summary data for 712 defendants in a sample of 4 weeks taken from the first half of 1968 are presented. Comparisons are made

to show the re-arrest rates for defendants initially charged with particular classes of crime. Personal characteristics are examined to determine if any are significant predictors of recidivism. A recidivism index is formulated to give the rate of re-arrest per man-day of exposure. Robbery cases are examined in more detail.

TN536. **Disclosures on: Viscous damped wind vane; nonskid road or runway; regrooved pneumatic tire with removal inserts; device for radially positioning a rotating wheel; method for fabricating precision waveguide sections; distortion-cancelling loudspeaker system; cryogenic fluid density measurement system; and controlled-atmosphere weathering device,** D. Robbins and A. J. Englert, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 536, 25 pages (June 1970).

Key words: Accelerated weathering test; acoustic distortion, cancelling; averaging wind vane; cryogen density, measuring; distortion-cancelling loudspeakers; grooved runway; hydroplaning skidding, prevention of; loudspeaker system; photoactivated weathering test; radial positioning, wheel on shaft; rubber-surfaced road; slush cryogen density; tire groove insert; tire regrooving; waveguide, precision fabrication; waveguide, adjustable width; weathering test; wheel-shaft angle, shifting during rotation; wind vane, damped.

This Note describes and illustrates eight developments that are believed to embody interesting and unusual solutions to current problems in their fields.

TN537. **Nomographs for use in the fabrication and testing of Ge(Li) detectors,** A. H. Sher, Nat. Bur. Stand. (U.S.), Tech. Note 537, 18 pages (Aug. 1970).

Key words: Capacitance; detector resolution; effective Fano factor; Ge(Li) detector; lithium-ion drift; nomograph; oxygen concentration.

Six nomographs which can facilitate the fabrication and testing of lithium-drifted germanium gamma-ray detectors [Ge(Li) detectors] have been constructed which relate the following parameters: (1) time, temperature, applied bias, and drifted depth; (2) lithium mobility, crystal resistivity, and oxygen concentration; (3) area, capacitance, and drifted depth for planar Ge(Li) detectors; (4) drifted depth, length, and capacitance for coaxial Ge(Li) detectors; (5) total spectral resolution, system noise, and detector resolution; and, (6) detector resolution, gamma-ray energy, and effective Fano factor. The use of these nomographs is described and illustrative examples are given.

TN538. **Automated fingerprint identification,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 538, 33 pages (Aug. 1970).

Key words: Computerized-fingerprint-identification; fingerprint; pattern recognition.

A procedure is described for determining whether two fingerprint impressions were made by the same finger. The procedure uses the x and y coordinates and the individaul directions of the minutiae (ridge endings and bifurcations). The identity of two impressions is established by computing the density of clusters of points in $\Delta x - \Delta y$ space where Δx and Δy are the differences in coordinates that are found in going from one of the fingerprint impressions to the other. Experimental results using machine-read minutiae data are given along with results from a previously reported procedure that utilized constellations of minutiae in its matching process.

TN539. **Improvements in oscilloscopic measurements in high-speed experiments,** A. Cezairliyan, M. S. Morse, and H. A. Berman, Nat. Bur. Stand. (U.S.), Tech. Note 539, 20 pages (Oct. 1970).

Key words: High-speed measurements; high-speed recording; oscilloscopes.

Two refinements in oscilloscopic recording have been made which improve considerably the recording of isolated events in heavy current discharge studies, where substantially rectangular pulses are employed. The accuracy of the method employed has been verified experimentally to be in the region of 0.01 to 0.1 percent. The first refinement is a unit for the differential suppression of the incoming signal by an adjustable amount, and the second refinement is a system by which time markers are sent to several oscilloscopes at adjustable time intervals simultaneously with the actual incoming signal.

TN541. **Preliminary study on the characteristics and design parameters for a Mössbauer resonant detector,** J. J. Spijkerman, J. C. Travis, P. A. Pella, and J. R. DeVoe, Nat. Bur. Stand. (U.S.), Tech. Note 541, 65 pages (Jan. 1971).

Key words: Conversion electrons; iron; Mössbauer spectroscopy; resonant detector.

Progress in the design and fabrication of a resonant detector for Mössbauer spectroscopy is described. This report begins with a review of all of the methods of detection for this spectroscopy and describes the expected advantages of the resonant detector. If one uses conversion electron detection, considerable enhancement in signal to noise ratio and decrease in linewidth may be realized. Efforts to produce an iron bearing resonant material are described.

TN542. **Activities of the NBS spectrochemical analysis section July 1969 to June 1970,** B. F. Scribner, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 542, 114 pages (Nov. 1970).

Key words: Analysis; computer program; electron probe microanalysis; optical spectrometry; pre-concentration techniques; spectrochemical analysis; standard reference materials; x-ray fluorescence analysis.

Spectrochemical research activities, improvements in equipment, and applications, especially to the certification of NBS Standard Reference Materials, are summarized. In electron probe microanalysis, a comprehensive computer correction program for accurate analysis of materials relative to single elements or simple compounds was developed, an improved lithium-doped silicon detector was found to provide increased resolution, and improvements in microprobe instrumentation produced a high level of stability. Studies of procedures for correction of x-ray fluorescence measurements were made, instrumental changes resulted in marked improvement in performance reliability, and new applications were made. In optical emission spectrometry, studies were made of beryllium determination in an air pollution investigation and trace analyses were made of organic materials to parts per billion (10^{-9}) limits. Methods of pre-concentration of impurities are described for optical emission and isotope dilution spark source mass spectrometric analysis of ingot iron, botanical materials, and high purity reagents. Work on Standard Reference Materials resulted in certification of stainless steel, clays, ferrosilicon, blast furnace irons, white irons, lead bearing metal, and ductile irons. Listings are given of 18 publications and 28 talks by members of the Section during the year.

TN543. **Electrochemical analysis section: Summary of activities July 1969 to June 1970,** R. A. Durst, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 543, 92 pages (Nov. 1970).

Key words: Acidity; conductivity; coulometric analysis; electrochemical analysis; ionic activity; ion-selective electrodes; pH measurements; potentiometry; standard reference materials.

This survey of the activities of the Electrochemical Analysis Section, Analytical Chemistry Division, covers the period from July 1969 to June 1970. An attempt is made to briefly summarize a year's progress on the technical projects of the Section, to indicate the composition and capabilities of the unit as a whole, and to stress the Section's role in the mission of the Institute. Summaries of the work in each of the Section competences are given. In the area of acidity measurements, work continued on the standardization of tris(hydroxymethyl)aminomethane for use as a biologic pH buffer material and standard for clinical pH measurements. Progress toward reference standards for the calibration of ion-selective electrodes is reported including pM and pCl values for both NaCl and KCl. A study using the silver sulfide ion-selective electrode for measuring trace silver ion losses due to adsorption on selected surfaces is described. High-precision coulometry is used to determine the atomic weight of zinc, the purity of EDTA, and the stoichiometry of gallium arsenide.

TN544. **Analytical coordination chemistry section: Summary of activities, July 1969 to June 1970,** O. Menis and J. I. Shultz, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 544, 151 pages (Sept. 1970).

Key words: Bilirubin solvent extraction with β-isopropyltropolone; clinical; filter; fluorimetric standards; inert gas fusion; lead-base alloys; multi-element flame spectrometer; spectrophotometric standards; steels and metallo-organics; thermal analysis DTA Standards; trace elements-glass standards.

Progress in research and development in several areas of analytical chemistry, as related to the Standard Reference Materials program is described. Based on the need for spectrophotometric standards by clinical chemists, both solid and liquid filters for calibrating the photometric scale are being developed. Similar needs and plans are reviewed for fluorimetric quantum yield standards. Development of flame spectrometry instruments are described which include a high precision multi-element flame spectrometer for simultaneous atomic absorption and flame emission, a ratio recording double beam spectrometer, new burner designs and the evaluation of a hollow cathode designed by Grimm. The multichannel spectrometer provides for the simultaneous determination of elements such as Na, K, Ca, CaOH and Mg with Li as the internal standard, and a seventh position for background of wavelength scan, and a digital system with tape for computer calculations.

The beginning of a comprehensive study of the absorbing and non-absorbing lines in atomic absorption is presented. Description is given of homogeneity studies and the analysis of glass standards containing 60 elements at the 0.2 to 500 ppm level with a relative standard deviation of 1-2 percent. Gold, iron, manganese, nickel, potassium, rubidium and strontium were determined, without prior chemical separations by spectrophotometric or atomic absorption and flame emission methods. A precise method for the flame emission determination of aluminum in ferrous materials by derivative optical scanning is also described.

Solution complexation studies involve the reactions of metals with bilirubin and the evaluation of equilibrium constants and kinetics in solvent extraction of iron and vanadium with β-isopropyltropolone.

In the area of thermal analysis, provisional certification of potassium nitrate (SRM 756) and quartz (SRM 755) for temperature scale DTA standards, and the studies of sulfur, stearic acid and hexachloroethane for the lower temperature scale are reported. For gases in metals, improvements in inert gas fusion analysis involved instrumental modifications which permitted sample changes in less than 12 seconds. Finally, the characterization of the following Standard Reference Materials are discussed: lead-bearing alloys, SRM 53e and 1132; carbon steel, SRM 20g; stainless steel, SRM 101f; low-carbon stainless steel, SRM 166c; metallo-organic, SRM 1061c, special steels, SRM 361, 362 and 365.

TN545. **Microchemical analysis section: Summary of activities July 1969 to June 1970,** J. K. Taylor, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 545, 126 pages (Dec. 1970).

Key words: Air pollutant analysis; chemical analysis; gas analysis; microchemical analysis; microscopic analysis; polarographic analysis.

This report describes the research activities and scientific programs of the Microchemical Analysis Section of the Analytical Chemistry Division of the National Bureau of Standards, Institute for Materials Research during the period July 1969 to June 1970. General Activities are reviewed in areas of gas analysis polarography, chemical microscopy, and classical microchemical analysis. Research activities described in some detail include: preparation and analysis of carbon monoxide mixture for standard reference materials; evaluation of sulfur dioxide permeation tubes as analytical standards; polarographic methods for determination of trace elements in a number of materials; certification of urea as a microchemical standard. A chapter reviewing the state-of-the-art of analysis for air pollutants is also included.

TN 546. **Analytical Mass Spectrometry Section: Summary of activities, July 1969 to June 1970,** W. R. Shields, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 546, 120 pages (Nov. 1970).

Key words: Instrumentation; isotopic analysis; mass spectrometry; procedures.

This report describes the advances in instrumentation and the research activities of the Analytical Mass Spectrometry Section during the period July 1969 to June 1970.

Advances in instrumentation include the construction of a computer controlled mass spectrometer with appropriate interconnecting components, power supplies with greatly increased stability and the utilization of a magnetic field control.

Elements studied during this period include: B, Cu, Ag, Pb, Tl, U, Pu, K, Rb, Ni and Mo. Chemical procedures are given for Cu, Ag, Pg, Tl, U, K, Rb, Ni and Mo. Mass spectrometric procedures are given for Pb, Tl, U, K, Ni and Mo. Chemical procedures for the intercomparison of redox standards are also given.

TN547. **Organic chemistry section: Summary of activities July 1969 to June 1970,** R. Schaffer, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 547, 134 pages (Nov. 1970).

Key words: "Azobilirubin"; bilirubin; β-NAD; β-NADH; cholesterol; cortisol; D-mannitol; electron spin resonance; proton magnetic resonance; skew conformations; standard reference materials; uric acid; VMA.

This report of the Organic Chemistry Section of the National Bureau of Standard's Institute for Materials Research provides a summary of a year's scientific activity; as such, it covers both work that was completed and some that is still in progress. The development of Standard Reference Materials (SRMs) and their certification constitute a significant output that we term the sample aspect of our programs. The research component appears in the form of journal publications.

About one-half of the report concerns SRMs. Spectrophotometric measurements of bilirubin and of "azobilirubin" in simple solvents and in serum or proteins are given much attention. D-Glucose for use as a clinical standard is examined by gas-liquid chromatography and differential scanning calorimetry to ascertain changes in the proportions of the anomeric forms of the sugar during these measurements. Additional compounds for development as SRMs are cortisol, 4-hydroxy-3-methoxy-DL-mandelic acid (VMA), D-mannitol, and the reduced form of β-NAD. Some properties thus far studied on commercially available specimens are reported.

In carbohydrate research programs, the purity of 1,2:4,5-di-*O*-isopropylidene-D-fructose and the importance of using it pure for conversion into pure D-psicose are described. The proton magnetic parameters of the unquestioned, skew conformation of 3-*O*-benzoyl-1,2,4-*O*-benzylidyne-α-D-ribopyranose are analyzed. These parameters have major utility as a model for conformational analysis. Iterative analysis of p.m.r. spectra and the conformations of some D-glucose derivatives are described. Also, work is reported on cyclic polyhydroxy compounds, including oxidation, electron spin resonance, and new derivatives.

Finally, a number of other topics are described: iodination of β-diketones with periodic acid, and reactions of bilirubin, hemin, and related bile pigments; also, some work on the detection of polynitro aromatic compounds is given.

TN548. **Activation Analysis Section: Summary of activities, July 1969 to June 1970,** P. D. LaFleur and D. A. Becker, Editors, Nat. Bur. Stand. (U.S.), Tech. Notes 548, 164 pages (Dec. 1970).

Key words: Activation analysis; Cockcroft-Walton neutron generator; computer programming; NBS LINAC; NBS reactor; standard reference materials.

This survey of the activities of the Activation Analysis Section covers the period July 1969 to June 1970. An overview of the progress made by the various projects in the Section is given. A discussion of the operating characteristics of the NBS Reactor for activation analysis is given and the research activities of the various projects are discussed. Special attention is given to the many practical problems encountered by the Section during the year, and the results of the solutions to these problems, especially the analysis of Trace Elements in Glass Standard Reference Material (SRM) and of the botanical SRM. The quantitative analysis for boron using the nuclear track technique is discussed as well as extension of the analysis for uranium using this technique.

An extensive discussion of the value of 3-MeV neutrons in neutron generator activation analysis and the experimental parameters for using these neutrons is discussed. The new target and pneumatic transfer systems at the NBS LINAC for photon activation analysis are described and the application of photon activation analysis for determining thallium in glass and high purity metals and gold, manganese and iron in high purity cadmium is discussed. Research into determination of nitrogen by photon activation analysis is described.

A computer program, ALSPIS, for peak finding and integration is described and the application of a mini-computer to the Activation Analysis Section is noted.

TN549. **Separation and Purification Section: summary of activities July 1969 to June 1970,** D. H. Freeman and W. L. Zielinski, Jr., Editors, Nat. Bur. Stand. (U.S.), Tech. Note 549, 86 pages (Jan. 1971).

Key words: Air pollution; bilirubin; infrared analysis; ion exchange; liquid chromatography; purification; separation; styrene/divinylbenzene; zeolites.

This represents the report of activities for the Separation and Purification Section for fiscal year 1970. Studies on the properties of ion exchange Standard Reference Material microbeads is extended into the effect of humidity on bead volume, thermal effects on bead stability, and measurement of ion exchanger capacity. Zeolitic particles are evaluated for their potential as ion exchange microstandards. Preliminary investigations are completed for the quantitative infrared measurement of cross-linking in poly (styrene/divinylbenzene) copolymers. Light and electron microscopy are used to help reveal the heterogeneity in a test dust standard. Progress is reported in the development and understanding of analytical liquid chromatography with an increased direction toward gel chromatography. The selection of apparatus components, their performance, and their application to examination of the clinical Standard Reference Material, bilirubin, is described. Particle contamination in inorganic salts and in container walls are examined, the former by ultrafiltration and accurate light scattering measurements and the latter by microscopic methods.

TN550. **A systems programmer's guide for implementing OMNITAB II,** S. T. Peavy, R. N. Varner, and S. G. Bremer, Nat. Bur. Stand. (U.S.), Tech. Note 550, 43 pages (Nov. 1970).

Key words: ANSI FORTRAN; double precision; general-purpose computer program; implementation of OMNITAB II; labeled common; machine independent; OMNITAB II; overlay; segmentation; system parameters; transportable computer programs.

OMNITAB II is a general-purpose program which permits direct use of a computer without prior knowledge of computer languages. Every effort has been made to produce a system as machine independent as possible to make implementation of any large computer configuration relatively easy. However, there are a few modifications which may have to be made.

This Technical Note provides assistance to the systems programmer, with the task of implementing OMNITAB II, by pointing out where difficulties may occur and how to cope with them. It furthermore outlines a method for segmenting the OMNITAB II system which is very large. It is a partial documentation of the OMNITAB program.

OMNITAB II is a large system requiring a large computer. Overlay and segmentation are virtually essential. A method for segmenting OMNITAB II is outlined. The method should be useful for many computers.

TN551. **Test problems and results for OMNITAB II,** R. N. Varner and S. T. Peavy, Nat. Bur. Stand. (U.S.), Tech. Note 551, 190 pages (Dec. 1970).

Key words: Accuracy; ANSI FORTRAN; computer system implementation; examples; OMNITAB II; software; test problems.

The lack of test problems and results for many software packages is a great hindrance to both the systems programmer and the general user. In this publication a set of fifty-two test problems and results for the OMNITAB II system is provided to assist individuals in checking the implementation of the OMNITAB II program on their particular computer. The general user will also find these descriptive examples instructive in the use of OMNITAB commands.

TN552. **OMNITAB II user's reference manual,** D. Hogben, S. T. Peavy, and R. N. Varner, Nat. Bur. Stand. (U.S.), Tech. Note 552, 264 pages (Oct. 1971).

Key words: Automatic printing; Bessel functions; data analysis; data manipulation; easy and effective programming in English; list of instructions; matrix operations; numerical analysis; OMNITAB II user oriented computing system; self-teaching; statistical analysis.

OMNITAB II, a highly user-oriented system for a large com-

er, is designed to make computing easy, accurate and effec-, particularly for persons who are not programmers. It is a eral-purpose program, which can be learned quickly, for both ple and complex numerical, statistical and data analysis. OM-TAB executes instructions written in the form of simple En-h sentences. Problem-solving is further enhanced by the natu-structure of the system and its many features. OMNITAB been used successfully in government, industry and universi-across the country and in several centers abroad. The system been implemented on large computers of at least seven dif-ent manufacturers.

The original version of OMNITAB has been completely written to make it as machine independent as possible and to plement many improvements. This manual describes Version . Details are presented so that the user can easily find the cific information needed in any particular instance. PART A a simple, compact introduction to OMNITAB for people who ve had no experience using a large computer. PART B scribes the general and special features of the OMNITAB stem. PART C gives explanations, with short examples, for use of specific instructions. PART D is a complete alphabeti-list of the instructions which are in the system.

N553, Superseded by Technical Note 47.

N554. **Annotated accession list of data compilations of the NBS Office of Standard Reference Data,** H. M. Weisman and G. B. Sherwood, Nat. Bur. Stand. (U.S.), Tech. Note 554, 196 pages (Sept. 1970).

Key words: Accession list; atomic and molecular properties; chemical kinetics; colloid and surface properties; fundamental particles properties; general collections; mechanical properties; nuclear properties; solid state properties; thermodynamic and transport properties.

The National Bureau of Standards, Office of Standard Reference Data has attempted to acquire all significant reference data compilations on a worldwide basis. This publication lists the collection of documents so acquired, together with their abstracts. The documents are organized in the following categories: General Collections, Nuclear Properties (including Fundamental Particles Properties), Atomic and Molecular Properties, Solid State Properties, Chemical Kinetics, Colloid and Surface Properties, Mechanical Properties, and Thermodynamic and Transport Properties. Sources of availability for the listed publications are also provided.

N555. **Methods of measurement for semiconductor materials, process control, and devices, Quarterly Report, January 1 to March 31, 1970,** W. M. Bullis and A. J. Baroody, Jr., Editors, Nat. Bur. Stand. (U.S.), Tech. Note 555, 63 pages (Sept. 1970).

Key words: Alpha-particle detectors; aluminum wire; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, seventh of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; evaluation of wire bonds, metallization adhesion, and die attachment; and measurement of thermal properties of semiconductor devices and electrical properties of microwave devices. Work on related projects on silicon nuclear radiation detectors and specification of germanium for gamma-ray detectors is also described. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN556. **Development and current status of the standard nuclear instrument module (NIM) system,** L. Costrell, Nat. Bur. Stand. (U.S.), Tech. Note 556, 15 pages (October 1970).

Key words: Instrumentation; instruments; modules; nuclear; standards, NIM.

The standard Nuclear Instrument Module (NIM) system described in AEC Report TID-20893 is widely used in laboratories throughout the world. This report presents a history of the development and reviews the current status of the NIM system.

TN557. **The brake pedal force capability of adult females,** R. W. Radlinski and J. I. Price, Nat. Bur. Stand. (U.S.), Tech. Note 557, 25 pages (Oct. 1970).

Key words: Automotive braking systems; brakes; brake pedal forces; Federal Motor Vehicle Safety Standards; pedal effort; women, strength of.

A survey of the brake pedal force capability of 105 women employees at the National Bureau of Standards, Washington, D.C., was performed utilizing two stationary passenger automobiles as test vehicles. Results showed that over 50% of the test subjects could not achieve an average sustained brake pedal force of 200 lb, a value which is considered an acceptable braking system input force under certain conditions of the current Federal Motor Vehicle Safety Standard (FMVSS No. 105) for passenger vehicle braking system performance.

TN558. **Lubbock tornado: a survey of building damage in an urban area,** N. F. Somes, R. D. Dikkers, and T. H. Boone, Nat. Bur. Stand. (U.S.), Tech. Note 558, 38 pages (Mar. 1971).

Key words: Anchorage; building performance; glazing; hailstones; masonry; mobile homes; roofs; structural engineering; wind load.

The Building Research Division of the National Bureau of Standards' Institute of Applied Technology sent a three-man team to investigate the damage to buildings and other structures caused by the tornado which struck Lubbock, Texas, on May 11, 1970. The team members—the authors of this report—carried out photographic surveys on the ground and from a helicopter on the days of May 14, 15, and 16, 1970. The report is based largely on data gathered during this period but includes some data provided by other agencies and individuals whose assistance is acknowledged in the report. The report concludes that current good practice in the design and construction of buildings and mobile homes would have greatly reduced the damage observed at Lubbock. It also notes that natural disasters provide full-scale tests of buildings and urges the development of performance criteria with respect to wind loads for certain building elements.

TN559. **Spectroradiometry and conventional photometry—an interlaboratory comparison,** D. A. McSparron, K. Mohan, R. C. Raybold, R. D. Saunders, and E. F. Salewski, Nat. Bur. Stand. (U.S.), Tech. Note 559, 197 pages (Nov. 1970).

Key words: Barnes colorimeter; chromaticity coordinate; color correction; cool white fluorescent lamp; correlated color temperature; daylight fluorescent lamp; heterochromatic photometry; integrating sphere; intercomparison; luminous flux; photometry; spectroradiometry.

This report summarizes the results of a fluorescent lamp intercomparison carried out under the aegis of the National Bureau of Standards Photometry Section. The purpose of the intercomparison was to evaluate the interlaboratory precision obtainable in photometric and spectroradiometric measurements. The tests were also designed to disclose suspected systematic errors in measurement techniques.

The intercomparison consisted of five parts: (1) A homochromatic, photometric measurement of cool white fluorescent lamps and a heterochromatic, photometric measurement of a daylight fluorescent lamp and an incandescent lamp utilizing cool white fluorescent lamps as standards, all within an integrating sphere. (2) Spectroradiometric measurement of the above mentioned lamps in an integrating sphere. (3) Spectroradiometric measurement of a 25 cm section of the fluorescent lamps in a baffled enclosure. (4) An experiment designed to reveal systematic errors in heterochromatic photometry. (5) Measurement of the x and y chromaticity coordinates with a Barnes colorimeter.

TN560. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report April 1 to June 30, 1970,** W. M. Bullis and A. J. Baroody, Jr., Editors, Nat. Bur. Stand. (U.S.), Tech. Note 560, 58 pages (Nov. 1970).

Key words: Alpha-particle detectors; aluminum wire; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, eight of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Principal emphasis is placed on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; evaluation of wire bonds, metallization adhesion, and die attachment; and measurement of thermal properties of semiconductor devices and electrical properties of microwave devices. Work on related projects on silicon nuclear radiation detectors and specification of germanium for gamma-ray detectors is also described. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN561. **Unassigned.**

TN562. **A right angle ^{3}He cryostat incorporating a high field superconducting solenoid,** H. Marshak and R. B. Dove, Nat. Bur. Stand. (U.S.), Tech. Note 562, 22 pages (Dec. 1970).

Key words: ^{3}He cryostat; ^{3}He refrigerator; nuclear orientation; superconducting solenoid.

Construction and operation of a novel ^{3}He cryostat, incorporating a large superconducting solenoid mounted at right angles to the cryostat's vertical axis, is described. This new cryostat which is part of the transportable National Bureau of Standards ^{3}He refrigerator, has been used successfully for nuclear orientation studies at the Atomic Energy Research Establishment, Harwell, England.

TN563. **Surface pressure fluctuations near an axisymmetric stagnation point,** R. D. Marshall, Nat. Bur. Stand. (U.S.), Tech. Note 563, 67 pages (Aug. 1971).

Key words: Disk; pressure fluctuations; stagnation point; turbulence.

Surface pressure fluctuations on a circular disk placed normal to a turbulent air stream have been investigated. Turbulence intensities of approximately 10% were produced by a coarse grid installed at the test-section entrance. The turbulent field in t neighborhood of the disk was homogeneous and nearly isotrop

Experimental results indicate that existing linear theor which do not consider distortion of the flow fail to predict the f ture of surface pressure fluctuations on a bluff body. Only wavelengths which are large compared to the body do the theories yield satisfactory results. A strong attenuation of t high frequency components occurs as the flow stagnates. This accompanied by a transfer of energy from short to lo wavelengths. The opposite effect is observed as the flow attai a radial direction and approaches the edge of the disk. A neut wavelength which undergoes little change in energy was o served. Integral scales of surface pressure fluctuations are mu larger than the lateral integral scale of the free-stream turb lence.

Pressure-velocity correlations indicate the existence of t distinct regions, an inner region in which correlations and o timum delay times exhibit considerable change along the rad of the disk, and an outer region where there is little depender on radial distance. Maximum values of the optimum correlatio are found in the outer region. There is qualitative agreem between the experimental results and theoretical predictio which consider the effect of vortex stretching.

TN564. **Glass limit standards deposited at NBS for railw highway and airway traffic signal colors—history, permanen -and colorimetric properties,** G. W. Haupt, Nat. Bur. Sta (U.S.), Tech. Note 564, 121 pages (June 1971).

Key words: Aircraft signals; color standards; filter p manence; limit filters; railroad signals; signal colors; sig standards; spectral transmittance of glass filters; traf signals.

Signal glass limit standards for railway, highway, and aviati colors, selected by user-organizations, are on deposit at the N tional Bureau of Standards. Many duplicates of these standa have been issued by NBS.

The first standards were selected in 1931 for railway u Highway standards were adopted in 1940, and selection of av tion standards began in 1942. At the present time the NBS custodian of 63 standards for these signal colors.

Permanence of the filters is examined, based on colorimet conversions for CIE standard illuminant A derived from sp trophotometric measurements made on different instrume over periods of years.

Spectral transmittance data and the resulting colorimetric d are given for 9 illuminants ranging in distribution temperatu from 1500 to 3250 kelvins and for CIE standard illuminants and C. Figures show, for several filters of each color, the shi occurring both in chromaticity (x,y) and in redness a brightness index (u,W*) with changes in illuminant.

TN565. **ARPA-NBS program of research on high temperatu and laser materials, reporting period 1 January to 30 June, 19** A. D. Franklin and H. S. Bennett, Editors, Nat. Bur. Sta (U.S.), Tech. Note 565, 84 pages (Jan. 1971).

Key words: Aluminum oxide; band structure; borides; bi optical properties; chemical analysis; chromium ion corundum; crystal defects; crystal growth; density of stat diffusion; glass; high temperature materials; laser dama laser degradation; laser glass; laser materials; mass tra port; neodymium glass; optical properties; opto-elastic p perties; oxides; ruby; rutile; titanium; titanium dioxi transition metal.

Brief reviews are given of work performed during this repo ing period of several problems in the areas of High Temperatu Materials and Laser Materials. Under the High Temperatu

aterials extremely pure Al_2O_3 crystals have been prepared and alysed chemically with the aim of providing specimens for search on mass transport, electronic, and similar properties. xygen diffusion data on TiO_2, obtained by the gas uptake ethod, agree with literature values, and work is now proceeding developing a sectioning technique for oxygen diffusion. The tical constants of titanium have been determined over the visi- e portion of the spectrum. Soft x-ray spectra, nmr data, össbauer spectra, magnetic susceptibility, and other probes of e electronic density of states have been determined for a group diborides of the first-series transition metals (Sc, Ti, V, Cr, d Mn) and interpreted in terms of the *d*-electron contribution the density of states near the Fermi level. Both this project d the previous one on the optical properties of titanium have en completed. Under Laser Materials, the measurement of lk optical properties and chemical analyses of ruby and Nd- ass are complete. Several techniques for determining the Cr^{3+} ntent in laser ruby have been developed and shown to agree; ith these, it has been shown that very little loss of Cr^{3+} occurs hen ruby turns orange under optical (x-ray or γ-ray) irradiation. theory of laser pulse-induced damage at foreign particles in d-glass has been worked out; it suggests that detection before mage might be easiest with pulses of microsecond or longer uration. A high-power Nd-glass laser, Q-switched, has been rchased for damage studies. The beam characteristics, which ust be properly controlled for meaningful damage threshold easurements, are currently being studied.

N566. **Wet traction of tractionized tires,** A. H. Neill, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 566, 14 pages (Feb. 1971).

Key words: Siping; stability; stopping distance; tires; traction; tractionizing.

A series of dynamic vehicle tests was performed at NBS to valuate the performance of tractionized or siped tires. Stopping istance and lateral breakaway data is presented from a two heel diagonally braked automobile which clearly shows that ped tires do not represent any improvement in the lateral sta- ility or stopping distance characteristics of a typical passenger utomobile.

N567. **Reactor Radiation Division annual progress report for period ending October 31, 1970,** R. S. Carter, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 567, 66 pages (Mar. 1971).

Key words: Crystal structure; diffraction; molecular structure; neutron; nuclear reactor; radiation; scattering.

The reactor has completed its first year of full power operation o it is now appropriate to review the progress made during the ast year. This report is the first annual progress report of the Reactor Radiation Division.

N568. **Simulation of air traffic control radar beacon code assignment plans. Final report,** R. D. Elbourn and J. F. Gilsinn, Nat. Bur. Stand. (U.S.), Tech. Note 568, 76 pages (Mar. 1971).

Key words: Air traffic control; beacon code assignment; digital simulation; radar beacon system.

In the Air Traffic Control Radar Beacon System transponders in the aircraft use one of 4096 identity codes when replying to interrogation from the Secondary Surveillance Radar. Two types of plans for assigning identity codes to aircraft were tested by simulating in a digital computer a peak day's IFR traffic in the USA. In one type each Air Route Traffic Control Center assigns codes independently of all the others, while in the other type a single master center makes all the code assignments for the USA. Four other types of plans are discussed, and an assignment plan of mixed type is proposed for further study. The strategy of simulation and the use of the SIMSCRIPT language are discussed in an appendix.

TN569. **Hurricane Camille—August 1969. A survey of structural damage along the Mississippi Gulf Coast,** R. D. Dikkers, R. D. Marshall, and H. C. S. Thom, Nat. Bur. Stand. (U.S.), Tech. Note 569, 71 pages (Mar. 1971).

Key words: Buildings; failure; hurricanes; mobile homes; roofs; structural engineering; tides; wind.

One week after Hurricane Camille devastated the Mississippi-Louisiana Gulf Coast with 125 mph winds and 20-ft tides on August 17, 1969, a four-man NBS team investigated the damage to buildings and other structures. This report presents photographic survey data from this investigation along with additional data on wind speeds and storm surge. Based on these data, suggestions are made pertaining to the improvement of building design and construction practices.

TN570. **Determination of deep impurities in silicon and germanium by infrared photoconductivity,** W. R. Thurber, Nat. Bur. Stand. (U.S.), Tech. Note 570, 13 pages (Mar. 1971).

Key words: Deep impurities; germanium; infrared; photoconductivity; photoresponse; semiconductors; silicon.

The feasibility of using infrared photoresponse and photoconductivity measurements to study deep impurities in germanium and silicon is examined by reviewing the literature. It is concluded that photoconductivity is useful in detecting the presence of specific impurities because each impurity has a long wavelength cut off in response associated with its ionization energy. However, when there are several deep impurities in the same specimen, it is difficult to be certain of detecting each one because some have broad cut offs and many have nearly the same ionization energies. Photoconductivity as a general technique has serious limitations for determining the total concentration of deep impurities. The equations for determining impurity concentration from the magnitude of the photoconductivity signal depend on the relative influence of deep and shallow centers. Equations are derived for several situations and experimental results from the literature are discussed for each one. Only uncompensated centers are available for photoionization and therefore the total concentration can not be obtained directly. In some situations the response due to a deep center is independent of its concentration. Other techniques for studying deep impurities are discussed briefly.

TN571. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report July 1 to September 30, 1970.** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 571, 58 pages (Apr. 1971).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, ninth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Work is continuing on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; specification of germanium for gamma-ray detectors; evaluation of wire bonds, metallization adhesion, and die attachment; measurement of thermal properties of semiconductor devices and electrical properties of microwave devices; and characterization of silicon nuclear radiation detectors. New effort is being started on the measurement of transit-time and related carrier transport properties in junction devices. Supple-

mentary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN572. **On computer performance measurement programming measuring indexing adroitness by isolating complex primes,** G. W. Reitwiesner, Nat. Bur. Stand. (U.S.), Tech. Note 572, 25 pages (Apr. 1971),

Key words: Assessment; complex; composite; computer; criteria; evaluation; Gaussian primes; indexing; measurement; performance; prime; program; test.

This writing, describing a computer performance test program, is concerned not primarily with specific measurements, but rather with a procedure for making measurement regarding specific properties of computer operation.

The program is written in a particular problem-oriented programming language; therefore assessment perforce spans the effects of the computer hardware, of the programming language, and of the intervening compiler processes.

The objective of the test is to assess adroitness in certain indexing operations. Assessment is accomplished by measuring execution time of a recursive programming loop.

The test problem was chosen as a convenient artifice to use certain specific indexing-type operations in the programming employed for solution.

The test program performs a simple computation for which the solution is completely definitive, yet for which both the solution and the time for achieving it are variable under parameters whose values are introduced as program input data.

TN573. **Application of capacitor microphones and magnetic pickups to the tuning and trouble-shooting of microelectronic ultrasonic bonding equipment,** G. G. Harman and H. K. Kessler, Nat. Bur. Stand. (U.S.), Tech. Note 573, 24 pages (May 1971).

Key words: Capacitor microphone; flip-chip; magnetic pickup; microelectronic interconnections; spider bonding; ultrasonic bonding; wire bonding.

Microelectronic ultrasonic wire bonding equipment typically welds wires to integrated circuits at frequencies between 50 and 65 kHz. Mechanical vibrations of these frequencies are difficult to measure directly and malfunctions of the system may not be recognized. Two different methods of measuring these vibrations are described. The first method involves use of a capacitor microphone and a tapered tip, and the second method use of a small magnetic pickup. Procedures are given for establishing a specific ultrasonic vibration amplitude, tuning the ultrasonic system to resonance, and diagnosing both mechanical and electrical problems in wire bonding equipment. Although these techniques and procedures were developed for ultrasonic wire bonding equipment, they are applicable to other ultrasonic welding systems of lead attachment, such as flip-chip, beam lead and spider bonding.

TN574. **ARPA-NBS program of research on high temperature materials and laser materials, reporting period July 1 to December 31, 1970,** A. D. Franklin and H. S. Bennett, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 574, 44 pages (May 1971).

Key words: Al_2O_3; crystal growth; damage threshold; glass; high temperature materials; laser; oxides; oxygen diffusion; pure materials; sapphire.

Progress reports are given for projects on the growth of ultrapure Al_2O_3 crystals, the development of a mass spectrometer-based sectioning technique for measuring oxygen diffusion in oxides, the development of a precision facility for measuring the threshold energy in a laser beam producing damage in a trans parent substance, and the study of the factors influencing thi damage threshold in glass.

TN575. **On the absorptance of cavity-type receivers,** J. C. Gei and J. C. Richmond, Nat. Bur. Stand. (U.S.), Tech. Note 57 38 pages (July 1971).

Key words: Absorptance; black coatings; cavity ab sorptance; cavity reflectance; laser-source reflectomete Parsons black; retro-reflectance.

The directional-hemispherical reflectance of a number of fl samples that had been coated with Parsons Optical Blac Lacquer procured from Thos. Parsons and Sons and The Epple Laboratory, respectively, was measured at 0.6328 and 1.15 μ with a laser-source integrating sphere reflectometer. Th reflectance varied significantly with method of application, an was significantly higher for the Eppley lacquer than for the Pa sons lacquer. The reflectance of two cavity receivers, one coate with each lacquer, was also measured. At 0.6328 μm th reflectance of the Parsons cavity was higher, but at 1.15 μm was lower. The measured reflectance of the Parsons cavity wa appreciably higher than that computed from the measure reflectance of the lacquer and the geometry of the cavity, assun ing the coating to be a perfectly diffuse reflector. Retro reflectance measurements revealed that both lacquers reflecte more radiant energy back into directions near the direction of i cidence than would a perfect diffuser of the same direction hemispherical reflectance, but the Parsons lacquer was by far th more pronounced retro-reflector. The principal conclusion that the diffuse assumption can lead to significant errors in com puting the absorptance of cavity-type receivers, when the cavit coating is in fact not diffuse.

TN576. **Computer code for the calculation of thermal neutron ab sorption in spherical and cylindrical neutron sources,** V Spiegel, Jr. and W. M. Murphey, Nat. Bur. Stand. (U.S), Tech Note 576, 25 pages (May 1971).

Key words: Manganous sulfate bath calibration of neutro sources; neutron; neutron standards.

A computer code has been written in FORTRAN IV for th calculation of thermal neutron absorption in spherical and cylin drical neutron sources. The formalism of the calculation, th structure of the computer code, a listing of the code, and som sample results are presented. The comparison of the results c this calculation to experiment appears elsewhere.

TN577. **Method of calibrating weights for piston gages,** H. L Almer, Nat. Bur. Stand. (U.S.), Tech. Note 577, 54 page (May 1971).

Key words: Balance; buoyancy; calibration; standards; sub stitution weighing; transposition weighing; true mass; uncer tainty; value.

Generally weights for piston gages have odd denominatio that are often not readily calibrated by intercomparison method Therefore, these weights are frequently calibrated by direct com parison methods. This paper presents direct comparis methods for calibrating piston gage weights for use with bo equal-arm balances and single-pan balances. Methods of estima ing the uncertainty of the values obtained are given. Also i cluded are methods of checking for blunders or gross errors.

TN578. **Determination of dynamic loads in a high-frequen direct-stress fatigue machine,** D. C. Robinson, Nat. Bur. Stan (U.S.), Tech. Note 578, 24 pages (June 1971).

Key words: Dynamic loads; dynamometer; fatigue machin

A refined test procedure is given for accurately recording th dynamic signals from instrumented test bars used to measu

ads during simulated fatigue tests. Loads indicated by the load ansducer of a direct-stress fatigue machine are compared with ose determined from these instrumented test bar specimens hich have been calibrated under static conditions. An applica-n of this procedure is described for a resonant, electromag-tic, direct-stress fatigue machine having an optical dynamome-r for indicating programmed loads. The variables investigated ere the operating frequency, cyclic load and specimen stiffness. addition, the influence of test fixture mass on the load mea-rements was determined at one test frequency. The mean ads indicated by the instrumented test bars are compared with ose indicated by the dynamometer to determine the errors in ad measurements under various test conditions.

N579. **Testing of cover glasses for hemacytometer chambers,** J. S. Beers, Nat. Bur. Stand. (U.S.), Tech. Note 579, 7 pages (Sept. 1971).

Key words: Cover glass, test method for; hemacytometer; interferometry; planarity.

If cover glasses used with hemacytometer chambers are not ufficiently flat, a volume error, causing erroneous blood cell ounts, may be introduced in the chamber. This document escribes a method of testing cover glasses for conformity to a lanarity specification.

N580. **Unassigned.**

TN582. **Activities of the NBS Spectrochemical Analysis Section, July 1970 to June 1971,** K. F. J. Heinrich and S. D. Rasberry, Nat. Bur. Stand. (U.S.), Tech. Note 582, 126 pages (Jan. 1972).

Key words: Analysis; computer program; electron probe; microanalysis; optical spectrometry; pre-concentration techniques; spectrochemical analysis; standard reference materials; x-ray fluorescence analysis.

Spectrochemical research activities, improvements in equip-nent and applications, especially to the certification of NBS Standard Reference Materials, are summarized. In optical emis-ion spectroscopy, studies have been carried out on a modified as-sheath arc excitation source. Application has been made of his source and several other conventional excitation sources to analytical problems related to both standard reference materials and other materials being investigated at NBS. Newly derived computation procedures for quantitative x-ray fluorescence anal-ysis are described as well as new instrumentation added for x-ray spectrochemical studies. In electron probe microanalysis, research and new instrumentation has been directed to improved detection limits and quantitation; special emphasis has been given to methods for small particles and biological thin cuts. Methods of pre-concentration of impurities have been advanced and applied, in some cases at parts per billion (10^{-9}) limits, to water pollution, river sediment specimens. Mercury, cadmium, and lead were among the elements determined. Work on Standard Reference Materials resulted in certification of several special steels, several high temperature alloys, a high-silicon steel and a titanium alloy, among others. Listings are given of 8 publications and 25 talks by members of the Section during the year.

TN583. **Electrochemical Analysis Section: Summary of activities, July 1970 to June 1971,** R. A. Durst, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 583, 113 pages (Feb. 1973) 75 cents, SD Catalog No. C13.46:583.

Key words: Acidity; coulometric analysis; electrochemical analysis; ionic activity; ion-selective electrodes; pH measurements; polarography; potentiometry; Standard Reference Materials.

This survey of the activities of the Electrochemical Analysis Section, Analytical Chemistry Division, covers the period from July 1970 to June 1971. An attempt is made to briefly summarize a year's progress on the technical projects of the Section, to indicate the composition and capabilities of the unit as a whole, and to stress the Section's role in the mission of the Institute. Summaries of the work in each of the Section competences are given. In the area of acidity measurements, work was completed on the standardization of tris(hydroxymethyl)aminomethane for use as a biologic pH buffer material and standard for clinical pH measurements. High-precision coulometry is used to determine the atomic weight of zinc, the stoichiometry of gallium arsenide, and the purity of KCl and NaCl. Polarography is used to determine trace elements in a variety of environmental samples and Standard Reference Materials.

TN584. **Analytical Coordination Chemistry Section: Summary of activities July 1970 to June 1971,** O. Menis and J. I. Shultz, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 584, 175 pages (Dec. 1971).

Key words: Aluminum in steel; bilirubin; DTA standards; fluorescence filters Tl(I), Ce(III), Pb(II); glass filters (SRM 930); mercury in botanical; quantum efficiencies.

Progress in research in spectrophotometry, spectrofluorometry, flame emission, atomic absorption, thermal analysis and related programs is described. Efforts to improve accuracy of spectrophotometric measurements led to the construction of a high accuracy spectrophotometer, certification of glass filters, establishment of a more accurate value for molar absorptivity of the acid dichromate system, and the evaluation of spectrally neutral filters of interest for automation in clinical studies. The linearity of the single beam spectrophotometer was calibrated by the light addition technique. Glass filters were calibrated at 4 wavelengths with an uncertainty of 0.5 percent. Data for the dichromate system in perchloric acid led to new values for the dimerization equilibrium constant.

Studies were made of new fluorescence filters incorporating Ti(I), Ce(III), Pb(II) and rare earths in a variety of glass matrices. Quantum efficiencies of Tl in KCl and Eu in a silicate matrix were determined.

Developments in instrumentation led to increased sensitivity and improved precision and accuracy by flame spectroscopy. Mg, Ca, K and Na were determined with the multichannel spectrometer. A newly designed optical system and an ultrasonic spraying system provided increased signal and efficiency. The repetitive optical scan of flame emission overcame matrix and flame background problems for the determination of aluminum in steel. Certification was made on eight new materials in cooperation with the International Confederation on Thermal Analysis.

TN585. **Microchemical Analysis Section: Summary of activities, July 1970 to June 1971,** J. K. Taylor, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 585, 77 pages (Jan. 1972).

Key words: Air pollution analysis; carbon monoxide; fire research; microchemical analysis; nitrogen dioxide; ozone; particulate analysis; sulfur dioxide.

This report describes the scientific program of the Microchemical Analysis Section of the Analytical Chemistry Division of the National Bureau of Standards, Institute for Materials Research during July 1970 to June 1971. General activities are reported in the areas of air pollution measurement standards including both gases and particulates, in the field of microchemical analysis, in fire research and in electrochemical analysis performed under an international research grant pro-

gram. A sulfur dioxide standard reference material for use in monitoring ambient atmosphere, and the initial work on a similar standard for stationery sources are described. Research activities on potential standard reference materials for ozone, nitrogen dioxide, and carbon monoxide are also described.

TN587. **Organic Chemistry Section: Summary of activities, July 1970 to June 1971,** R. Schaffer, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 587, 131 pages (Aug. 1972).

Key words: Bilirubin; cholesterol; cortisol; e.s.r.; D-mannitol; NADH; n.m.r.; purity; SRM; Standard Reference Materials; VMA.

This report of the Organic Chemistry Section of the National Bureau of Standard's Institute for Materials Research provides a summary of a year's scientific activity; as such, it covers both work that was completed and some that is still in progress. The development of Standard Reference Materials (SRM's) and their certification, and journal publications describing aspects of that work, as well as other research activities, are the output of the Section.

In the SRM category, the major subjects of this report are bilirubin, cholesterol, cortisol, D-glucose, 4-hydroxy-3-methoxy-DL-mandelic acid (VMA), D-mannitol, and the reduced form of nicotinamide adenine dinucleotide (NADH).

Studies concerning carbohydrates include synthetic work with D-psicose, n.m.r. employing internuclear double-resonance, and mass spectroscopy of 6-deoxy-1,2:3,5-di-*O*-isopropylidene-α-D-glucose, spectroscopic studies of derivatives of 6-amino-6-deoxy-D-glucose-6-^{15}N (employing mass spectrometry, Fourier-transform, ^{13}C-n.m.r. and heteronuclear, ^{15}N indor techniques), and *p*-bromophenylosotriazoles of inositols.

Other research utilized e.s.r. and involved periodic acid oxidation of azines, solid-state oxidation of benzenehexol on active manganese dioxide, and the formation of stable radical-anions from glyoxal bis(phenylhydrazone).

TN589. **Separation and Purification Section: Summary of activities—July 1970 to June 1971,** D. H. Freeman and W. L. Zielinski, Jr., Editors, Nat. Bur. Stand. (U.S.), Tech. Note 589, 64 pages (Oct. 1971).

Key words: Clinical Standard Reference Materials; fraction collecting; gas chromatography; interactive gels; liquid chromatography design; nitrilotriacetic acid.

This is the annual progress report on the activities of the Separation and Purification Section. During the past year our studies in liquid chromatography, its application, control, and systems design were continued at an accelerated rate. Mobile phase flow was treated as an analogy to current in direct current circuitry, following removal of liquid pulses generated by a piston pump. A sophisticated, yet simple and inexpensive liquid chromatograph design is fully described. This design has been incorporated into all liquid chromatography studies being conducted in this Section. The operating parameters of this system design are discussed. The development of the underlying theory and synthesis procedures for interactive gels has led to the control and prediction of solute retention, selectivity, and a magnified column capacity for use in fraction collection and ancillary characterization of solute impurities in clinical Standard Reference Materials. A gas chromatographic method is described for the analysis of nitrilotriacetic acid based upon the formation of its trisilyl ester derivative.

TN590. **A preliminary design of a data retrieval language to handle a generalized data base: DRL,** E. Fong, Nat. Bur. Stand. (U.S.), Tech. Note 590, 26 pages (July 1971).

Key words: Data base; data retrieval; data structure; information storage and retrieval; language extension; preprocessor; programming language.

DRL (Data Retrieval Language) is a high-level programming language for information retrieval. The language includes a data description language which can describe fixed-length hierarchical data structures, and DRL includes a data retrieval statement whereby a user can retrieve data by specifying conditions on the data value. DRL also has an environment declaration statement in which the user can indicate specific peripheral devices by unit number for files. The rest of the language consists of an operation repertory of input-output functions and other data manipulations.

DRL is implemented as a preprocessor to FORTRAN V on the UNIVAC 1108, under EXEC II Operating system. Keywords act as triggers and are replaced by blocks of FORTRAN code.

The purpose of this project is to investigate the design of an information retrieval language to handle a generalized data base. The DRL system consists of a set of primitives utilizing both compile-time macros and run-time subroutines. These primitives are embedded in a high-level procedure-oriented programming language—the "host language"—FORTRAN in this case. These primitives form a base upon which a class of languages can be defined.

TN591. **A technique for measuring the surface temperature of transistors by means of fluorescent phosphor,** D. J. Brenner, Nat. Bur. Stand. (U.S.), Tech. Note 591, 49 pages (July 1971).

Key words: Surface temperature; temperature measurement; temperature-sensitive phosphor; thermographic phosphor; transistor-chip temperature.

A technique that uses temperature-sensitive phosphor (TSP) to make quantitative measurements of transistor-chip surface temperatures over the range of 170-210 °C is described. The experimental procedure consisted of depositing a thin coating of phosphor on uncapped power transistors, and then photographing the visible fluorescence generated under near-ultraviolet (uv) excitation. The cooler regions produced a brighter fluorescence than the hotter areas. The surface temperatures of operating transistors were determined by comparing, on a point-by-point basis, the photographic density of operating photographs to the density of a family of calibration photographs. Repeated temperature measurements always fell within a 4 °C overall error range when the phosphor surface was scanned with a 25×25 μm aperture. The error band dropped to less than 2 °C when a 50×50 μm aperture was used. Coarseness of the phosphor coating seemed to limit spacial resolution to about 25 μm. Any narrow temperature range between 20 and 400 °C can probably be measured by selecting a suitable level of uv irradiation and/or a suitable phosphor.

TN592. **Methods of measurement for semiconductor material process control, and devices, quarterly report October 1 to December 31, 1970,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 592, 72 pages (Aug. 1971).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; metallization; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, tenth of a series, describes

S activities directed toward the development of methods of asurement for semiconductor materials, process control, and ices. Significant accomplishments during this reporting iod include successful application of the surface photovoltage nnique, a non-contacting method, to the measurement of car- diffusion length in silicon epitaxial layers and development a novel, but simple, method for measurement of acceleration l terminal angular velocity of a photoresist spinner. Work is ntinuing on measurement of resistivity, carrier lifetime, and ctrical inhomogeneities in semiconductor crystals; specifica- n of germanium for gamma-ray detectors; evaluation of wire nds, metallization adhesion, and die attachment; measurement hermal properties of semiconductor devices, transit-time and ated carrier transport properties in junction devices, and elec- al properties of microwave devices; and characterization of con nuclear radiation detectors. Supplementary data concern- staff, standards committee activities, technical services, and blications are included as appendixes.

N593. **Wire-bond electrical connections: testing, fabrication and degradation-A bibliography 1957-1971,** H. A. Schafft, Nat. Bur. Stand. (U.S.), Tech. Note 593, 58 pages (Jan. 1972).

Key words: Bibliography; degradation (wire-bond); discrete devices; electrical interconnection; fabrication (wire-bond); failure (wire-bond); hybrid circuits; integrated circuits; microelectronics; reliability; testing (wire-bond); wire-bond.

More than 245 papers relevant to wire-bond type electrical in- connections used in microelectronic and low-power discrete d hybrid devices are listed together with key words. The bliographic search concentrated on compiling papers which ap- ared in the period from 1965 to 1970, inclusive. The selection papers was generally limited to those that were pertinent to re-bonds where the wire diameter is less than about 50 μm (2 ils) and where the wire is bonded by either thermocompressive ultrasonic means. Two indexes are provided: (1) an Author dex and (2) a Key Word Index. The latter includes a tabulation the literature citations.

N594-1. **Optical radiation measurements: Fundamental principles of absolute radiometry and the philosophy of this NBS program (1968 to 1971),** J. Geist, Nat. Bur. Stand. (U.S.), Tech. Note 594-1, 59 pages (June 1972).

Key words: Absolute detector radiometry; electrically calibrated detectors; International Pyrheliometric Scale; irradiance; radiometry.

The philosophy of the present NBS program in realizing a cale of total irradiance with electrically calibrated (absolute) de- ectors, a theoretical analysis of the sources of error in such a cale realization, a description of the electrically calibrated de- ector developed from 1968 to 1971, and participation in the hird International Pyrheliometer Comparison are presented.

N594-2. **Optical radiation measurements: Photometric instrumentation and research (1970 to 1971),** E. F. Zalewski, A. R. Schaefer, K. Mohan, and D. A. McSparron, Nat. Bur. Stand. (U.S.), Tech. Note 594-2, 44 pages (Sept. 1972).

Key words: Instrumentation; lamp orientation; lamp power circuitry; lamp stability; photodetector amplifier; photometry.

This document was written primarily to serve two purposes. First, some of the basic instrumentation which has recently been developed for use in photometry at NBS is described. The design and application of photodetector amplifiers, lamp power circuitry, and mechanical instrumentation are discussed. Second, three photometric experiments are described: the stability testing of some flux lamps and intensity lamps and the determination of the dependence of relative intensity on orientation. These experiments and their conclusions have proven useful in pointing out areas which need further investigation and in planning the directions of future work.

TN594-3. **Optical radiation measurements: Photometric calibration procedures,** V. I. Burns and D. A. McSparron, Nat. Bur. Stand. (U.S.), Tech. Note 594-3, 35 pages (Nov. 1972).

Key words: Calibration procedures; color temperatures; luminous flux; luminous intensity; photometry; uncertainty.

The National Bureau of Standards supplies calibrations of luminous intensity, luminous flux and color temperature on a routine basis. The procedures, equipment, and techniques used to perform these calibrations as of October 1972 are described. Details of the uncertainty information currently available, including estimates and procedures for determining uncertainties of the reported values, are also presented.

TN594-4. **Optical radiation measurements: The impact of radiometry and photometry and the role of NBS,** B. Steiner, Nat. Bur. Stand. (U.S.), Tech. Note 594-4, 56 pages (Mar. 1973) 80 cents, SD Catalog No. C13.46:594-4.

Key words: Agriculture; clinical analysis; economic impact; energy crisis; meteorology; photometry; phototherapy; pollution; radiometry; remote sensing.

Serious measurement discrepancies universally plague quantitative measurement in the electro-optics industry. The impact of the resulting problems is reviewed and the role of NBS explored. The measurement discrepancies arise chiefly through the recent explosive expansion of this industry. The growth has precipitated a complex development in the variety and accuracy of measurements required. The impact of problems in optical radiation measurement falls in many areas. One is the increasing Federal responsibility for public life defined in recent legislation. Another is the influence of good optical radiation measurement on the technical development of the electro-optics industry. The impact of these measurements on a number of public issues is reviewed: public health, public safety, the energy crisis, meteorology, pollution, agriculture, crime prevention, and surveillance from air and space. The economic impact of improved measurement both on a fair domestic market and on the balance of payments operates through unit production cost, quality control, product improvement, and innovation. Leadership by NBS has been urged by the industry not only in fulfillment of its legislative responsibility but also to permit the focus of elaborate and impartial resources on the complex problem of optical radiation measurement. In keeping with its mission to help improve industrial technology and the competitiveness of American industry, NBS has an opportunity of major proportions in the electro- optics industry. Leaders of this industry are calling for NBS initiatives to resolve many of the measurement problems now hindering further progress.

TN594-5. **Optical radiation measurements: Stability and temperature characteristics of some silicon and selenium photodetectors,** K. Mohan, A. R. Schaefer, and E. F. Zalewski, Nat. Bur. Stand. (U.S.), Tech. Note 594-5, 16 pages (June 1973) 35 cents, SD Catalog No. C13.46:594-5.

Key words: Fatigue; light memory; photocells; photodiodes; photometry; radiometry; selenium; silicon; stability; temperature dependence.

This paper describes the comparison of some characteristics of selenium barrier layer photocells and silicon PIN and PN type photodiodes operated in the photovoltaic or nonbiased mode. The work was done to study the suitability of these detectors specifically for goniometric measurements of flux and possibly

for other photometric (or radiometric) measurements. The characteristics studied were the stability of detector output over approximately twenty hours, fatigue or light memory effects over short periods of time, and the temperature dependence of detector output.

TN594-6. **Optical radiation measurements: The present state of radiometry and photometry,** B. Steiner, Nat. Bur. Stand. (U.S.), Tech. Note 594-6, 56 pages (Mar. 1974) SD Catalog No. C13.46:594-6.

Key words: measurement system; photometry; professional societies; radiometry; standards.

The electro-optics industry and the public that depends on it are part of an informal but influential system for optical radiation measurement. The growth of this industry and of public concerns related technically to it have put severe new strains on this measurement system. The system itself must therefore be analyzed. The state of the art, on which the measurement system depends, is surveyed in terms of basic measurement parameters. The measurement system is analyzed in terms of its three basic components: the flow of physical standards, the generation of procedural standards, and the funding framework. The roles of the professional society and of the Council for Optical Radiation Measurement are reviewed. New requirements of the system are identified. Finally, the methodology of the study is reviewed in detail.

TN594-7. **Optical radiation measurements: Approximate theory of the photometric integrating sphere,** W. B. Fussell, Nat. Bur. Stand. (U.S), Tech. Note 594-7, 39 pages (Mar. 1974) SD Catalog No. C13.46:594-7.

Key words: illuminance distribution; integrating sphere; lamp comparisons; photometric accuracy; photometry; total luminous flux.

An approximate mathematical theory of the photometric integrating sphere is developed. The analysis is accurate to the first order in the ratio of the baffle area to the sphere wall area. The sphere is assumed to be occupied by a circular baffle and a spherical lamp; the centers of the baffle and the lamp lie on a diameter of the sphere. The surfaces of the sphere and the baffle are assumed to reflect in a uniformly diffuse manner. The lamp is assumed to absorb a fraction of the radiation incident upon it, and to transmit (or specularly reflect) the remainder. The luminance distribution at the sphere window is derived for a general source input at any point of the sphere wall. A model lamp illuminance distribution is assumed, and a formula for the fractional error in comparing the total luminous fluxes of two lamps in the integrating sphere, is derived. The physical significance of the formula is described.

TN594-8. **Tables of diffraction losses,** W. B. Fussell, Nat. Bur. Stand. (U.S.), Tech. Note 594-8, 39 pages (June 1974) SD Catalog No. C13.46:594-8.

Key words: diffraction; diffraction losses; Fresnel diffraction; Kirchhoff diffraction theory; photometry; radiometry; scalar diffraction theory.

Tables of diffraction losses are given for a range of typical experimental geometries for wavelengths from 0.2 to 100 micrometers. The scaling relationships for the diffraction losses for varying wavelengths and geometries are also given, and sample calculations are presented. General formulas are given for the diffraction losses; the formulas are derived from the Kirchhoff scalar paraxial diffraction theory. The accuracy of the tabulated values is estimated.

TN594-9. **Optical radiation measurements: Describing spectrophotometric measurements,** W. H. Venable, Jr., and J. J. Hsia, Nat. Bur. Stand. (U.S.), Tech. Note 594-9, 49 pa (Nov. 1974) SD Catalog No. C13.46:594-9.

Key words: accuracy; appearance; colorimetry; definit of spectrophotometry; error analysis; photometry; radiat transfer; reflectance; scattering; spectrophotometry; tra mittance.

A general method is presented to describe spectrophotome measurements mathematically. All space is divided into inst ment space or sample space. Idealized absolute and relative m surements are defined at the boundary between the instrum and sample space by four descriptors: a radiance input L, a sc tering function S, a relative responsivity R, and a scaling funct K. Real measurements are also defined at the boundary described by these four descriptors, and general expressions fractional error are derived. A 45-degree, 0-degree reflecta measurement is used as a specific example to illustrate an ap cation of this method to describing measurements and perfo ing an error analysis.

TN594-10. **Optical radiation measurements: The NBS 20-, and 85-degree specular gloss scales,** J. J. Hsia, Nat. Bur. Sta (U.S.), Tech. Note 594-10, 32 pages (July 1975) SD Cata No. C13.46:594-10.

Key words: accuracy; appearance; error analysis; gl photometry; reflectance; scattering; spectrophotome specular gloss.

The 20-, 60-, and 85-degree specular gloss scales established at NBS with an accuracy of about one half gloss u This is one of many programs of the spectrophotometry grou the Optical Radiation Section of NBS directed toward impro the accuracy and assurance of spectrophotometric meas ments made throughout the scientific and industrial commun

The specular gloss scales are established through a uni technique employing polarized light flux both parallel and pendicular to the plane of incidence. General calibration ec tions are derived. NBS instrumentation and measurem procedures are described. Instrument calibration and e analyses are performed. Some of the analyses can also be app to reflectance measurements in general.

TN594-11. **Optical radiation measurements: Development o NBS reference spectrophotometer for diffuse transmittance reflectance,** W. H. Venable, Jr., J. J. Hsia, and V. R. Weid *Nat. Bur. Stand. (U.S.), Tech. Note 594-11,* 47 pages (1976) SD Catalog No. C13.46:594-11.

Key words: bidirectional reflectance factor; dif reflectance; diffuse transmittance; reflectance; s trophotometry.

A new reference spectrophotometer, designed primarily the analysis of diffuse transmittance and reflectance, has b developed in the Institute for Basic Standards at NBS. spectrophotometer consists of a broad band monochrom with optional bandpasses of 2, 5, 10, and 20 nanometers. exit aperture of the monochromator is provided with special ror optics to collimate and switch the beam for optional use reference or sample beam. These collimated beams are dire into a dark room where a variety of sample mounts, light gat ing devices, and detectors can be installed. Measurements which provisions have been made or are planned incl directional-hemispherical reflectance of solids, liquids, and p ders, directional-hemispherical reflectance as a function of a of incidence, diffuse transmittance, haze, and bidirecti reflectance factor. This technical note describes the design of instrument in detail, and gives the results of the performa tests and detailed error analyses which have been carried ou date.

TN594-12. **Optical radiation measurements: The translucent blurring effect—Method of evaluation and estimation,** J. J. Hsia, *Nat. Bur. Stand. (U.S.), Tech. Note 594-12,* 31 pages (Oct. 1976) SD Catalog No. C13.46:594-12.

Key words: blurring effect; edge loss; error analysis; flux loss; plastics; reflectance; scattering; spectrophotometry; translucency; transmittance; Vitrolite glass.

The translucent phenomenon which causes flux loss in the spectrophotometric measurement is described. Methods for mathematically evaluating the flux loss are examined, and experimental methods using laser and conventional light sources are described. A widely used Vitrolite glass standard is employed to demonstrate the error estimation and correction.

TN595. **Effect of ceramic spectral emissivity variations on the computed luminous emissivity of the NBS standard of light,** W. B. Fussell, Nat. Bur. Stand. (U.S.), Tech. Note 595, 58 pages (Sept. 1971).

Key words: Ceramic; light; photometry; spectral emissivity; standard.

A simplified model of the National Bureau of Standards (NBS) 1970 design for the standard of light (platinum point blackbody) is introduced. This model is used to calculate the apparent luminous emissivity of the base of the sighttube of the standard of light, and of the wall near the base, by two different methods. The first method includes the effect of variations with wavelength in the spectral emissivity of the ceramic composing the sighttube; the second method does not include the effect of ceramic spectral emissivity variations. The results of the two methods are compared and their difference (about 6×10^{-6}) is found to be negligible for the NBS 1970 design when the sighttube is made of alumina, compared with other uncertainties and the precision of measurement. A formula is derived for estimating the apparent luminous emissivity of the standard of light, given: a. the length-to-diameter ratio of the sighttube; b. the half-angle of the conical base; c. the wall thickness of the sighttube; d. the thermal conductivity of the sighttube ceramic; e. the average thermal and luminous emissivities of the sighttube ceramic.

TN596. **The flammable fabrics program 1970. U.S. Department of Commerce report of activities under the Flammable Fabrics Act 1970,** Nat. Bur. Stand. (U.S.), Tech. Note 596, 68 pages (Sept. 1971).

Key words: Annual report to Congress; blankets; carpets and rugs; children's sleepwear; cooperation; flammability; flammability reduction; mattresses; research; small carpets and rugs; standards; test development.

This Annual Report to the Congress, required by the Flammable Fabrics Act, covers calendar year 1970. Specific flammability standards outputs were standards for carpets and rugs and for small carpets and rugs, a proposed standard for children's sleepwear, and notices of possible need and institution of proceedings for standards for certain items of children's apparel, all blankets, and all mattresses. Research included studies, in-house and by contract, on subjects such as full scale carpet burn experiments and heat transfer from burning fabrics. Studies of the feasibility of reducing flammability included pyrolysis of textile materials and chemical aspects of fire retardancy. Test development was completely related to the standards outputs, and training ranged from the preparation of bibliographies through Congressional and public presentations to full time Research Associateship participation in the program. Cooperation was carried out with HEW, the public, industry, and voluntary standards groups.

TN597. **Tabulation of data on semiconductor amplifiers and oscillators at microwave frequencies,** C. P. Marsden, Nat. Bur. Stand. (U.S.), Tech. Note 597, 48 pages (Dec. 1971).

Key words: Amplifiers; basic characteristics; microwave; oscillators; semiconductor; solid state.

This tabulation includes some of the basic characteristics of semiconductor microwave devices, specifically amplifiers and oscillators of foreign and domestic origin.

TN598. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report January 1 to March 31, 1971,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 598, 54 pages (Oct. 1971).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, eleventh of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include application of tuning and other related procedures for ultrasonic wire bonders in an industrial environment with a reported reduction of rejection rate at visual inspection by more than a factor of two, more complete evaluation of the photovoltaic method for determining radial resistivity profiles of circular semiconductor wafers, and identification of test conditions in which a d-c calibration curve may properly be used in measurements of thermal resistance. Work is continuing on measurement of resistivity, carrier lifetime, and electrical inhomogeneities in semiconductor crystals; specification of germanium for gamma-ray detectors; evaluation of wire bonds and die attachment; measurement of thermal properties of semiconductor devices, transit-time and related carrier transport properties in junction devices, and electrical properties of microwave devices; and characterization of silicon nuclear radiation detectors. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN599. **A survey of selected document processing systems,** E. Fong, Nat. Bur. Stand. (U.S.), Tech. Note 599, 67 pages (Oct. 1971).

Key words: Bibliographic system; computer package; data base; document processing; document storage and retrieval; information retrieval; text; text processing.

There are many document processing systems that are commercially available or government-owned. These systems emerged in the evolution from early efforts in library automation to current on-line systems. Due to the diverse nature of the facilities provided in the document processing systems, it is difficult to evaluate them. The purpose of this paper is to present a list of features as a set of dimensions along which to compare the surveyed systems. The feature list is also developed to serve as a common basis for describing document processing systems. Another purpose of this paper is to provide a reference tool for the eight systems surveyed. They are CIRCOL, DDC ITIRC, The Mead Data Central, MEDLARS II, New York Times Information Bank, ORBIT II, and RECON/STIM. This paper first explored the characteristics of available, large document processing systems in general. An overview of the eight systems surveyed is presented. The paper then defines the feature list. The description of the eight systems surveyed according to the feature list outline is included as an Appendix.

TN600. **Corrections and calculations on an x-ray diffraction line profile: a computer program,** R. E. Schramm, Nat. Bur. Stand. (U.S.), Tech. Note 600, 34 pages (June 1971).

Key words: Computer programs; Fourier analysis; nickel steels; statistics; x-ray analysis; x-ray diffraction.

This computer program was written to perform corrections and make calculations on an x-ray diffraction profile before Fourier analysis. The corrections are for background and for variations of intensity with the Bragg angle. Also calculated are the separation of the $K\alpha_1$-$K\alpha_2$ doublet and the centroid and position of peak maximum with their standard deviations. There is also an option to smooth the profile.

TN601. **Unassigned.**

TN602. **A broadband noncontacting sliding short,** W. Larson and R. D. Hunter, Nat. Bur. Stand. (U.S.), Tech. Note 602, 18 pages (June 1971).

Key words: Microwave; reflection coefficient; return loss; shorted termination; sliding short; waveguide.

A new sliding short that eases microwave measurements also yields superior electrical and mechanical properties. Easily fabricated by encasing noncontacting cylindrical brass slugs in a block of polytetrafluoroethylene, the device slides smoothly and prevents metal-to-metal contact with the inside walls of precision waveguide.

Design details and results of intercomparing other short circuits are given.

TN603. **Construction of a flashlamp-pumped dye laser and an acousto-optic modulator for mode-locking,** D. A. Jennings and D. L. Baldwin, Nat. Bur. Stand. (U.S.), Tech. Note 603, 33 pages (July 1971).

Key words: Acousto-optic modulator; flashlamp-pumped dye laser; mode-locking; subnanosecond pulses.

In this paper is presented the design of a flashlamp-pumped dye laser capable of emitting light pulses 500 ns (FWHM) with a risetime of 300 ns. The energy output in the visible region of light is 1 to 10 mJ with an energy conversion efficiency of about 0.01% at a repetition rate of 30 pps. The design of an acousto-optic modulator used to mode-lock the dye laser by intracavity loss modulation is presented. The laser output for a given cavity length depends on the frequency and voltage applied to the modulator; a 10–100% modulated output can be obtained with 1–20 V rms, whereas a train of light pulses narrower than 0.8 ns (FWHM) can be obtained with 80 V rms.

TN604. **Efficient numerical and analog modeling of flicker noise processes,** J. A. Barnes and S. Jarvis, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 604, 22 pages (June 1971).

Key words: Analog noise simulation; computer noise simulation; digital filters; flicker noise; fractional integration; recursive digital filters.

It is shown that by cascading a few simple resistor-capacitor filters, a filter can be constructed which generates from a white noise source a noise signal whose spectral density is very nearly flicker, $|f|^{-1}$, over several decades of frequency f. Using difference equations modeling this filter, recursion relations are obtained which permit very efficient digital computer generation of flicker noise time-series over a similar spectral range. These analog and digital filters may also be viewed as efficient approximations to integrators of order one-half.

TN605. **An evaluation of positive displacement cryogenic volumetric flowmeters,** J. A. Brennan, J. W. Dean, D. B. Mann, and C. H. Kneebone, Nat. Bur. Stand. (U.S.), Tech. Note 605, 134 pages (July 1971).

Key words: Cryogenic; flow; flowmeters; liquid nitrogen; measurement; positive displacement.

The National Bureau of Standards (NBS) and the Compressed Gas Association (CGA) have jointly sponsored a research program on cryogenic flow measurement. A cryogenic flow research facility was constructed and was first used to evaluate commercially available cryogenic flowmeters operating on a positive displacement principle.

The operation and the accuracy of the flow facility is briefly described. The performance of the flowmeters on liquid nitrogen is described by reporting the precision and bias of the meters before and after an 80-hour stability test and by defining the existence of temperature, flow rate, subcooling, and time order (wear) dependencies.

Meters were evaluated with flow rates ranging from 0.0012 to 0.0063 m^3/s (20 to 100 gpm), pressures ranging from 0.22 to 0.77 MN/m^2 (32 to 112 psia), and with temperatures ranging from 72 to 90 K.

TN606. **Cryogenic flow research facility provisional accuracy statement,** J. W. Dean, J. A. Brennan, D. B. Mann, and C. H. Kneebone, Nat. Bur. Stand. (U.S.), Tech. Note 606, 40 pages (July 1971).

Key words: Accuracy statement; cryogenic; flow facility; liquid nitrogen; measurement.

The National Bureau of Standards and the Compressed Gas Association have jointly sponsored a research program on cryogenic flow measurement. A cryogenic flow research facility was constructed and was first used to evaluate commercially available cryogenic flowmeters operating with liquid nitrogen on a positive displacement principle.

The performance of the flow facility was simultaneously being evaluated during the meter tests. This is a summary report of the performance evaluation of the flow facility. An accuracy statement is given for both totalized mass and volumetric flow.

TN607. **The errors in plasma measurements by the microwave cavity techniques,** K-B Persson and E. G. Johnson, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 607, 64 pages (Oct. 1971).

Key words: Collision frequency; helium negative glow discharge; microwave cavity; plasma density.

This report presents the results of a theoretical and experimental study of the microwave cavity techniques used in measuring electron density and collision frequency in transient plasmas. Sources of errors are discussed and certain calibration procedures are recommended to minimize the error. In particular, the abnormal negative glow discharge in helium is presented as an inexpensive reference plasma for calibration purposes.

TN608. **Steam-water, critical flow in a venturi,** R. V. Smith, Nat. Bur. Stand. (U.S.), Tech. Note 608, 25 pages (July 1971).

Key words: Critical flow; pressure profile; steam; venturi; water.

This paper is the second part of an analytical and experimental investigation, in which the primary object was to test the hypothesis that the flow of the gas phase controls critical and near critical two-phase flow for cases where the gas and liquid flow essentially in separate streams. In the first part of the investigation, a two-component system (air-water) was used. The results presented here substantiate the hypothesis. The analytical results also indicate the use of one dimensional flow equations with reasonably accurate estimates for droplet size and for the drag and heat transfer coefficients (without consideration of mass transfer–vaporization or condensation) describe critical and near-critical flow reasonably well. This indicates that mass transfer may be a secondary effect for these flow conditions.

TN609. **Study of cryogenic storage tank fatigue life. Low temperature testing of AISI 304 and 310 stainless steels,** R. P. Reed, R.

. Durcholz, R. E. Schramm, and T. J. Patrician, Nat. Bur. tand. (U.S.), Tech. Note 609, 86 pages (Aug. 1971).

Key words: Fatigue; fracture; impact; low temperature; mechanical property equipment; stainless steel.

wo 300 series stainless steels were tested for impact-fatigue and tensile properties as a function of temperature, percent nsformed phase (martensite), stress level, and specimen metry. These alloys were studied to predict the fracture racteristics of parent material and weld joints in large ogenic dewars which are subjected to periodic stresses. Nor- ly, AISI 304 is employed in the construction of such dewars. der fatigue loading conditions at cryogenic temperatures, the avior of AISI 304 is complicated by the gradual transforma- n to a martensitic structure. The influence of this transforma- n on the fracture characteristics was studied. For this purpose, new impact-fatigue test and necessary equipment were veloped.

he fatigue strength of AISI 304 and 310 exhibit similar nds, but at a given fatigue life and temperature, the fatigue ength of AISI 304 is slightly superior. AISI 310 displays an durance limit of about 20,000 psi; the 304 limit is 25-30,000 . However, the lowest endurance limit (weakest) specimens ear to be the triaxially-loaded AISI 304 weld specimens ich have an endurance limit near 10,000 psi. Little tempera- e-dependence of the impact-fatigue properties was observed.

N610. **Application of VLF theory to time dissemination,** W. F. Hamilton and J. L. Jespersen, Nat. Bur. Stand. (U.S.), Tech. Note 610, 170 pages (Nov. 1971).

Key words: Diurnal phase; Omega; time; time dissemination; VLF propagation; zonal harmonics.

The characteristics of time dissemination systems are scussed. Particular emphasis is placed on the advantages and oblems of very low frequency (VLF) timing systems. The rameters affecting VLF propagation along with causes of riations in these parameters, are discussed. Three methods of mputing VLF propagation delays—mode theory, geometric- otics, and zonal harmonics—are compared. The method of nal harmonics, used for the calculations in this paper, is scussed in more detail. A method of calculating reflection coef- cients for a continuously varying ionosphere is described. The eoretical values are compared with experimental measure- ents. Graphical results of the calculations are included.

N611. **NBS frequency-time broadcast station WWV, Fort Collins, Colo.,** P. P. Viezbicke, Nat. Bur. Stand. (U.S.), Tech. Note 611, 29 pages (Oct. 1971).

Key words: High frequency; standard radio frequencies; time-frequency broadcasts; time signals; WWV.

This report describes the design and construction of the National Bureau of Standards frequency-time broadcast station ocated at Fort Collins, Colo. The principal function of the station is to broadcast basic standards of frequency and time signals n frequencies of 2.5, 5, 10, 15, 20, and 25 MHz. These high requency transmissions, which can be received on the simplest f equipment, provide the necessary accuracy required to fulfill ome of the needs of industry, Government, and the public. The echnical and administrative supervision of the station is under he Time and Frequency-Time Broadcast Services Section, National Bureau of Standards, Boulder, Colo.

TN612. **Frequency shifts due to Ramsey type interrogation in atomic beam tubes,** H. Hellwig, J. A. Barnes, D. J. Glaze, and P. Kartaschoff, Nat. Bur. Stand. (U.S.), Tech. Note 612, 25 pages (Feb. 1972).

Key words: Cavity phase shift; cesium beam tube; frequency accuracy; frequency standard; power shift; resonance line shape.

Part I: A phase difference between the two interaction regions of a Ramsey excitation resonance structure results in a frequency bias in the measured beam resonance. A simple mathematical model is discussed which describes the dependence of this bias on the phase difference, the microwave power level, the modulation amplitude, and the resonance linewidth. This dependence results from the interaction of the modulated microwave excitation frequency with the asymmetric shape of the slightly shifted resonance line. In a first order approximation, no dependency on the frequency modulation amplitude is expected. Near-linear dependencies on the linewidth and microwave power level which are quite pronounced even at relatively small cavity phase differences are predicted. The theoretical results are compared with one set of experimental data on the microwave power dependence as measured in 1969 with the primary cesium beam standard NBS-III. After a correction is applied to remove the power dependence due to spectral impurity of the microwave excitation, the remaining measured power dependence agrees quantitatively with that calculated using a cavity phase difference of about 3 milliradians.

Part II: One of the most serious effects limiting the accuracy of atomic beam resonators is the uncertainty of phase shifts between the oscillating fields in a Ramsey excitation cavity. A technique using the linewidth dependence on the excitation power to measure the phase-shift induced bias has recently been proposed. The conditions under which this method is valid and their implications on the design of beam optics will be discussed with consideration of available experimental results.

TN613. **Martensite transformation detection in cryogenic steels (magnetometer development),** F. R. Fickett, Nat. Bur. Stand. (U.S.), Tech. Note 613, 31 pages (Dec. 1971).

Key words: Fatigue monitor; low temperature; magnetometer; martensite; nondestructive.

This report presents design criteria for a magnetometer device developed to determine the martensite concentration in 304 stainless steel. Specifically, the device is designed to monitor the cold tank of an airborne liquid oxygen container which is subject to periodic stress pulses. The amount of martensite is relatable to the plastic strain and thus provides a mechanism for the prediction of impending failure.

The magnetometer, developed after a critical review of the constraints, is an excitation coil-Hall effect system. The system is very versatile in design and is easily adapted to particular problems. It is relatively insensitive to thermal and mechanical shock and easily capable of detecting martensite at the 1 percent level.

TN614. **Longitudinal magnetoresistance in polar semiconductors,** R. L. Peterson, Nat. Bur. Stand. (U.S.), Tech. Note 614, 47 pages (Apr. 1972).

Key words: Magnetophonon effect; magnetoresistance; semiconductors; transport theory.

The magnetophonon effect due to resonant interactions of charge carriers with optical phonons in nondegenerate polar semiconductors is studied when several elastic scattering mechanisms are simultaneously active also. The simple model of the band structure, and the displaced Maxwellian distribution function are used. Analytical expressions for drift mobility are given for $B = 0$ and the quantum limit, and are compared with the results of other techniques where possible. The numerical calculations show that whenever magnetophonon oscillations are seen in the ohmic regime, maxima occur near the resonance magnetic

fields for all lattice temperature and strengths of scattering mechanisms which compete with the optical phonon scattering. This is in contrast with typical experimental findings, in which minima usually (but not always) appear near the resonance fields for ohmic, longitudinal, conditions. The explanation of the minima must therefore be sought in the use of a distribution function in which carrier-carrier scattering is less important.

TN615. **WR15 thermal noise standard,** W. C. Daywitt, W. J. Foote, and E. Campbell, Nat. Bur. Stand. (U.S.), Tech. Note 615, 154 pages (Mar. 1972).

Key words: Error analysis; millimeter wave; noise; Nyquist's theorem; thermal noise standard.

This note describes the design and construction of a WR15 thermal noise power standard. The standard is designed to operate around the Silver Point Temperature (963.19 °C) with a noise temperature output accurate to approximately ± 2 K.

Complete details of the theory, design, construction, and performance tests are given.

TN616. Revised March 1974. **Frequency standards and clocks: A tutorial introduction,** H. Hellwig, Nat. Bur. Stand. (U.S.), Tech. Note 616 (Revised), 72 pages (Mar. 1974) SD Catalog No. C13.46:616 (Rev.).

Key words: cesium beam; clocks (atomic); crystal oscillator; frequency accuracy; frequency stability; frequency standards; hydrogen maser; quartz crystal; rubidium gas cell; timekeeping.

The topic of frequency standards and clocks is treated in a tutorial and nonmathematical way. The concepts of time, frequency stability, and accuracy are introduced. The general physical principles and design features of frequency standards and clocks are described. The design, performance, and limitations of quartz crystal oscillators and atomic devices (cesium, hydrogen, rubidium) are discussed in detail and critically compared for laboratory devices as well as for devices intended for field usage.

TN617. **Thermophysical properties of parahydrogen from the freezing liquid line to 5000 R for pressures to 10,000 psia,** R. D. McCarty and L. A. Weber, Nat. Bur. Stand. (U.S.), Tech. Note 617, 169 pages (Apr. 1972).

Key words: Density; dielectric constant; enthalpy; entropy; equation of state; fixed points; heat transfer coefficients; hydrogen; index of refraction; Joule-Thomson; latent heat; melting point; Prandtl number; specific heat; speed of sound; surface tension; thermal conductivity; thermal diffusivity; vapor pressure; viscosity; volume.

Tables of thermophysical properties of para hydrogen are presented for temperatures from the melting line to 5000 R for pressures from 1 to 10,000 psia. The tables include entropy, enthalpy, internal energy, density, volume, speed of sound, specific heat, thermal conductivity, viscosity, thermal diffusivity, Prandtl number and the dielectric constant for 65 isobars. Also included in the isobaric tables are quantities of special utility in heat transfer and thermodynamic calculations: $(\partial P/\partial V)_T$, $(\partial P/\partial T)_V$, $V(\partial H/\partial V)_P$, $V(\partial P/\partial U)_V$, $-V(\partial P/\partial V)_T$, $1/V(\partial V/\partial T)_P$.

In addition to the isobaric tables, tables for the saturated vapor and liquid are given which include all of the above properties, plus the surface tension. Tables for the P-T of the freezing liquid, index of refraction and the derived Joule-Thomson inversion curve are also presented.

TN618. **WR15 microwave calorimeter and bolometer unit,** M. E. Harvey, Nat. Bur. Stand. (U.S.), Tech. Note 618, 41 pages (May 1972).

Key words: Calorimeter; microwave; power; standard.

A microwave calorimeter which serves as the National Bure of Standards (NBS) standard for power measurements in frequency range 50 to 75 GHz has been completed and eva ated recently. Included here are descriptions of the princi changes in the calorimeter and bolometer unit from the WR models which are of similar design. Also included are constr tion details, accessory equipment, operation procedure, a error analysis. An improved thermal isolating waveguide secti and calorimeter flange are features of this calorimeter.

A careful error analysis permits the determination of the eff tive efficiency of a standard bolometer unit to estimated limits systematic uncertainty of ±0.23%. The estimated 3σ limit random uncertainty is 0.05%.

TN619. **Millimeter attenuation and reflection coefficient measu ment system,** B. C. Yates and W. Larson, Nat. Bur. Sta (U.S.), Tech. Note 619, 175 pages (July 1972).

Key words: Attenuation; measurement system; millimet reflection coefficient, VSWR.

This paper presents the details to implement a WR 15 atten tion and reflection coefficient magnitude measurement syste A discussion of precision and of systematic error is given alo with equations for estimating limits of the error. Machi drawings are provided to fabricate the waveguide standards a necessary hardware not commercially available.

TN620. **Frequency and phase stabilization of an HCN laser locking to a synthesized reference,** J. S. Wells and D. Halfo Nat. Bur. Stand. (U.S.), Tech. Note 620, 56 pages (May 19 60 cents, SD Catalog No. C13.46:620.

Key words: Fast linewidth; frequency noise; HCN las infrared frequency synthesis; laser frequency measu ments; laser linewidth; laser stabilization; phase lock laser.

Infrared frequencies as high as 88 THz have recently be synthesized using diode harmonic mixers with accuracies parts in 10^9. Stabilized lasers are needed to make frequency m surements of higher accuracy. The HCN laser is the low frequency basis laser used in these synthesis schemes and its s bilization has been the subject of recent interest. The laser is s bilized by locking it to a phase locked microwave referer chain. Two servo loops are utilized. The first loop is a relativ slow frequency lock loop with the correction applied to a P

TN621. **Liquid-vapor equilibrium in the binary systems of H and He^3 with nD_2 and nH_2,** M. J. Hiza, Nat. Bur. Stand. (U.S Tech. Note 621, 66 pages (July 1972).

Key words: Binary systems; gas solubility; He^4-nD_2; H nD_2; He^4-nH_2, He^3-nH_2; liquid-vapor equilibrium; n vapor pressure; nH_2 vapor pressure.

Experimental data are reported for the equilibrium liquid a vapor phase compositions of the He^4-nD_2 and He^3-nD_2 syste from 20 to 30 K and the He^4-nH_2 and He^3-nH_2 systems from to 28 K. The maximum experimental pressures were 20 and atm (2.0 and 1.6 MN/m²) for the He^4 and He^3 systems, resp tively. In addition, vapor pressures were measured from 20 to K for nD_2 and from 20 to 30 K for nH_2.

Values of Henry's constants, enhancement factors, K-valu and heats of solution were derived from the experimental d for each system. The derived properties are compared with th derived from previous data for the He^4-nH_2, He^4-pH_2, and H nH_2 systems.

river. This loop not only accommodates thermal expansion of ne laser, but also serves as an acquisition aiding loop for the econd servo. The latter is a phase locked system with the cor-ection applied to the laser discharge current.

Details of the laser design and some noise considerations rela-ve to the microwave reference chain are presented along with ome experimental data which indicate the results of the sta-ilization techniques. Data regarding the system stability and im-roved fast linewidth are included.

N622. **Thermophysical properties of helium-4 from 4 to 3000 R with pressures to 15,000 psia,** R. D. McCarty, Nat. Bur. Stand. (U.S.), Tech. Note 622, 141 pages (Sept. 1972).

Key words: Density; dielectric constant; enthalpy; entropy; equation of state; fixed points; heat transfer coefficients; helium 4; index of refraction; Joule-Thomson coefficient; lambda line; latent heat; melting point; Prandtl number; specific heats; speed of sound; surface tension; thermal conductivity; thermal diffusivity; vapor pressure; viscosity; volume.

Tables of thermophysical properties of helium 4 are presented r temperatures from 4 to 3000 Rankine for pressures to 15,000 ia. The tables include entropy, enthalpy, internal energy, den-y, volume, speed of sound, specific heat, thermal conductivity, scosity, thermal diffusivity, Prandtl number and the dielectric nstant for 74 isobars. Also included in the isobaric tables are antities of special utility in heat transfer calculations: $(\partial P/\partial V)_T$, $P/\partial T)_\rho$, $V(\partial H/\partial V)_P$, $V(\partial P/\partial U)_V$, $-V(\partial P/\partial V)_T$, $1/V(\partial V/\partial T)_P$.

In addition to the isobaric tables, tables for the saturated vapor id liquid are given which include all of the above properties, us the surface tension. Tables for the $P\rho T$ of the freezing quid, $P\rho T$ of the lambda line, index of refraction and the rived Joule-Thomson inversion curve are also presented.

N623. **Invariance of the cross ratio applied to microwave network analysis,** R. W. Beatty, Nat. Bur. Stand. (U.S.), Tech. Note 623, 23 pages (Sept. 1972).

Key words: Anharmonic ratio; automatic network analyzers; cross ratio; microwave network analysis; reflection coefficient; scattering coefficient.

The historical background and theory is given of the applica-on of the mathematical principle "invariance of the cross ratio" microwave network analysis. Further developments to im-rove the accuracy of automatic network analyzers are sug-ested.

N624. **An evaluation of several cryogenic turbine flowmeters,** J. A. Brennan, R. W. Stokes, D. B. Mann, and C. H. Kneebone, Nat. Bur. Stand. (U.S.), Tech. Note 624, 90 pages (Oct. 1972).

Key words: Cryogenic; flow; liquid nitrogen; mass; mass flowmeters; measurement; turbine flowmeters; volume flowmeters.

The National Bureau of Standards (NBS) and the Compressed as Association (CGA) have jointly sponsored a research pro-am on cryogenic flow measurement. A cryogenic flow research cility was constructed and has been used to evaluate cryogenic owmeters operating on several different principles.

The operation and the accuracy of the flow facility is briefly escribed. The performance of the flowmeters in liquid nitrogen described by reporting the precision and bias of the meters be-re and after an 80-hour stability test and by defining the ex-tence of temperature, pressure, flow rate, subcooling, and time rder (wear) dependencies.

Meters were evaluated with flow rates ranging from 20 to 210 gpm (1.3 to 13.2 l/s), pressures ranging from 32 to 112 psia (0.22 to 0.77 MN/m²), and with temperatures ranging from 72 to 90 K.

TN625. **Computer programs for thermodynamic and transport properties of hydrogen (Tabcode-II),** H. M. Roder, R. D. McCarty, and W. J. Hall, Nat. Bur. Stand. (U.S.), Tech. Note 625, 226 pages (Oct. 1972) $1.75, SD Catalog No. 13.46:625.

Key words: Computer programs; density; enthalpy; entropy; heat capacity at constant pressure; heat capacity at constant volume; heat capacity ratio; heat transfer coefficient; hydrogen; pressure; saturation boundary; temperature; thermal conductivity; velocity of sound; viscosity.

The thermodynamic and transport properties of para and equilibrium hydrogen have been programmed into a series of computer routines. Input variables are the pair's pressure- temperature and pressure-enthalpy. The programs cover the range from 1 to 5000 psia (34 MN/m²) with temperatures from the triple point to 6000 °R (3300 K) or enthalpies from − 130 Btu/lb (− 623 J/mol) to 25,000 Btu/lb (117000 J/mol). Output variables are enthalpy or temperature, density, entropy, thermal conductivity, viscosity, velocity of sound, heat capacity at constant pressure, heat capacity at constant volume, the heat capacity ratio, and a heat transfer parameter. Property values on the liquid and vapor boundaries are conveniently obtained through two small routines. The programs achieve high speed by using linear interpolation in a grid of precomputed points which define the surface of the property returned. The maximum errors arising from the linear interpolation are shown on individual deviation plots for each combination of variables. Error estimates for the sources of data are similarly displayed.

TN626. **The generation of an accurate and uniform time scale with calibrations and prediction,** K. Yoshimura, Nat. Bur. Stand. (U.S.), Tech. Note 626, 64 pages (Nov. 1972) 60 cents, SD Catalog No. C13.46:626.

Key words: Accurate and uniform time scale; Allan variance; dispersion of time scale; ensemble time (error); prediction interval; primary standard and clocks.

We express a predicted time interval (or frequency) of a single clock as a weighted sum of frequency data obtained by calibrations against a primary standard, and derive a matrix equation for the optium weighting coefficients (called the optimum filter response function) involving the Allan variances. Two approaches are used. One of the approaches turns out to be a generalization of Barnes' approach in his 1966 IEEE paper.

We solve the matrix equation to get the optimum filter response functions for white noise frequency modulation (FM), flicker noise FM and linear combinations of them. Other important time dispersive mechanisms exist in practice but are not considered here. We obtain the result that the mean square time prediction error would increase as elapsed time t^2 for the case without intermediate calibrations.

We obtain the result that with a small number of good clocks one can construct a time scale whose accuracy is limited by the accuracy of a primary standard. We show that, over a long time range, linear prediction algorithms based on frequency calibrations with a primary standard give a time scale of much better accuracy and stability than when intermittent calibrations are not used, and that (at least for statistically identical clocks), *no advantage is gained* by using the time scale itself as a "primary standard" for intermediate calibrations.

TN627. **Computation of spectral data for a Josephson junction circuit,** E. G. Johnson, Jr. and D. G. McDonald, Nat. Bur.

Stand. (U.S.), Tech. Note 627, 63 pages (Nov. 1972) 60 cents, SD Catalog No. C13.46:627.

Key words: Differential equation; fast Fourier transform; Josephson junction; nonlinear integral-differential equation; spline theory.

A computer program has been developed to study power flow between different frequency channels in a Josephson junction circuit. This paper discusses the mathematical assumptions used to get such results. They are the trapezoidal approximation from spline theory and the use of a finite range of frequencies to characterize the frequency spectrum. This paper describes the program and provides the FORTRAN listing, flow charts, and discusses how to use the program. A discussion of possible sources of errors is also included.

TN628. **On the utility of the m-6-8 potential function,** H. J. M. Hanley and M. Klein, Nat. Bur. Stand. (U.S.), Tech. Note 628, 77 pages (Nov. 1972) 70 cents, SD Catalog No. C13.46:628.

Key words: Dispersion coefficients; m-6-8 potential; parameter selection; second virial coefficients; transport properties.

The calculation of transport and equilibrium properties of simple gases with the m-6-8 potential function is discussed. Properties referred to specifically are the viscosity, diffusion, thermal conductivity and second virial coefficients, and the thermal diffusion factor. Gases referred to are argon, krypton, xenon, nitrogen, oxygen, carbon dioxide and methane. We also discuss in detail the general behavior of a model potential with respect to the fitting of data and the selection of potential parameters. The m- 6-8 appears to be the simplest model potential which can satisfactorily be used to fit data over a wide temperature range. The relationship of the potential to independent theory is briefly examined.

TN629. **Superconducting quantum interference devices: An operational guide for rf-biased systems,** D. B. Sullivan, Nat. Bur. Stand. (U.S.), Tech. Note 629, 47 pages (Nov. 1972) 50 cents, SD Catalog No. C13.46:629.

Key words: Electrical measurements; quantum interference devices; superconductivity.

The report discusses a number of practical considerations concerning the operation and application of rf-biased Superconducting QUantum Interference Devices (SQUID's). In the course of routine operation of these devices one amasses a set of operational rules, many of which never reach the open literature. This report is aimed at filling that void. Topics of discussion include: the readout circuitry, operational limits of the SQUID, rf-coupling to the SQUID, flux transformers, and shielding.

TN630. **Developments in cryoelectronics,** R. A. Kamper and D. B. Sullivan, Nat. Bur. Stand. (U.S.), Tech. Note 630, 73 pages (Nov. 1972) 70 cents, SD Catalog No. C13.46:630.

Key words: Electronics; Josephson effect; precise measurements; superconductivity.

This is a survey of progress to date in the development of new electronic instruments taking advantage of the unique properties of superconductors.

TN631. **Thermophysical properties of helium-4 from 2 to 1500 K with pressures to 1000 atmospheres,** R. D. McCarty, Nat. Bur. Stand. (U.S.), Tech. Note 631, 161 pages (Nov. 1972) $1.25, SD Catalog No. C13.46:631.

Key words: Density; dielectric constant; enthalpy; entropy; equation of state; fixed points; heat transfer coefficients; helium 4; index of refraction; Joule-Thomson coefficient; lambda line; latent heat; melting point; Prandtl number; specific heats; speed of sound; surface tension; thermal conductivity; thermal diffusivity; vapor pressure; viscosity; volume.

Tables of thermophysical properties of helium 4 are presented for temperatures from 2 to 1500 K for pressures to 1000 atmospheres. The tables include, entropy, enthalpy, internal energy, density, volume, speed of sound, specific heat, thermal conductivity, viscosity, thermal diffusivity, Prandtl number and the dielectric constant for 62 isobars. Also included in the isobaric tables are quantitites of special utility in heat transfer calculations: $(\partial P/\partial V)_T$, $(\partial P/\partial T)_\rho$, $V(\partial H/\partial V)_P$, $V(\partial P/\partial U)_V$, $-V(\partial P/\partial V)_T$, $1/V(\partial V/\partial T)_P$.

In addition to the isobaric tables, tables for the saturated vapor and liquid are given which include all of the above properties, plus the surface tension. Tables for the $P\rho T$ of the freezing liquid, $P\rho T$ of the lambda line, index of refraction and the derived Joule-Thomson inversion curve are also presented. A computer program to calculate the various properties is also available. Inquiries should be addressed to the National Bureau of Standards, Cryogenic Data Center, Boulder, Colorado 80302.

TN632. **Frequency stability specification and measurement: High frequency and microwave signals,** J. H. Shoaf, D. Halford, and A. S. Risley, Nat. Bur. Stand. (U.S.), Tech. Note 632, 70 pages (Jan. 1973) 65 cents, SD Catalog No. C13.46:632.

Key words: Allan variance; frequency stability measurements; measurement system description; phase noise, spectral density; stability definitions; terminology standards.

This report gives concise definitions for specifying stability for measurements in the frequency domain and time domain. Standards of terminology and of measurement techniques are recommended. Measurement systems in the high frequency and microwave regions are described in adequate detail so that the systems may be duplicated.

TN633. **Critical two-phase flow for cryogenic fluids,** R. V. Smith, K. R. Randall, and R. Epp, Nat. Bur. Stand. (U.S.), Tech. Note 633, 80 pages (Jan. 1973) 70 cents, SD Catalog No. C13.46:633.

Key words: Analyses; analytical models; choking flow; critical flow; cryogenic fluids; helium; hydrogen; oxygen; reviews; two-phase flow.

This work presents a state-of-the-art survey intended to be useful to a designer of equipment involving two-phase flow of cryogenic fluids. It is desirable to assess the probability of critical, or choking flow in such a system and, if possible, estimate the critical flow rate. The literature is surveyed, primarily since Smith (1963), and the predictive results for several analytical models are evaluated and compared with experimental data. These results are discussed; however, no firm conclusions are reached because, often, the spread of experimental data is equivalent to the predictive results from the models. Finally, computer evaluations are presented for oxygen, hydrogen and helium along with some design recommendations.

TN634. **Lorenz ratios of technically important metals and alloys,** J. G. Hust and L. L. Sparks, Nat. Bur. Stand. (U.S.), Tech. Note 634, 133 pages (Feb. 1973) $1.25, SD Catalog No. C13.46:634.

Key words: Alloys; compilation; cryogenic; electrical resistivity; Lorenz ratio; metals; thermal conductivity.

A comprehensive review and compilation of the world liter-

re on Lorenz ratio of technically important metals and alloys presented. Lorenz ratio, electrical resistivity, thermal conductivity and characterization data are compiled in tabular form and e Lorenz ratio data are presented in graphical form as well. ata are included here only if the research reported both thermal nductivity and electrical resistivity of the specimens. No attempt has been made to smooth data or present recommended alues.

N635. **Some applications of cryogenics to high speed ground transportation,** V. C. Arp, A. F. Clark, and T. M. Flynn, Nat. Bur. Stand. (U.S.), Tech. Note 635, 29 pages (Feb. 1973) 35 cents, SD Catalog No. C13.46:635.

Key words: Levitation; magnetic suspension; materials fatigue data; refrigeration; superconducting magnets; transportation.

The current status (December 1972) of worldwide research on gh speed ground transportation techniques is reviewed. Parcular attention is given to studies of magnetic levitation using perconducting magnets, including comparison with alternative agnetic techniques and with air suspension systems. Superconucting levitation appears to be a strong contender in the U.S. epartment of Transportation hopes to select in the late 1970's he best of the possible levitation techniques for subsequent adanced development. Cryogenic engineering research needed in upport of major development of a superconducting levitated ystem is identified.

N636. **Modeling of atomic clock performance and detection of abnormal clock behavior,** W. A. Ganter, Nat. Bur. Stand. (U.S.), Tech. Note 636, 39 pages (Mar. 1973) 50 cents, SD Catalog No. C13.46:636.

Key words: Atomic clock model; detection; flicker noise; sequential test; time scale.

We have assumed that the nominal performance of an atomic lock can be well characterized by (1) a noise amplitude and (2) mix of white and flicker pure noise processes. A number of pecific kinds of changes are assumed that a clock might encounter. We assume that these changes can occur with either ign and with varying magnitudes. The changes considered are noise amplitude different from nominal, a flicker component in he noise mix which is different from nominal, a step jump in the ime counts for a clock and a linear (frequency jump) or uadratic (frequency drift) trend in the time counts for a clock.

Detection of a change is accomplished with a multiple sequenial test having compound limits. The test is designed to respond uickly to an actual change but to make few incorrect detections identify the wrong change) or false detections (when no change rom nominal operation has occurred). When a change is deected for a clock, the laboratory time scale can be adjusted accordingly for this condition.

TN637. **Theory of UHF and microwave measurements using the power equation concept,** G. F. Engen, Nat. Bur. Stand. (U.S.), Tech. Note 637, 68 pages (Apr. 1973) 70 cents, SD Catalog No. C13.46:637.

Key words: Microwave; microwave measurements; power equation; power measurement; terminal invariant.

Theoretical considerations indicate that, in addition to other advantages, UHF and microwave measurements based on the power equation concept should exhibit reduced sensitivity to certain connector imperfections. This has now been experimentally confirmed in a number of laboratories, and interest in these methods is increasing. The previously described measurement techniques, for implementing this concept, have relied heavily upon tuning procedures, while current trends are towards automation where tuning is impractical if not impossible.

By assuming a phase detection capability (such as is found in automated systems) it is possible to eliminate the tuning requirement. Moreover, this generalization has made it possible to summarize the earlier results in a compact form. In addition, this paper includes a number of new measurement ideas.

It is expected that this report will serve as a major reference in the continuing development of detailed measurement procedures which exploit the power equation concept.

TN638. **A synchronous satellite time delay computer,** W. F. Hamilton and D. W. Hanson, Nat. Bur. Stand. (U.S.), Tech. Note 638, 39 pages (July 1973) 45 cents, SD Catalog No. C13.46:638.

Key words: Satellite timing; slant range; synchronous satellites; time delay.

A special purpose slide rule designed to compute the free space propagation delay between a synchronous satellite and points on the earth's surface is discussed. The slide rule was developed to provide users of time information relayed by geostationary satellites a means of computing the propagation delays without dealing directly with the satellite's orbital elements. The delays computed with the slide rule are compared with the values obtained from orbital elements using a high precision digitial computer. The limitations and accuracy of the slide rule are discussed. A sample slide rule which may be cut out and used is included in the report.

TN639. **Publications and services of the National Bureau of Standards, Cryogenics Division, Institute for Basic Standards, Boulder, Colo. 80302, 1953-1972,** J. R. Mendenhall, V. J. Johnson, and N. A. Olien, Nat. Bur. Stand. (U.S.), Tech. Note 639, 82 pages (Aug. 1973) 75 cents, SD Catalog No. C13.46:639.

Key words: Author indexes; bibliography; cryogenics; liquefaction; metrology; properties of fluids; properties of solids; subject indexes; superconductivity; transport processes.

This NBS Technical Note catalogs the publications of the Cryogenics Division, along with author and subject indexes, for the period 1953 through 1972. It also contains a listing of available thermodynamic properties charts, bibliographies, and miscellaneaous reports of cryogenic interest.

A resumé of the activities of and services provided by the Cryogenics Division is also included.

TN640. **Considerations for the precise measurement of amplifier noise,** D. F. Wait, Nat. Bur. Stand. (U.S.), Tech. Note 640, 129 pages (Aug. 1973) $1.25, SD Catalog No. C13.10.46:640.

Key words: Amplifier noise; effective input noise temperature; mismatch error; mismatch uncertainty; noise figure.

For the best accuracy in measuring noise figure, attention needs to be given to the choice of the hot and the cold noise standards and to mismatch problems. Tables and graphs are presented to aid in choosing the proper measurement conditions, and an example is given to demonstrate their use. This paper essentially supplements a previous paper (included in an appendix), treating in more detail topics that become important when state-of-the-art measurements are required.

TN641. **Survey of the properties of the hydrogen isotopes below their critical temperatures,** H. M. Roder, G. E. Childs, R. D. McCarty, and P. E. Angerhofer, Nat. Bur. Stand. (U.S.), Tech. Note 641, 122 pages (Oct. 1973) $1.25, SD Catalog No. C13.46:641.

Key words: Compilation; density; deuterium; electrical properties; enthalpy; entropy; fixed points; hydrogen; mechanical properties; optical properties; specific heat; thermophysical properties; transport properties; tritium; vapor pressure.

The survey covers PVT, thermodynamic, thermal, transport, electrical radiative and mechanical properties. All isotopic as well as ortho-para modifications of hydrogen have been included. Temperatures are limited to those below the respective critical points, in general below 40 K. The pressure range is not restricted, that is solid, liquid, and gas phases are covered. However, with the exception of hydrogen, very little data exists at pressures other than saturation. The literature surveyed includes all references available to the Cryogenic Data Center up to June of 1972, and for several subjects, through March of 1973. The total number of documents considered was nearly 1500 of which about 10 percent contain pertinent information and are referenced in this report. The various properties are presented in the form of tables of graphs; if extensive tables have been published elsewhere, the reader is referred to the original sources.

TN642. **Summary of WR15 flange evaluation at 60 GHz,** B. C. Yates and G. J. Counas, Nat. Bur. Stand. (U.S.), Tech. Note 642, 32 pages (Oct. 1973) 40 cents, SD Catalog No. C13.46: 642.

Key words: Attenuation; flange measurements; reflection coefficients; VSWR.

The measurement results of flange loss and reflection coefficient magnitude at 60 GHz (WR15 waveguide) of various flange configurations are presented. Included are the effects of alignment pins, surface finish, metallic contact surface, contact area, and flange bolt torque.

TN643. **Measurement of rf power and attenuation using superconducting quantum interference devices,** R. A. Kamper. M. B. Simmonds, C. A. Hoer, and R. T. Adair, Nat. Bur. Stand. (U.S.), Tech. Note 643, 93 pages (Aug. 1973) $1.00, SD Catalog No. C13.46:643.

Key words: Josephson effect; quantum interference; rf attenuation; rf measurement; rf power; superconductivity.

This report is the product of the first two years' work on a project to exploit an entirely new principle for the measurement of rf power and attenuation, namely the Superconducting QUantum Interference Device (SQUID). This is a simple circuit of superconducting metal, operating at a very low temperature in a bath of liquid helium. It functions as a sensor of magnetic flux with an almost perfectly periodic response over a wide dynamic range. It may therefore be used to measure dc or rf electrical quantitites such as current, power, attenuation, etc., in circuits inductively coupled to it. Measurements of these quantities can be made by counting off periods in the response of the SQUID (flux quanta) in the same way that we measure length with a laser by counting off wavelengths of light.

This work is partly funded by the CCG under project number 72-72. It has reached the stage of a demonstration that the new principle can indeed be used for precise measurement. We have developed and tested prototype systems for measuring power and attenuation as accurately as we can test by the conventional means available to us. A single calibration with dc is required to measure absolute rf power in the range of frequency from 0 to 1 GHz at levels from 10^{-8}W to 10^{-3}W with an uncertainty of ± 0.1 dB at the port of the SQUID. Transferring this measurement to calibrate a source of power would require a proper evaluation of the intervening network over the full range of frequency. We have demonstrated the feasibility of extending our measur ments of power to much lower levels. No external calibration required to measure rf attenuation directly over a dynamic ran of 45 dB with an rms deviation of ± 0.002 dB from calibratio performed by the NBS Calibration Service.

After an elementary exposition of the basic principles of o technique, we describe: the SQUIDs themselves; the prototy systems we have developed to measure rf power and attenu tion; systematic errors and fundamental limitations of the me surements that can be performed with them; and the obvious a immediate improvements that can be applied to them. V reserve an appendix for detailed drawings and instructions f the fabrication of components.

In order to make this report self-contained, we have includ the material from previous reports that has successfu withstood the test of time.

TN644. **Application of a non-ideal sliding short to two-port l measurement,** M. P. Weidman and G. F. Engen, Nat. B Stand. (U.S.), Tech. Note 644, 40 pages (Oct. 1973) 50 cen SD Catalog No. C13.46:644.

Key words: Efficiency; loss; reflectometer; sliding sho two-port.

A detailed, applications-oriented, description of a method measuring two-port losses is given. The technique involved u a non-ideal sliding short circuit and a tuned four-arm reflecto ter. Most, if not all, of the components used in this technique c be put together using commercially available items. It is the tent of this discussion to provide enough detail and explanati so that a technician with some working knowledge of microwa measurements can set up and make loss measurements.

The reference made to two-ports implies a broad range devices from a simple flange or connector to waveguide coa adaptors and even more elaborate configurations with a defi ble input and output connection.

TN645. **Time and frequency broadcast experiments from ATS-3 satellite,** D. W. Hanson and W. F. Hamilton, Nat. B Stand. (U.S.), Tech. Note 645, 115 pages (Nov. 1973) $1. SD Catalog No. C13.46:645.

Key words: Dissemination; frequency; satelli synchronization; time.

An experiment designed to reveal the advantages and spe problems associated with the broadcasting of time and freque information from geostationary satellites is discussed. Inclu are discussions concerning satellite motion, time delay variat doppler shift due to the motion, and calculation of de Receiver or ground station equipment requirements, t recovery techniques, timing resolution and accuracy, and spe advantages of satellite broadcasts for time and frequency semination are also discussed. Specially equipped sites in N and South America gathered data from the experimental sate broadcast which in turn were used to determine the potential curacy of satellite dissemination, the results of which presented. Delay computation aids for the user were designe provide a simple and inexpensive means of computing free sp delays between the master clock and the user via a geostatio satellite. The aids, delay overlays on an earth map and a circ slide rule, are discussed with examples. Qualitative discuss of the signals and broadcast format are given. Final comm are made concerning the results of the experiment and how t might reflect upon a final system design for a permanent ser using one or more geostationary satellites.

TN646. **Status report on primary frequency standards,** H. H

wig, Nat. Bur. Stand. (U.S.), Tech. Note 646, 15 pages (Sept. 1973) SD Catalog No. C13.46:646.

Key words: accuracy; atomic frequency standards; cesium beam tubes; clocks; hydrogen masers; lasers; primary frequency standards.

This report surveys the state-of-the-art in atomic frequency standards with exclusive regard to their use as primary frequency reference; i.e., only accuracy is discussed. The report covers operational standards as well as devices which are still in the research or exploratory development phase. It is predicted that accuracies of better than 1×10^{13} will be achieved within a few years, and that, as a consequence of new techniques, accuracy may be treated statistically in the not too distant future. Also, clocks may become available which state accuracy continually.

TN647. **Microwave attenuation measurement system (series substitution),** W. Larson and E. Campbell, Nat. Bur. Stand. (U.S.), Tech. Note 647, 28 pages (Feb. 1974) SD Catalog No. C13.46:647.

Key words: attenuation; measurement; rotary-vane attenuator; series substitution.

A dual detection microwave bridge circuit has been incorporated in a series substitution system for the measurement of microwave attenuation devices. The use of an optical rotary-vane attenuator in the system yields practical resolution and stability of 0.00005 dB from zero to 30 dB. The dual detection system has several favorable features: (1) it employs a single microwave source which reduces cost, (2) measurements are obtained without power stabilization of the microwave signal source, and (3) this waveguide configuration enables measurements of attenuation devices at any length with minimum of effort and movement of waveguide components.

The system configuration is convenient for both attenuation difference, and insertion loss measurements from zero to 70 dB over the WR90 waveguide band of 8.2 to 12.4 GHz.

TN648. **Thermophysical properties of nitrogen from the fusion line to 3500 R (1944 K) for pressures to 150,000 psia (10342 $\times 10^5$ N/m²),** R. T. Jacobsen, R. B. Stewart, R. D. McCarty, and H. J. M. Hanley, Nat. Bur. Stand. (U.S.), Tech. Note 648, 162 pages (Dec. 1973) SD Catalog No. C13.46:648.

Key words: density; dielectric constant; enthalpy; entropy; equation of state; fixed points; heat transfer coefficients; index of refraction; Joule-Thomson; latent heat; melting point; nitrogen; Prandtl number; specific heat; speed of sound; surface tension; thermal conductivity; thermal diffusivity; vapor pressure; viscosity; volume.

Tables of thermophysical properties of nitrogen are presented for temperatures from the fusion line to 3500 R for pressures to 3000 psia, and from the fusion line to 1500 R for pressures above 3000 psia to 150,000 psia. The tables include values of entropy, enthalpy, internal energy, density, specific volume, velocity of sound, specific heats (C_v and C_p), thermal conductivity, viscosity, thermal diffusivity, Prandtl number, and the dielectric constant for selected isobars. Additional tables are included for values of: $(\partial P/\partial V)_T$, $(\partial P/\partial T)_\rho$, $V(\partial H/\partial V)_\rho$, $(\partial P/\partial U)_v$, $V(\partial P/\partial V)_T$, and $(\partial V/\partial T)_p$, which have special utility in heat transfer calculations. Tables of selected isobars for the liquid and vapor phases, and for the saturated vapor and saturated liquid are included.

An equation of state is presented for liquid and gaseous nitrogen for the temperature and pressure ranges of these tables. In the determination of the equation of state, all of the P-ρ-T (pressure-density-temperature) data available from the published literature were reviewed, and appropriate corrections made to bring experimental temperatures into accord with the International Practical Temperature Scale of 1968. The coefficients of the equation of state were determined by a weighted least squares fit to selected P-ρ-T data and simultaneously to C_v data determined by corresponding states analysis from oxygen data, and to data which defined the phase equilibrium criteria for the saturated liquid and saturated vapor. A vapor pressure equation, melting curve equation, and an equation to represent the ideal gas heat capacity of nitrogen are also presented. The equation of state is estimated to be accurate to within 0.5 percent in the liquid region, to within 0.1 percent for supercritical isotherms up to 15,000 psia, and to within 0.3 percent from 15,000 to 150,000 psia. The vapor pressure equation is accurate to within ± 0.01 K between the triple point and the critical point.

TN649. **The standards of time and frequency in the U.S.A.,** J. A. Barnes and G. M. R. Winkler, Nat. Bur. Stand. (U.S.), Tech. Note 649, 91 pages (Feb. 1974) SD Catalog No. C13.46:649.

Key words: astronomical time measurements; clock synchronization; clocks; Coordinated Universal Time (UTC); frequency; frequency standards; International Atomic Time (TAI); International Radio Consultative Committee (CCIR); International Scientific Radio Union (URSI); International Time Bureau (BIH); international time organizations; leap seconds; national time/frequency standards; NBS time and frequency; Precise Time and Time Interval (PTTI); time; time coordination; time interval; time scales; Treaty of the Meter (standards); U.S.A. standard time zones; USNO time and frequency.

This paper describes the national responsibilities for standards of time and frequency in the U.S.A. The National Bureau of Standards (NBS) and the U.S. Naval Observatory (USNO) are the two organizations chiefly involved in distributing accurate and precise time and frequency information within the U.S.A. The NBS is responsible for the "custody, maintenance, and development of the national standards" of frequency and time (interval) as well as their dissemination to the general public. The mission of the USNO includes the "provision of accurate time" for electronic navigation systems, communication, and space technology. This is an integral part of its work concerned with the publication of ephemerides which are used in support of navigation and in the establishment of a fundamental reference system in space.

Both agencies provide the U.S. contribution to the Bureau International de l'Heure (BIH) [International Time Bureau], which has the responsibility of publishing definitive values of Universal Time (UT), International Atomic Time (TAI), and Coordinated Universal Time (UTC).

TN650. **An evaluation of selected angular momentum, vortex shedding and orifice cryogenic flowmeters,** J. A. Brennan, R. W. Stokes, C. H. Kneebone, and D. B. Mann, Nat. Bur. Stand. (U.S.), Tech. Note 650, 69 pages (Mar. 1974) SD Catalog No. C13.46:650.

Key words: angular momentum; cryogenic; flow; liquid nitrogen; mass; mass flowmeters; measurement; orifice; volume flowmeters; vortex shedding.

The National Bureau of Standards (NBS) and the Compressed Gas Association (CGA) have jointly sponsored a research program on cryogenic flow measurement. Cryogenic flowmeters operating on the principles of angular momentum (mass flow), vortex shedding (volume flow), and pressure drop are reported.

The operation and the accuracy of the flow facility is briefly described. The performance of the flowmeters in liquid nitrogen is described by reporting the precision and bias of the meters before and after an 80-hour stability test and by defining the existence of temperature, pressure, flow rate, subcooling, and time order (wear) dependencies.

Meters were evaluated with flow rates ranging from 20 to 210

gpm (0.00126 to 0.0132 m^3/s), pressures ranging from 32 to 112 psia (0.22 to 0.77 MPa), and with temperatures ranging from 72 to 90 K.

TN651. **Scattering-matrix description and near-field measurements of electroacoustic transducers,** D. M. Kerns, Nat. Bur. Stand. (U.S.), Tech. Note 651, 40 pages (Mar. 1974) SD Catalog No. C13.46:651.

Key words: electroacoustic transducer measurement techniques; near-field measurement techniques; scattering matrix description of electroacoustic transducers.

Recently developed and successfully applied analytical techniques for the measurement of microwave antennas at reduced distances are "translated" into corresponding techniques for the measurement of electroacoustic transducers in fluids. The basic theory is formulated in scattering-matrix form and emphasizes the use of plane-wave spectra for the representation of sound fields. This theory, in contrast to those based on asymptotic description of transducer characteristics, is suitable for the formulation and solution of problems involving interactions at arbitrary distances. Two new techniques (in particular) are described: One, utilizing deconvolution of planar scanning data, taken with a known transducer at distances d which may be much less than the Rayleigh distance d_R ($\equiv D^2/2\lambda$), provides a means of obtaining complete effective directivity functions, *corrected for the effects of the measuring transducer.* Applicability of a (two-dimensional, spatial) sampling theorem and the "fast Fourier transform" algorithm, which greatly facilitate the necessary computations, is shown. The second technique provides a means of extrapolating received signal as a function of distance (observed with $d \sim d_R$) to obtain on-axis values of effective directivity. Other possible applications are indicated. These techniques rigorously utilize observed output of nonideal (but linear) measuring transducers.

TN652. **Development and construction of an electromagnetic near-field synthesizer,** F. M. Greene, Nat. Bur. Stand. (U.S.), Tech. Note 652, 44 pages (May 1974) SD Catalog No. C13.46:652.

Key words: electromagnetic-field hazards; electromagnetic-field synthesizer; electromagnetic radiation-exposure testing (non-ionizing); near fields; RF biological hazards.

This publication describes work done by the National Bureau of Standards for the USAF School of Aerospace Medicine at Brooks AF Base involving the development, design, construction and testing of a prototype EM near-field synthesizer. The purpose of the contract was to provide a means of independently generating high-level electric and magnetic near fields in the frequency range 10 to 30 MHz. These fields are to be used in various ratios by the USAFSAM in their EM radiation exposure program for determining the biological effects of hazard-level, non-ionizing EM fields on human beings.

The synthesizer consists of a balanced, parallel-plate strip line to generate the "desired" electric field, and a single-turn quadruple-feed inductor placed parallel to and midway between the plates to generate the "desired" magnetic field. Methods used to reduce the "unwanted" E- and H-field components associated with the above, as well as the methods used to reduce the coupling between the two field systems are discussed. The result is a synthesizer in which the electric- and magnetic-field components can be adjusted essentially independently over wide ranges of magnitude, relative time-phase, and spatial orientation to simulate various near-field configurations.

Previous research has been largely limited to the use of plane-wave fields for evaluating RF biological hazards. This new device will allow researchers to investigate any near-field effects that may occur at high field levels.

TN653. **The thermophysical properties of methane, from 90 to 500 K at pressures to 700 bar,** R. D. Goodwin, Nat. Bur. Stand. (U.S.), Tech. Note 653, 280 pages (Apr. 1974) SD Catalog No. C13.46:653.

Key words: densities; enthalpies; entropies; equation of state; internal energies; isobars; isochores; isotherms; Joule-Thomson inversion; latent heats of vaporization; melting line; orthobaric densities; PVT data; specific heats; speeds of sound; vapor pressures.

Thermophysical properties of methane are tabulated at uniform temperatures from 90.68 to 500 K along isobars to 700 bar. A novel equation of state is employed for the first time, having origin on the vapor-liquid coexistence boundary. Computations are based almost entirely on ideal gas specific heats and experimental P-ρ-T data via the equation of state, without weighting to data for derived properties. Good agreement with such data confirms validity of the equation and method. New P-ρ-T data are reported at 0.3 to 1.7 times the critical density.

TN654. **Electromagnetic noise in Robena No. 4 coal mine,** W. D. Bensema, M. Kanda, and J. W. Adams, Nat. Bur. Stand. (U.S.), Tech. Note 654, 194 pages (Apr. 1974) SD Catalog No. C13.46:654.

Key words: amplitude probability distribution; coal mine noise; digital data; electromagnetic interference; electromagnetic noise; emergency communications; Fast Fourier Transform; Gaussian distribution; impulsive noise; magnetic field strength; measurement instrumentation; spectra density; time-dependent spectral density.

Two different techniques were used to make measurements o the absolute value of electromagnetic noise in an operating coa mine, Robena No. 4, located near Waynesburg, Pa. On technique measures noise over the entire electromagnetic spec trum of interest for brief time periods. With present instrumenta tion, the spectrum can be covered from 40 Hz to 400 kHz. It i recorded using broad-band analog magnetic tape, and the nois data are later transformed to give spectral plots. The othe technique records noise envelopes at several discrete frequen cies for a sufficient amount of time to provide amplitude proba bility distributions.

The specific measured results are given in a number of spectra plots and amplitude probability distribution plots. The genera results are that at frequencies below 10 kHz, power line nois within the mine is severe. Impulsive noise is severe near arcin trolleys, and at lower frequencies near any transmission line Carrier trolley phone signals and harmonics are stron throughout the mine whenever the trolley phone is in operatio

Additional information beyond that included in this report ma be obtained from the authors, who are with the Electromagnetic Division of the National Bureau of Standards.

TN655. **Cryogenic refrigerators—an updated survey,** T. R Strobridge, Nat. Bur. Stand. (U.S.), Tech. Note 655, 12 page (June 1974) SD Catalog No. C13.46:655.

Key words: cost; cryogenic refrigerators; efficiency volume; weight.

In 1969, we gave efficiency, weight, volume, and cost data fo 95 cryogenic refrigerators and liquefiers excluding air separatio plants. Recently, the survey was repeated. The original data an those for 49 additional refrigerators and liquefiers are presente spanning refrigeration capacities from 0.2 to 10^6 W and tempera tures from 1.85 to 90 K. Generally, there is no change in th trends exhibited by the older data except that the high tempera ture, low capacity new units seem to be larger, heavier, an slightly less efficient than in prior years. Presumably, these e fects are due to efforts to increase useful life and reliabilit

sts remain the same as predicted before even though no dollar ue adjustments were made.

656. **Standard time and frequency: Its generation, control, and lissemination by the National Bureau of Standards,** J. B. Mil- on, Nat. Bur. Stand. (U.S.), Tech. Note 656, 21 pages (June 974) SD Catalog No. C13.46:656.

Key words: clock synchronization; frequency and time dissemination; primary frequency standard; standard frequency broadcasts; time interval; time scales.

The Time and Frequency Division of the National Bureau of ndards maintains primary frequency standards, which pro- e a realization of the internationally-defined second, and two mic time scales, AT(NBS) and UTC(NBS). AT(NBS) is de- ndent upon the primary frequency standards, an ensemble of mmercial cesium clocks, and a computer algorithm to process data. The UTC(NBS) scale is derived from AT(NBS) by the dition of small annual frequency adjustments and leap second ustments to keep its time nominally synchronous with the in- national time scale UTC. The UTC(NBS) time scale is used calibrate the clocks and secondary standards necessary for the eration of the NBS radio stations, WWV, WWVH, WWVB, d WWVL. These stations transmit various standard frequency d time signals throughout the world, and, in addition, provide tain official announcements such as geoalert warnings, marine ather advisories, and radio propagation forecasts.

N657. **Calculated and measured S_{11}, S_{21}, and group delay for simple types of coaxial and rectangular waveguide 2-port standards,** R. W. Beatty, Nat. Bur. Stand. (U.S.), Tech. Note 657, 67 pages (Dec. 1974) SD Catalog No. C13.46:657.

Key words: Automatic network analyzers; coaxial; coaxial line step discontinuities; group delay; scattering coefficients; standards; 2-ports; waveguide; waveguide discontinuities.

Formulas, simple computer programs, graphs and tables are ven to aid in the design and construction of 2-port standards r rectangular waveguide and coaxial line. Only standards nsisting of reduced height waveguide, increased ODIC (out- de diameter of inner conductor), or reduced IDOC (inside ameter of outer conductor) coaxial line are considered. xamples of the calculation of S_{11}, S_{21} and group delay, and their easurement with automatic network analyzers are given. ome of the important sources of error in the standards are scussed and design data are presented for specific standards.

N658. **Development of electric and magnetic near-field probes,** F. M. Greene, Nat. Bur. Stand. (U.S.), Tech. Note 658, 53 pages (Jan. 1975) SD Catalog No. C13.46:658.

Key words: electric near-field probe; electromagnetic-field hazard; field-strength measurements; magnetic near-field probe; near-field measurements; r-f hazard measurements; semiconducting transmission line.

This publication describes the development and design of mall electric and magnetic near-field probes for measuring azard-level fields up to 20,000 V/m and 100 A/m, respectively. hey were originally designed to be used over the frequency ange from 10 to 30 MHz, and consist of short dipole antennas nd small, single-turn balanced, loop antennas to measure the lectric- and magnetic-field components, respectively. The robes are intended for use by various researchers in their elec- romagnetic, radiation-exposure programs for determining the ef- ects of hazard-level, nonionizing, EM fields on living tissue, lectroexplosive devices, and volatile fuels.

In order to later extend the use of the probes to frequencies bove 30 MHz, a detailed analysis was made of several types of measurement errors likely to be encountered. The principal errors result from a variation with frequency in: the effective length and impedance of the dipoles; and the electric-dipole response and partial resonance of the loops. Corresponding corrections are given for each type of error as a function of the operating frequency from 10 to 1000 MHz, and as a function of the physical and electrical sizes of the probes.

As a result of the analysis, the dipoles can now be used for measurements at frequencies up to 750 MHz and the loops to 75 MHz with an estimated uncertainty of 0.5 dB. Applying recommended corrections will provide a substantial further increase in the usable frequency range.

TN659. **An earth-based coordinate clock network,** N. Ashby, Nat. Bur. Stand. (U.S.), Tech. Note 659, 35 pages (Apr. 1975) SD Catalog No. C13.46:659.

Key words: clocks; coordinate time; general relativity; time.

This paper investigates some of the possible operational procedures for synchronizing clocks at fixed sites spread around on the earth's surface, to within a 1 nanosecond level of accuracy. Since a common synchronization procedure is by transport of standard clocks in commercial jet airline flights, and most of the effects we shall discuss are fractional corrections to the elapsed time, as a criterion of whether an effect is significant at the 1 nanosecond level we take for comparison purposes an elapsed time $T_e = 10$ hours. This is a typical time for an intercontinental airplane flight. Analysis of a number of effects which might affect clock synchronization is carried out within the framework of general relativity. These effects include the gravitational fields of the earth, sun, and moon, and orbital motion, rotation, and flattening of the earth. It is shown that the only significant effects are due to the gravitational field and rotation of the earth, and motion of the transported clocks. Operational procedures for construction of a synchronized coordinate clock network using light signals and transported standard clocks are discussed and compared.

TN660. **Molecular beam tube frequency biases due to distributed cavity phase variations,** S. Jarvis, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 660, 43 pages (Jan. 1975) SD Catalog No. C13.46:660.

Key words: accuracy evaluation; atomic beam frequency standards; cavity phase shift.

For atomic beam frequency standards, an analysis is described for estimating the frequency bias due to distributed cavity phase difference over finite beam widths, and for estimating the resulting inaccuracy in power shift and beam reversal experiments. Calculated atomic trajectories and simplified rf-field distributions are used, as well as certain assumptions about beam tube alignment. The results are applied to one of the present NBS primary time and frequency standards and a shorter tube geometry.

One conclusion is that beam reversal experiments are not necessarily much more accurate than power shift experiments and that the use of both methods (plus the use of pulse techniques) is desirable.

TN661. **Advances in the measurement of rf power and attenuation using SQUIDS,** R. A. Kamper, M. B. Simmonds, R. T. Adair, and C. A. Hoer, Nat. Bur. Stand. (U.S.), Tech. Note 661, 27 pages (Sept. 1974) SD Catalog No. C13.46:661.

Key words: Josephson effect; quantum interference; rf attenuation; rf measurement; rf power; superconductivity.

This report covers the progress made in the application of Superconducting QUantum Interference Devices (SQUIDs) to the measurement of rf power and attenuation during the year from July 1973 to June 1974. The earlier work on this project was re-

ported in NBS Technical Note 643, which contains a detailed introduction to the principles involved. We will assume the reader to be familiar with the material we presented there, since we do not repeat it in this report. In order to make the connection as smooth as possible, we have retained our earlier chapter titles as far as possible.

During the year we have developed stable SQUIDs with preset junctions which survive thermal cycling and mechanical shock. Further work is required to arrive at a version suitable for precise rf measurements. We have assembled a "breadboard" system capable of measuring rf power at levels down to 10^{-15}W in the range of frequency from 100 MHz to 1 GHz. We have extended the dynamic range of our system to measure rf attenuation to 60 dB, and developed the hardware to partially automate its operation and to accommodate step attenuators. We have tested a portable version of this system, and are in process of designing an improved version based on what we learned from the first one.

TN662. **A review of precision oscillators,** H. Hellwig, Nat. Bur. Stand. (U.S.), Tech. Note 662, 24 pages (Feb. 1975) SD Catalog No. C13.46:662.

Key words: accuracy; atomic clocks; clocks; crystal oscillator; frequency standards; stability; survey of clocks.

Precision oscillators used in PTTI applications include quartz crystal, rubidium gas cell, cesium beam, and hydrogen maser oscillators. A general characterization and comparison of these devices is given including accuracy, stability, environmental sensitivity, size, weight, power consumption, availability and cost. Areas of special concern in practical applications are identified and a projection of future performance specifications is given. An attempt is made to predict physical and performance characteristics of new designs potentially available in the near future.

TN663. **Characterization of a high frequency probe assembly for integrated circuit measurements,** R. L. Jesch and C. A. Hoer, Nat. Bur. Stand. (U.S.), Tech. Note 663, 55 pages (Apr. 1975) SD Catalog No. C13.46:663.

Key words: high frequency probe assembly; integrated circuit transistors; parasitic element; S-parameters.

A detailed, applications-oriented description of a measurement technique that characterizes a high-frequency probe assembly for integrated circuit measurements is given along with the procedure that extracts the parasitic effects of the probe assembly from measurements made at the input connectors of the probe assembly. The scattering parameters of an integrated-circuit device or transistor can now be extracted and accurately determined up to 2 GHz at the wafer stage of assembly. This represents a significant advance over conventional techniques that enable only dc parameters to be measured. Measurement results using this technique are given along with the precision of values obtained as well as the nature of the measurement bias introduced by the probe assembly.

TN664. **Hydrogen-future fuel—A bibliography (with emphasis on cryogenic technology),** N. A. Olien and S. A. Schiffmacher, Nat. Bur. Stand. (U.S.), Tech. Note 664, 131 pages (Feb. 1975) SD Catalog No. C13.46:664.

Key words: cryogenic technology; data; energy fuel; hydrogen; hydrogen properties; LNG/SNG; production; safety; storage.

This NBS Technical Note is a compilation of references dealing directly and indirectly with the possible future use of hydrogen as a fuel. The references were selected using an automated information system operated by the Cryogenic Data Center. This bibliography of references emphasizes the use of cryogenic technology in the hydrogen field. Articles are indexed under 40 subject headings and an author index is included. Over 1600 references are included in this bibliography.

TN665. **A pyroelectric power meter for the measurement of low level laser radiation,** C. A. Hamilton and G. W. Day, Nat. Bur. Stand. (U.S.), Tech. Note 665, 41 pages (Feb. 1975) SD Catalog No. C13.46:665.

Key words: laser; power; pyroelectric.

A 1 cm² plastic (PVF_2) pyroelectric detector, developed in this laboratory, has been applied to measure low level laser power. The result is a compact instrument which has a low noise equivalent power (10^{-8} W/Hz$^{1/2}$), and fast response (1 s averaging time), and which is precise ($\sigma \sim \pm 1\%$), uniform ($\sim \pm 1\%$), and inherently free from short term drift. This note describes the fabrication of the detector, the design of the instrument, and the results of an extensive evaluation of three such instruments.

TN666. **Efflux of gaseous hydrogen or methane fuels from the interior of an automobile,** J. M. Arvidson, J. Hord, and D. B. Mann, Nat. Bur. Stand. (U.S.), Tech. Note 666, 56 pages (Mar. 1975) SD Catalog No. C13.46:666.

Key words: automobile; detection; dispersion; explosion; fire; hydrogen; leakage; methane; safety; vents.

Gasoline-powered automobiles are being converted to operate on gaseous fuels such as H_2 or CH_4. These fuels are commonly stored in containers located in the trunk of the car. Potential leakage of these gaseous fuels into the passenger compartment of the vehicle constitutes a safety threat. Definitive experiments were performed to identify the explosion hazards, establish venting criteria and obviate general safeguards for H_2 or CH_4 fueled passenger vehicles. Appropriately designed ventilation systems significantly reduce the safety hazards associated with accumulated combustible gases. Vents are recommended for all autos *converted* to burn H_2 or CH_4 and may possibly be eliminated in new cars that are *designed* for gaseous fuel operation. Combustible gas warning systems are recommended, at least in the interim, for all (converted and new-design) gaseous fueled vehicles. H_2 and CH_4 gases appear equally safe as vehicular fuels in used in properly designed vehicles.

TN667. **Upper-bound errors in far-field antenna parameters determined from planar near-field measurements. Part I: Analysis,** A. D. Yaghjian, Nat. Bur. Stand. (U.S.), Tech. Note 667, 120 pages (Oct. 1975) SD Catalog No. C13.46:667.

Key words: antennas; error analysis; far-field pattern; near-field measurements; planar scanning; plane-wave spectrum.

General expressions are derived for estimating the errors in the sum or difference far-field pattern of electrically large aperture antennas which are measured by the planar near-field scanning technique. Upper bounds are determined for the far-field errors produced by (1) the nonzero fields outside the finite scan area, (2) the inaccuracies in the positioning of the probe, (3) the distortion and nonlinearities of the instrumentation which measures the amplitude and phase of the probe output, and (4) the multiple reflections. Computational errors, uncertainties in the receiving characteristics of the probe, and errors involved with measuring the input power to the test antenna are briefly discussed.

TN668. **The use of National Bureau of Standards high frequency broadcasts for time and frequency calibrations,** N. Hironaka and C. Trembath, Nat. Bur. Stand. (U.S.), Tech. Note 668, 4 pages (May 1975) SD Catalog No. C13.46:668.

Key words: dissemination; frequency; high frequency broadcasts; standard; time.

Methods to determine time or frequency by reception of NBS gh frequency radio broadcasts are discussed. Results are lown for calibration of time signals to within ±100 icroseconds and calibration of frequency offset with a resolu-on of better than 1 part in 10^9. These results are achieved by sing a systematic approach and refined measurement technique.

N669. **The measurement of frequency and frequency stability of precision oscillators,** D. W. Allan, Nat. Bur. Stand. (U.S.), Tech. Note 669, 31 pages (May 1975) SD Catalog No. C13.46:669.

Key words: accurate frequency measurement; accurate time measurement; frequency; frequency stability; frequency stability analysis; models of frequency stability; picosecond time difference measurements.

The specification and performance of precision oscillators is very important topic to the owners and users of these oscilla-ors. This paper presents at the tutorial level some convenient ethods of measuring the frequencies and/or the frequency sta-ilities of precision oscillators—giving advantages and disad-antages of these methods.

Conducting such measurements, of course, gives additional nderstanding into the performance of the given pair of oscilla-ors involved. Further it is shown that by processing the data rom the frequency measurements in certain ways, one may be ble to state more general characteristics of the oscillators being neasured. The goal in this regard is to allow the comparisons of lifferent manufacturers' specifications and more importantly to elp assess whether these oscillators will meet the standard of erformance the user may have in a particular application.

The methods employed for measuring frequency are designed or state-of-the-art oscillators, and an effort has been made to llow for fairly simple, inexpensive, and/or commonly available components to be used in the measurement systems. The method or measuring frequency stability is basically that recommended y the IEEE subcommittee on Frequency Stability of the Technical Commitee on Frequency and Time of the IEEE Group on Instrumentation & Measurement.

TN670. **An infrared spectrometer utilizing a spin flip Raman laser, IR frequency synthesis techniques, and CO_2 laser frequency standards,** J. S. Wells, F. R. Petersen, G. E. Streit, P. D. Goldan, and C. M. Sadowski, *Nat. Bur. Stand. (U.S.), Tech. Note 670,* 54 pages (Jan. 1976) SD Catalog No. C13.46:670.

Key words: air quality measurements; improved resolution spectroscopy; infrared frequency measurements; infrared spectrometer; spin flip laser; tunable IR laser.

The central part of this spectrometer is a cw spin flip Raman laser which operates between 1900 and 1800 cm^{-1}. The spin flip laser has so far demonstrated capabilities of resolving spectra separated by 0.01 cm^{-1} and shows promise of exceeding this resolution capability. When used with an opto-acoustic detector or with a detector and a flow system, it is capable of making a variety of measurements of environmental interest. Many of these environmental applications require only wavelength metrology.

By using CO_2 laser standards as frequency references and incorporating infrared frequency synthesis techniques, spectroscopy with the spin flip Raman laser can be put on a frequency metrology basis. A CO_2 laser has been used with a metal-oxide-metal diode to synthesize a known frequency reference which was used to stabilize the CO pump laser. The MOM diode also has the potential for measuring the frequency difference between the SFRL and the CO pump laser, a step which will complete absolute frequency measurements with the SFRL. The progress toward achieving this goal, the potential capabilities of this unique spectrometer, and some future applications are discussed.

TN672. **Time domain automatic network analyzer for measurement of RF and microwave components,** W. L. Gans and J. R. Andrews, Nat. Bur. Stand. (U.S.), Tech. Note 672, 176 pages (Sept. 1975) SD Catalog No. C13.46:672.

Key words: attenuation; discrete Fourier transform; fast Fourier transform; insertion loss; jitter; microwave measurement; mismatch; network analyzer; noise; pulse generator; pulse measurement; sampling oscilloscope; scattering parameters; spectral analysis; time domain analysis.

This technical note describes in detail a new NBS instrument for the measurement of the scattering parameters (S_{ij}) of RF and microwave components. The instrument is the Time Domain Automatic Network Analyzer (TDANA). It utilizes time domain pulse measurements to obtain frequency domain parameters. The frequency range is dc to 18 GHz with a lower upper limit for large values of attenuation. The instrument consists of three major components: an ultra-fast pulse generator, a broadband sampling oscilloscope, and a digital minicomputer.

TN673. **Using six-port and eight-port junctions to measure active and passive circuit parameters,** C. A. Hoer, Nat. Bur. Stand. (U.S.), Tech. Note 673, 29 pages (Sept. 1975) SD Catalog No. C13.46:673.

Key words: admittance; automated precision measurements; correlator; current; impedance; microwave circuit parameters; microwave measurements; phase angle; power; ratio; reflection coefficient; reflectometer; self-calibration; six-ports; vector voltmeter; voltage.

This review paper brings together a number of old and new methods for measuring voltage, current, power, impedance, and phase angle using only amplitude type detectors. Vector voltmeters and reflectometers can be constructed to measure all of these quantities in terms of four amplitude measurements made on four arms of a six-port junction. Whereas previous uses of this type of instrument depended on precision components for accuracy, new equations switch this dependence primarily to detector linearity and only secondarily on the properties of the measuring device itself.

TN674. **Report on the 1975 survey of users of the services of Radio Stations WWV and WWVH,** J. A. Barnes and R. E. Beehler, Nat. Bur. Stand. (U.S.), Tech. Note 674, 91 pages (Oct. 1975) SD Catalog No. C13.46:674.

Key words: frequency; questionnaire; standard frequency and time broadcasts; time.

The users of the National Bureau of Standards (NBS) radio stations WWV and WWVH were surveyed by means of a questionnaire. The questionnaire was distributed to the station mailing list, published in some periodicals, and its availability was announced on the stations themselves and publicized in other periodicals. More than 12,000 completed questionnaires were returned, which revealed, among other things, that the 5, 10, and 15 MHz transmissions were the most used frequencies; 25 MHz was the least used. Of the information contained on the broadcasts, the voice time-of-day announcement was the most important, and the DUT1 values the least important. In general the returns were very supportive of the services, with only two of the more than 12,000 responses advocating a complete shutdown of the broadcasts.

TN675. **Heat transfer and flow of helium in channels—Practical limits for applications in superconductivity,** M. C. Jones and W. W. Johnson, *Nat. Bur. Stand. (U.S.), Tech. Note 675,* 45

pages (Jan. 1976) SD Catalog No. C13.46:675.

Key words: buoyancy; channels; film boiling; forced convection; helium I; helium II; mixed convection; nucleate boiling; subcritical; supercritical; transition; turbulent flow.

Heat transfer and fluid mechanics of helium flowing in channels are reviewed. Emphasis is placed on observed or anticipated limits of operation which might be expected to apply in applications of superconductivity. Topics included are: the high-heat-flux degradation of heat transfer and possible effects of buoyancy forces in supercritical helium; transition to film boiling in subcritical helium; limiting heat currents in helium II; and the possibility of oscillations in forced flow helium systems.

TN677. **Laser attenuators for the production of low power beams in the visible and 1.06 μm regions,** B. L. Danielson and Y. Beers, *Nat. Bur. Stand. (U.S.), Tech. Note 677,* 25 pages (Jan. 1976) SD Catalog No. C13.46:677.

Key words: beam splitter; laser attenuation; neutral density filter.

Some methods were investigated for the accurate attenuation of laser beams to very low levels; approximately 10^{-11} watts. This work was done at 1.06 and 0.6471 μm, but the conclusions are applicable throughout the visible region as well. Two types of devices were considered: wedged beam splitters and neutral density filters. The theory of the attenuation of a wedged beam splitter was described and some of the errors associated with these devices were discussed.

TN678. **An electrically calibrated pyroelectric radiometer system,** C. A. Hamilton, G. W. Day, and R. J. Phelan, Jr., *Nat. Bur. Stand. (U.S.), Tech. Note 678,* 50 pages (Mar. 1976) SD Catalog No. C13.46:678, $1.25.

Key words: detector; pyroelectric; radiometry.

A new type of radiometer based on an electrically calibrated pyroelectric detector is described. Emphasis is placed on system design and analysis with careful consideration of design tradeoffs. An evaluation of both systematic and random errors for the complete system yields an expression for the accuracy relative to the *electrical standards* by which it is calibrated. Throughout the paper the analysis should be sufficiently general that it can be applied to any Electrically Calibrated Pyroelectric Radiometer which employs the same basic principles.

TN679. **Frequency domain stability measurements: A tutorial introduction,** D. A. Howe, *Nat. Bur. Stand. (U.S.), Tech. Note 679,* 27 pages (Mar. 1976) SD Catalog No. C13.46:679.

Key words: fractional frequency fluctuations; frequency stability; phase fluctuations; power law noise processes; spectral density; spectrum analysis.

This report introduces the concept of stability measurements of oscillators by spectral analysis. Development of topics does not rely heavily on mathematics. The equipment and setup for stability measurements in the frequency domain are outlined. Examples and typical results are presented. Physical interpretations of common noise processes are discussed. The last section provides a table by which typical frequency domain stability characteristics may be translated to time domain stability characteristics.

TN680. **Application of infrared frequency synthesis techniques with metal-insulator-metal diodes to the spin flip Raman laser,** J. S. Wells, G. E. Streit, and F. R. Petersen, *Nat. Bur. Stand. (U.S.), Tech. Note 680,* 14 pages (Apr. 1976) SD Catalog No. C13.46:680.

Key words: frequency measurements on tunable lasers; IFS with a tunable laser; infrared frequency synthesis; SFRL frequency measurement; spin flip Raman laser.

Infrared frequency synthesis techniques with a metal-insulator-metal (MIM) diode have been extended to include the measurement of the frequency of a spin flip Raman Laser (SFRL). As a result of this extension, spectroscopy in the 5.3 μm region can be put on a frequency rather than a wave-length metrology basis. Additional observations with the diode are in qualitative agreement with recent work relating to nonlinear tuning over axial SFRL modes.

TN681. **A satellite-controlled digital clock,** J. V. Cateora, D. D. Davis, and D. W. Hanson, *Nat. Bur. Stand. (U.S.), Tech. Note 681,* 46 pages (June 1976) SD Catalog No. C13.46:681.

Key words: clock; microprocessor; satellite; time; time code.

A digital clock, resettable and controlled by the time code relayed by NOAA's SMS/GOES Satellites, is discussed. The clock's design is based upon a four bit microprocessor and uses the redundancy of the data to improve its performance. Satellite position is included in the clock's display for delay corrections to the received time.

A discussion of the generation, distribution, and reception of the time code is also included to aid the explanation of the clock's operation and performance.

TN682. **Implementation of the notch technique as an rf peak pulse power standard,** P. A. Simpson and P. A. Hudson, *Nat. Bur. Stand. (U.S.), Tech. Note 682,* 30 pages (July 1976) SD Catalog No. C13.46:682.

Key words: notch wattmeter; pulse-CW equalization; pulse modulated carrier systems; rf peak pulse power.

The theory and operation of a standard for measuring rf peak pulse power is described. The standard is based on the "notch" principle. It is constructed in coax for frequencies up to 4.4 GHz, and in WR-90 waveguide (8.2-12.4 GHz). The basic range is 1 to 10 mW but is extendable to cover 10 μW to 10 kW using directional couplers. Risetime of the system is 14 nanoseconds. A comprehensive error analysis is given. The uncertainty in coax is 3 percent and in waveguide is 4 to 6 percent depending upon peak power level.

TN683. **Models for the interpretation of frequency stability measurements,** J. A. Barnes, *Nat. Bur. Stand. (U.S.), Tech. Note 683,* 44 pages (Aug. 1976) SD Catalog No. C13.46:683.

Key words: flicker noise; frequency; frequency stability; oscillators; phase noise; stationary models.

The results of measurements of frequency stability are normally interpreted in the terms of models. Typically, these models are expressed as a power-law for the power spectral density (e.g., $S_y(f) = h_{-1}f^{-1}$). The experiments which provide the basis for these models are always limited in their range and include neither zero nor infinite Fourier frequency. Some authors have neglected the limits to the actual physical devices and the underlying data and have encountered mathematical difficulties with the models at either zero or infinite frequency or both. These problems are associated with the model and not the actual oscillators being modeled. By carefully taking into account actual limits of the device and constraining discussions to be concerned only with quantities which can be observed in a practical sense, one can avoid the problems of nonconvergence and nonstationarity.

Even for stationarity and convergent models, however, there is growing evidence that the typical Gaussian models may be inadequate. There appear to be occasional (sporadic) steps in the frequency of oscillators of a magnitude which is difficult to explain with conventional models.

TN684. **Thermophysical properties of ethane, from 90 to 600 K at pressures to 700 bar,** R. D. Goodwin, H. M. Roder, and G. C. Straty, *Nat. Bur. Stand. (U.S.), Tech. Note 684,* 326 pages (Aug. 1976) SD Catalog No. C13.46:684.

Key words: densities; enthalpies; entropies; equation of state; ethane; internal energies; isobars, isochores; isotherms; Joule-Thomson inversion; latent heats of vaporization; melting line; orthobaric densities; specific heats; speeds of sound; vapor pressures.

The thermophysical properties of ethane are tabulated at integral temperatures over the entire range of fluid states at temperatures from 90 to 600 K along isobars to 700 bar. A new form of the equation of state is employed for the first time. Thermodynamic functions in the compressed liquid at $T < T_c$ are obtained by use of specific heats C_v (T) along a high-density isochore, and C_σ (T) for the saturated liquid. Use of these new specific heat data and also of new PVT data provide the first reliable set of thermodynamic functions for compressed liquid ethane at temperatures below its normal boiling point.

TN686. **Ultrasonic calorimeter for beam power measurements,** T. L. Zapf, M. E. Harvey, N. T. Larsen, and R. E. Stoltenberg, *Nat. Bur. Stand. (U.S.), Tech. Note 686,* 36 pages (Sept. 1976) SD Catalog No. C13.46:686.

Key words: calorimeter; ultrasonic calorimeter; ultrasonic power measurements.

An ultrasonic calorimeter has been designed and constructed at the National Bureau of Standards for the measurement of beam power up to a few watts from ultrasonic transducers. The calorimeter, described as a twin, series flow, ultrasonic calorimetric comparator, operates in the frequency range from 1 to 15 MHz with uncertainties less than $\pm(7\% + 0.2$ mW). Twin vessels are provided so that thermal effects of an ultrasonic sound beam absorbed in one vessel can be compared rapidly with accurately measured dc electrical power in the other vessel. Absorbing liquid enters each vessel near the ultrasonic input port. The temperatures of the absorbing liquid at the input ports are equalized by a heat exchanger, and the mass-flow rates are the same in both vessels. Twin temperature sensors, located in the output flow from the vessels, are connected in an electrical bridge circuit. In automatic operation the bridge is connected to a feedback circuit. With ultrasonic power introduced into one vessel, the feedback circuit promptly applies power to an electrical heater in the other vessel to regain bridge balance. The ultrasonic power then equals the measured dc power corrected for known errors.

TN687. **Measurement of rf power-absorption in biological specimens (10 to 100 MHz),** F. M. Greene, *Nat. Bur. Stand. (U.S.), Tech. Note 687,* 29 pages (Nov. 1976) SD Catalog No. C13.46:687.

Key words: electromagnetic field hazards; electromagnetic field synthesizer; electromagnetic radiation-exposure testing (nonionizing); near-fields; rf biological hazards.

A method is described for accurately determining the rf power being absorbed by a biological specimen during nonionizing radiation-exposure testing using the NBS RF Near-Field Synthesizer in the frequency range 10 to 100 MHz. This method is based solely on measuring the forward and reflected power on the transmission line feeding the synthesizer. Commercially available rf wattmeters can be used, and an automatic data-acquisition system employed, if desired, to "read" the meters and rapidly calculate, display, and record the rf power flow.

The method has the advantage that the exact measuring point on the feed line is not critical, as it is with methods employing direct impedance measurements, and that the required measurements can be made without interfering with the exposure tests.

TN688. **Yagi antenna design,** P. P. Viezbicke, *Nat. Bur. Stand. (U.S.), Tech. Note 688,* 27 pages (Dec. 1976) SD Catalog No. C13.46:688.

Key words: antenna; director; driven element; gain; radiation pattern; reflector; Yagi.

This report presents data, using modeling techniques, for the optimum design of different length Yagi antennas. This information is presented in graphical form to facilitate the design of practical length antennas—from 0.2λ to 4.2λ long—for operation in the HF, VHF, and UHF frequency range. The effects of different antenna parameters on realizable gain were also investigated and the results are presented. Finally, supplemental data are presented on the stacking of two or more antennas to provide additional gain.

TN689. **A simulation of the fluctuations of international atomic time,** J. A. Barnes, *Nat. Bur. Stand. (U.S.), Tech. Note 689,* 23 pages (Nov. 1976) SD Catalog No. C13.46:689.

Key words: frequency stability; international atomic time: models; simulation; time scale simulation.

In the Annual Report for 1975 the International Time Bureau (BIH) published estimates of noise levels which model the fluctuations in the International Atomic Time Scale (TAI). Based on these noise levels for each type of noise, an Auto Regressive, Integrated, Moving Average (ARIMA) model is constructed. A resulting ARIMA model, which can simulate time fluctuations in TAI, is given by the relation

$$(1 - \phi_1 B - \phi_2 B^2)\,\Delta^2 \chi_t = (1 - \theta_1 B - \theta_2 B^2 - \theta_3 B^3 - \theta_4 B^4) a_t$$

where χ_t represents the time fluctuations in nanoseconds (ns) of TAI measured at successive intervals of ten days; B is the index-lowering operator defined by $B^n \chi_t \equiv \chi_{t-n}$; Δ^2 is the second difference operator equivalent to $(1 - B)^2$; a_t are random, independent variables with a normal distribution, zero mean, and variance of $(147 \text{ ns})^2$ and the coefficients ϕ_i and θ_i are given by

$$\phi_1 = 1.79, \theta_1 = 2.93,$$

$$\phi_2 = -.795, \theta_2 = -3.12, \theta_3 = 1.419, \theta_4 = -0.233.$$

TN690. **Is hydrogen safe?,** J. Hord, *Nat. Bur. Stand. (U.S.), Tech. Note 690,* 38 pages (Oct. 1976) SD Catalog No. C13.46:690.

Key words: explosion; fire; fuel; gasoline; hydrogen; methane; safety.

The safety aspects of hydrogen are systematically examined and compared with those of methane and gasoline. Physical and chemical property data for all three fuels are compiled and used to provide a basis for comparing the various safety features of the three fuels. Each fuel is examined to evaluate its fire hazard, fire damage, explosive hazard and explosive damage characteristics. The fire characteristics of hydrogen, methane and gasoline, while different, do not largely favor the preferred use of

any one of the three fuels; however, the threat of fuel-air explosions in confined spaces is greatest for hydrogen. Gasoline is believed to be the easiest and perhaps the safest fuel to store because of its lower volatility and narrower flammable and detonable limits. It is concluded that all three fuels can be safely stored and used; however, the level of safety risk for each fuel will vary from one application to another. Generalized safety comparisons are made herein but detailed safety analyses will be required to establish the relative safety of different fuels for each specific fuel application and stipulated accident. The technical data supplied in this paper will provide much of the framework for such analyses. Hydrogen safety guidelines, regulatory codes applicable to the distribution of hydrogen, and safety criteria for liquid hydrogen storage are compiled and presented.

TN691. **Clock synchronization and comparison: Problems, techniques and hardware,** J. E. Gray, *Nat. Bur. Stand. (U.S.), Tech. Note 691,* 12 pages (Nov. 1976) SD Catalog No. C13.46:691.

Key words: chronograph; frequency-stability measurement; instrumentation; laboratory technique; time measurement.

This report summarizes a lecture-discussion of practical problems in measurement electronics as experienced in a laboratory for precise timekeeping. It includes environment problems, instrumentation problems, procedural problems, and ends with a description of a convenient automatic measuring instrument, the chronograph.

TN700. **COMBO: A general-purpose program for searching, annotating, encoding-decoding, and reformatting data files,** R. McClenon and J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 700, 68 pages (1972).

Key words: Alphanumeric data files; data retrieval; editing program; file editor; FORTRAN program; general-purpose modular programming; reformatting program; report generator; searching program.

COMBO, a FORTRAN program for searching magnetic tape files, generating reports, and reformatting the file, is described and listed. The program is capable of reading separate card images from a file blocked in physical records and recognizing logical blocks marked by a fixed-field ID. Up to 99 different types of lines, each with its own format, can be recognized by examining a special code or label. The program can be instructed to search for the occurrence of each of certain character strings, using a different list for each type of line and two levels of Boolean logic. Lines can be broken into pieces, using either a fixed-field format or a single separator or flags to define the pieces, and the pieces can be rearranged, with labels or comments optionally inserted between them. Editing, in which specified strings are replaced by other strings, can also be performed. The program can accommodate a variable number of cards of each type per block. It was assembled from general-purpose subroutines of modular design and is substantially machine-independent.

TN701. **Unassigned.**

TN702. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report April 1 to June 30, 1971,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 702, 45 pages (Dec. 1971).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; methods of measurement; microelectronics; microwave devices; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, twelfth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include a demonstration of the high sensitivity of the infrared response technique by the identification of gold in a germanium diode doped to a level of 10^{11} gold atoms per cubic centimeter, verification that transient thermal response is significantly more sensitive to the presence of voids in die attachment than steady-state thermal resistance, and development of a simplified circuit for screening transistors for susceptibility to hot-spot formation by the current-gain technique. Work is continuing on measurement of resistivity of semiconductor crystals; study of gold-doped silicon; specification of germanium for gamma-ray detectors; evaluation of wire bonds and die attachment; measurement of thermal properties of semiconductor devices, transit time and related carrier transport properties in junction devices, and electrical properties of microwave devices; and characterization of silicon nuclear radiation detectors. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN703. **ARPA-NBS program of research on high temperature materials and laser materials, reporting period January 1 to June 30, 1971,** A. D. Franklin and H. S. Bennett, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 703, 39 pages (Dec. 1971).

Key words: Al_2O_3; crystal growth; damage threshold; glass; high temperature materials; laser; oxides; oxygen diffusion; pure materials; sapphire.

Progress reports are given for projects on the growth of ultrapure Al_2O_3 crystals, the development of a mass spectrometer-based sectioning technique for measuring oxygen diffusion in oxides and the development of a precision facility for measuring the threshold energy in a laser beam producing damage in a transparent substance.

TN704. **Unassigned.**

TN705, Superseded by Technical Note 762.

TN706. **Structural performance evaluation of innovative building systems,** F. Y. Yokel and N. F. Somes, Nat. Bur. Stand. (U.S.), Tech. Note 706, 16 pages (Aug. 1972).

Key words: Building; connections; housing; neoprene; performance criteria; performance evaluation; performance testing; reinforced concrete; standard tests; structure, testing.

Considerable attention has recently been focused on the development of performance criteria. Performance criteria are presently used in the U.S. by the Building Research Division of the Institute for Applied Technology, National Bureau of Standards, to evaluate innovative building systems.

While building codes and design standards are usually related to specific building materials and design solutions, performance criteria are derived from user requirements and are independent of specific technological solutions.

Many attributes inherent in traditional building systems which are acceptable to the user may not be present in untried innovative systems. The performance criteria therefore address themselves to many aspects of structural performance which are not considered in present codes and design standards.

The successful application of performance criteria depends on the feasibility of evaluating compliance.

Performance can be evaluated by analysis by judgment based on past experience, or by physical simulation. Deterioration with time must be considered, and performance criteria are viewed as minimum requirements which should be met at any time during the service life of a structure. An example is presented where physical testing was used to evaluate the performance of a high-rise housing system.

TN707. **Three-year inspection of nature-tone porcelain enamels on steel,** M. A. Baker, Nat. Bur. Stand. (U.S.), Tech. Note 707, 16 pages (Dec. 1971).

Key words: Acid resistance; color; continuity of coating; porcelain enamel; weather resistance.

A weather exposure test on nature-tone porcelain enamels on steel was initiated by the National Bureau of Standards and the Porcelain Enamel Institute in 1966. Laboratory measurements for changes in gloss and color were made after the enamels had been exposed for 0.5, 1 and 3 years at Kure Beach, N.C., Miami, Fla. and Gaithersburg, Md. The average gloss and color retained for all 450 specimens exposed at 3 sites for 3 years were 90.5 and 89.1 respectively. There was a tendency for the enamels exposed at the marine sites to rust around pinhole-type defects. Scanning electron microscope studies of these defects showed a layer of readily corrodible enamel on the bottom of the defects. A high-voltage test for continuity of coating was effective in detecting specimens that were apt to rust during the first year's exposure.

TN708. **Interlaboratory evaluation of smoke density chamber,** T. G. Lee, Nat. Bur. Stand. (U.S.), Tech. Note 708, 80 pages (Dec. 1971).

Key words: Building materials; fire tests; interlaboratory tests; optical density; round robin; smoke; smoke density chamber; statistical analysis.

Results are reported of an interlaboratory (round-robin) evaluation of the smoke density chamber method for measuring the smoke generated by solid materials in fire. A statistical analysis of the results from 10 material-condition combinations and 18 laboratories is presented. For the materials tested, the median coefficient of variation of reproducibility was 7.2 percent under non-flaming exposure conditions and 13 percent under flaming exposure conditions. A discussion of errors and recommendations for improved procedures based on user experience is given. A tentative test method description is included as an appendix.

TN709. **An x-ray diffraction method for determining the amount of austenite in an austenite-ferrite mixture,** C. J. Bechtoldt, Nat. Bur. Stand. (U.S.), Tech. Note 709, 15 pages (Feb. 1972).

Key words: Austenite; computer; ferrite; phase measurement; quantitative analysis; retained austenite; x-ray diffraction.

A method for determining the relative phase volume of austenite in an austenite-ferrite mixture is described in detail. Results obtained by applying this method to an austenite-ferrite stainless steel composite material are presented. The method can be extended to other multi-phase materials.

TN710-1. **Building research translation: Account of the principles of modular coordination: Industrialization in building,** G. Blachère, Nat. Bur. Stand. (U.S.), Tech. Note 710-1, 15 pages (Mar. 1972).

Key words: Conventions; dimensional coordination; industrialized production; modular coordination; tolerance.

This paper is translated from the French original and is published under the Building Research Division/Centre Scientifique et Technique du Bâtiment information exchange program.

Modular coordination is indispensable to the industrialized production of units for assembly in buildings. It must be subject to the limitations which are strictly necessary to achieve this end. A large module must be chosen, the reference for the coordinating dimensions must be fixed, and the tolerance problem solved. This is the theme of the report.

TN710-2. **Building research translation: An investigation of the protection of dwellings from external noise through facade walls,** P. Gilbert, Nat. Bur. Stand. (U.S.), Tech. Note 710-2, 26 pages (Mar. 1972).

Key words: Facade; noise; sound insulation; sound pressure level; walls.

This paper is translated from the French original and is published under the Building Research Division/Centre Scientifique et Technique du Bâtiment information exchange program.

An investigation was conducted to determine to what extent the installation of balconies and loggias at various angles of elevation from a noise source could improve the sound insulation of a facade wall. Measurements of the sound pressure level were first carried out on two types of facade, one incorporating traditional window joinery and the other incorporating sealed glazing. Following this, the sound insulation provided by facades fitted with open and closed balconies and loggias (with and without sound absorbent materials applied) was determined and compared with the previous measurements. It was found that for angles of elevation greater than 30°, both the closed balcony and the loggia fitted with absorbent materials appreciably improve the sound insulation, whereas the open balcony does not.

TN710-3. **Building research translation: New regulation on ventilation of dwellings, fixed heating facilities, and flues,** A. Chalandon, M. Schumann, and P. Dechartre, Nat. Bur. Stand. (U.S.), Tech. Note 710-3, 46 pages (May 1972).

Key words: Air infiltration and extraction, airtightness; discomfort index; duct system, collective and individual branch; flow rates; noise; pressure-loss-depression; thermal convection; ventilation.

Following studies on the ventilation of dwellings, the results of which have been published in CSTB "Cahiers," the CSTB has proposed certain changes in the regulations governing the ventilation of dwellings. At the same time, in the light of recent statistics on secondary emergency and relief heating, changes in the regulations governing fixed heating installations and flues were proposed. These proposals led to a new revised text of the French regulations, which we publish below, together with a new chapter on "ventilation" from the CSTB Technical Report.

TN710-4. **Building research translation: Thermal comfort requirement adjacent to cold walls—application to glazed opening,** J. Anquez and M. Croiset, Nat. Bur. Stand. (U.S.), Tech. Note 710-4, 54 pages (May 1972).

Key words: Curtains, effect of; environmental conditions; glazed openings; human response; thermal comfort requirement.

This paper is translated from the French original and is published under the Building Research Division/Centre Scientifique et Technique du Bâtiment information exchange program.

The thermal comfort of an individual inside a closed room in winter is essentially a function of the temperature of the air with which the human body transfers heat by convection, and also of the temperature of the room's walls with which the human body transfers heat by radiation. The presence of glazed openings (windows) which in winter are generally the coldest walls in a residence room, can thus be a source of discomfort.

The first part of the paper reports research conducted with a view to determining the thermal comfort requirement near to a cold wall. The research led to the definition of the "air-radiation requirement" for a plane surface element parallel to the wall, the requirement being that, at about 1 m from the wall, this temperature must remain above 16 or 17 °C.

The second part of the paper studies ways of satisfying the requirement near to glazed openings in a living room in winter. The solution to the problem will depend on numerous factors: climatic zone, average temperature of the room, position of heat sources, dimensions of the openings, type of glazing (single or double), presence or absence of curtains or screens.

TN710-5. **Building research translation: Use of an air-to-air heat exchanger to recover heat from air exhausted by mechanical ventilation,** P. Garrivier, Nat. Bur. Stand. (U.S.), Tech. Note 710-5, 62 pages (July 1972).

Key words: Exchanger dimensions; frost formation; heat exchanger; heating costs; mechanical systems; pollution; pressure loss; ventilation.

When a building is equipped with a mechanical system which both exhausts and supplies outdoor air, it may be profitable to install a heat exchanger between the two circuits. The CSTB has perfected such an exchanger, which meets the two principal requirements of the problem: good efficiencies and elimination of the polluted air intake. A method of calculating the optimal dimensions of the exchanger has also been devised.

TN710-6. **Building research translation: Ventilation air inlets for dwellings,** M. Croiset and H. Bizebard, Nat. Bur. Stand. (U.S.), Tech. Note 710-6, 62 pages (Jan. 1973) $1.00, SD Catalog No. C13.46:710-6.

Key words: Air inlet; discomfort index; draft; outside wall; ventilation; wind.

Preliminary tests have shown the existence of a "discomfort index," a function firstly of the difference between the temperature in the room and the temperature of the air current and, secondly of the speed of the air stream. The permissible limit for this index has been fixed at 2 °C, at least in that part of the room situated more than 20 cm from the outside walls and less than 2 meters in height.

Systematic artificial tests have resulted in satisfactory solutions being found for the air inlets into the outside walls.

- An elongated aperture placed above a radiator and fitted with a deflector so that cold air entering the room mingles with the ascending warm air current.
- An aperture located behind a convector heater so that the same result is achieved as in the case of the radiator.
- A row of apertures located along the heated ceiling placed so that entering air is diffused into the warm air before reaching the occupied zone.

Some calculations aimed at determining the orders of magnitude of the necessary sections and the possible force of the air current in a high wind, have revealed the need for a manual or an automatic regulator where a wall is exposed to wind.

TN710-7. **Building research translation: Weak thermal points or thermal bridges,** J. Berthier, Nat. Bur. Stand. (U.S.), Tech. Note 710- 7, 96 pages (May 1973) $1.25, SD Catalog No. C13.46:710-7.

Key words: Floors and panels; moisture condensation; thermal bridges; thermal insulation; U-values of walls.

Uniformity of temperature on the internal face is one of the essential hygrothermal qualities for a wall.

Cold bridges, which are the cause of uneven temperatures, constitute a weakness which ought to be corrected.

The author describes a large number of tests carried out with various types of wall (dense walls and lightweight panels) in order to assess the importance of cold bridges and to determine the effectiveness of possible remedies; he shows that the accepted theory used in the calculation of U-coefficients is unsatisfactory when estimating surface temperatures. The results obtained can be explained, however, by means of two simple hypotheses; on the basis of these there are practical rules which can be used in establishing the importance of cold bridges, and recommendations for reducing them.

TN711. **Measures for air quality, annual report—FY 1971,** J. R. McNesby and R. Byerly, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 711, 77 pages (Jan. 1972).

Key words: Air pollution; carbon monoxide; hydrocarbons; nitrogen oxide; ozone; particulates; standard reference materials; sulfur dioxide.

A compilation of reports covering the air pollution related projects at NBS during FY 1971. There are 23 projects in all, and they cover many areas of air pollution measurement. A table of contents lists descriptive project titles.

TN712. **Manual and computerized footprint identification,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 712, 13 pages (Feb. 1972).

Key words: Computerized-footprint-identification; footprint; pattern recognition.

Part 1 describes a manual footprint classification system that utilizes the ridge patterns adjacent to the toes on the sole of the right foot. This system is an extension of the FBI footprint classification system. Part 2 describes a method of coding minute details of these prints for storage in a computerized file. The computer can then search a similarly coded unknown print against this file and identify the most likely matching prints from the file.

TN713. **Electromagnetic multipole transitions in the recoupling picture, or, electron scattering without curls,** J. S. O'Connell, Nat. Bur. Stand. (U.S.), Tech. Note 713, 20 pages (Feb. 1972).

Key words: Electric transitions; electromagnetic operators; electron scattering; magnetic transitions; multipoles; recoupling.

The formation of the multipole operators from the fundamental charge, current, and moment operators of electron-nucleus scattering is carried through as an angular momentum recoupling problem rather than the usual vector algebra derivation. This point of view allows the electric and magnetic transition operators to be obtained in a simple and intuitive manner. The single particle reduced matrix elements of the charge, current, and moment operators are then calculated in the j-j coupling scheme using a flow chart technique developed by Danos.

TN714. **Reactor Radiation Division: Annual progress report for the period ending October 31, 1971,** R. S. Carter, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 714, 108 pages (Mar. 1972).

Key words: Crystal structure; diffraction; isotope, molecular structure; neutron; nuclear reactor; radiation.

The report is the annual progress report of the Reactor Radiation Division for the period October 1, 1970 to October 1, 1971. It summarizes the activities of the large number of users outside the Division as well as the work in the Division.

TN715. **Tabulation of published data on electron devices of the U.S.S.R. through December 1971,** C. P. Marsden, Nat. Bur. Stand. (U.S.), Tech. Note 715, 108 pages (June 1972).

Key words: Electron devices; electron tubes; semiconductors; U.S.S.R.

This tabulation includes published data on U.S.S.R. electron devices as collected from publications, mostly handbooks, published by the various ministries and institutes of the U.S.S.R. Information is given on all active devices ranging from receiving to microwave devices, semiconductor devices, and miscellaneous devices such as photographic flash tubes and thermistors. Supersedes NBS TN526.

TN716. **The ideal Lovibond color system for CIE standard illuminants A and C shown in three colorimetric systems,** G. W. Haupt, J. C. Schleter, and K. L. Eckerle, Nat. Bur. Stand. (U.S.), Tech. Note 716, 115 pages (Apr. 1972).

Key words: Chromaticity, Lovibond; CIE and Lovibond; colorimetry, Lovibond; color, Lovibond; glass color standards; Lovibond and CIE.

Tables are given which list luminous internal transmittances, luminous transmittances, and chromaticity coordinates of the ideal Lovibond color system for CIE standard illuminants A and C according to (1) the CIE 1931 (x,y)-system, (2) the CIE 1960 uniform-chromaticity-scale (UCS) (u,v)-system, and (3) the CIE 1964 (U*, V*, W*,)-system. Chromaticity diagrams for the (x,y)- and (u,v)-systems are shown together with horizontal and vertical cross-sections of the (U*, V*, W*) color solid for the entire ideal Lovibond color system produced by single-color units and two-color combinations of units for each illuminant. In addition, chromaticity diagrams and cross-sections are shown indicating the single color units of red, yellow, and blue for each CIE system and illuminant.

TN717. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report, July 1 to September 30, 1971,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 717, 52 pages (Apr. 1972).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonder; wire bonds.

This quarterly progress report, thirteenth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period included the disclosure of substantial differences in measurements of transistor delay time, a device characteristic frequently used as a screen in radiation hardness assurance tests, as measured with two different instruments; successful application of the infrared response technique to the study of radiation-damaged, lithium-drifted silicon detectors; and identification of a condition that minimizes wire flexure and reduces the failure rate of transistors under slow thermal cycling conditions. Work is continuing on measurement of resistivity of semiconductor crystals; study of gold-doped silicon; specification of germanium for gamma-ray detectors; evaluation of wire bonds and die attachment; measurement of thermal properties of semiconductor devices; noise properties of microwave diodes; and characterization of silicon nuclear radiation detectors. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN718. **Magnetic recording of acoustic data on audiofrequency tape recorders,** E. D. Burnett, E. L. R. Corliss, and R. D. Berendt, Nat. Bur. Stand. (U.S.), Tech. Note 718, 29 pages (Apr. 1972).

Key words: Acoustic measurements; calibrated tape recordings; data acquisition; magnetic recording; psychoacoustic data; recordings in the field; tape recording.

This Technical Note discusses the application of magnetic tape recording to storage and analysis of data obtained in the course of acoustic measurements. In general, the most suitable machines are those designed primarily for recording studios. Advantages in signal-to-noise ratios and extended linear range can be realized by careful choice of recording medium, adjustment of the equipment to optimum performance, and proper care in monitoring the recording process. General instructions for realizing these advantages are given. Particular emphasis is given to the procedures for making well-calibrated recordings in the field, for analysis of noise problems.

TN719. **A simple correction procedure for quantitative electron probe microanalysis,** K. F. J. Heinrich, R. L. Myklebust, H. Yakowitz, and S. D. Rasberry, Nat. Bur. Stand. (U.S.), Tech. Note 719, 49 pages (May 1972).

Key words: Absorption; atomic number; chemical elements; computation procedure; data reduction; electron probe microanalysis; fluorescence; time-sharing; x-ray analysis.

A calculation technique for data reduction in quantitative electron probe microanalysis is described. This technique is embodied in a computer program, called MULTI8, written in FORTRAN IV for batch processing. Six chemical elements may be determined simultaneously without redimensioning the program. The relative x-ray intensity data are corrected for atomic number, absorption and secondary fluorescence due to the characteristic lines. Options for calculating the mass fraction of one chemical element by difference or by stoichiometry are available in the program. Supersedes and extends NBS TN521.

TN720. **A simple hydraulic sinusoidal pressure calibrator,** J. S. Hilten, P. S. Lederer, and J. Sethian, Nat. Bur. Stand. (U.S.), Tech. Note 720, 27 pages (Apr. 1972).

Key words: Calibrator; dynamic; hydraulic; InterAgency Transducer Project; pressure transducer; sinusoidal pressure.

This paper describes a simple, accurate device for the sinusoidal calibration of pressure transducers. Calibration is achieved by vibrating a liquid tube on an electrodynamic shaker (vibration generator); the pressure transducer mounted at the base of the tube senses the sinusoidally varying pressure in the tube. The frequency range is 15 Hz to 2000 Hz with a maximum obtainable amplitude of 19.5 psi (134 kN/m^2) peak to peak. The transducer can easily be calibrated statically in the same device, thus permitting precise correlation between static and dynamic calibrations. Agreement between static and dynamic calibrations to within 0.1% has been achieved.

TN721. **NBS Special Foreign Currency Program in Israel 1970-71,** H. S. Peiser and M. Klein, Nat. Bur. Stand. (U.S.), Tech. Note 721, 175 pages (Apr. 1972).

Key words: Binational research cooperation; international scientific cooperation; Israel science and technology; physical science research administration; PL-480 programs; research planning; scientific research abstracts.

An overview is given of grants awarded by the National Bureau of Standards under the Special Foreign Currency Program in Israel authorized by Public Law 480 and its amendments. Each grant is identified by title, principal investigator, institution in Israel, NBS monitor working in close technical touch with the project in Israel, and the monitor's organizational unit within NBS. The relevant work is then described briefly under the three headings "Summary of Description of Project Goals," "Results and Implications to Date" and "List of Publications that Resulted from the Project." To demonstrate the wide use of such grants over the entire Program Structure of NBS, the grant descriptions are ordered by the elements of that Program Structure. Editorial comment on the significance and purpose of the NBS/PL 480 grant program is confined to a Foreword and Introduction. The editors judge this grant program to have had a high benefit to cost ratio from the viewpoint of NBS.

TN722. **Tensile creep of boron epoxy and boron epoxy-reinforced 7075-T6 aluminum alloy,** D. J. Chwirut, Nat. Bur. Stand. (U.S.), Tech. Note 722, 60 pages (May 1972).

Key words: Aluminum alloy; boron/epoxy; composite materials; creep; elastic follow-up technique; sandwich specimen.

Tensile creep tests were performed on twelve specimens of 0° unidirectional boron/epoxy and on twenty-four specimens of 7075-T6 aluminum alloy reinforced with 0° unidirectional boron/epoxy. An analytical procedure for predicting the creep properties of composite-reinforced metals is presented. Agreement between calculated and experimental creep curves varies with test temperature. These discrepancies between experiment and analysis are probably not due to an error in the analysis itself, but rather to uncertainty in the residual stresses in the specimens.

TN723. **A laser technique for investigating the effects of thermal transients on pressure transducer performance characteristics,** P. S. Lederer and J. S. Hilten, Nat. Bur. Stand. (U.S.), Tech. Note 723, 43 pages (May 1972).

Key words: Laser; performance characteristic; pressure transducer; temperature effects; test method; thermal transient.

A simple and repeatable testing technique was developed which makes it practical to obtain information on the zero shift and change in sensitivity of a pressure transducer while it is subjected to a thermal transient generated by a mechanically chopped cw laser beam. Several commercial, flush diaphragm, pressure transducers with ranges from up to 50 psi (3.45×10^5 N/m^2) were tested and showed zero shifts and changes in sensitivity of the order of 20% FS due to thermal transients with power densities up to 100 K W/m^2. The transducer under test can be pressure cycled while it is irradiated. In this way, zero shifts and sensitivity changes may be directly displayed in a procedure which requires a testing time of only about one minute.

TN724. **Properties of selected superconductive materials,** B. W. Roberts, Nat. Bur. Stand. (U.S.), Tech. Note 724, 100 pages (June 1972).

Key words: Bibliography; compilation of data; composition; critical field; critical temperature; crystallographic data; low temperature; superconductivity.

This is a noncritical compilation of data on superconductive materials with the exception of data on the elements that has been extracted from a portion of the literature published up to early 1971. The properties concerned are composition, critical temperature, critical magnetic fields, crystallographic data, and the lowest temperature tested for materials specifically explored for superconductivity. The compilation also includes, bibliography, general reference review articles and a special tabulation of high magnetic field superconductors. Supersedes and extends NBS TN482.

TN725. **A neutron moments computer code, moment I,** C. M. Eisenhauer, G. L. Simmons, and L. V. Spencer, Nat. Bur. Stand. (U.S.), Tech. Note 725, 38 pages (May 1972).

Key words: Carbon; computer code; gauss quadrature; moments; neutron transport; shielding.

In this paper we discuss a computer code for generating spatial-angular moments of neutron flux in an infinite medium. The equation for the flux moments is given and the techniques used for the solution are discussed. The structure of the computer code and of the main subroutines is also discussed. Details of the input and output data are given and the printout from a sample problem is included.

TN726. **Testing and fabrication of wire-bond electrical connections—a comprehensive survey,** H. A. Schafft, Nat. Bur. Stand. (U.S.), Tech. Note 726, 140 pages (Sept. 1972).

Key words: Bonding; degradation (wire bond); discrete devices; electrical interconnection; fabrication (wire bond); failure (wire bond); hybrid circuits; integrated circuits; microelectronics; reliability; semiconductor devices; survey (wire bond); testing (wire bond); thermocompression bonding; ultrasonic bonding; wire bond.

The fabrication and testing of wire-bond electrical connections used in integrated circuits, hybrid circuits, and low-power discrete semiconductor devices are surveyed comprehensively. The survey is generally restricted to wire-bond electrical connections where the wire diameter is less than 2 mils and where the wire is bonded either by thermocompressive or ultrasonic means. Under the general heading of fabrication, the essential features of the thermocompression and ultrasonic bonding processes, the fabrication procedures, and the characteristics of the constituent materials of the wire bond pertinent to high reliability are surveyed. Also included is a review of the interaction of gold and aluminum as one of the primary failure mechanisms in wire bonds. Both new and old test methods are surveyed with emphasis on their capabilities and limitations. In particular, the following test methods are discussed: visual inspection; pull, shear, air blast, push, ultrasonic stress, centrifuge, mechanical shock, variable frequency vibration, vibration fatigue, short-duration stress pulse, temperature cycling, thermal shock, bond interface resistance, and electrical continuity tests; noise measurement; and ultrasonic bond monitoring. Analyses of some of the methods with regard to the stress that the test imposes on the wire bond have been made and the results are used in discussing the relevant methods.

TN727. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report October 1 to December 31, 1971,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 727, 79 pages (June 1972).

Key words: Alpha-particle detectors; aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; nuclear radiation detectors; probe techniques (a-c); resistivity; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonding; wire bonds.

This quarterly progress report, fourteenth of a series, describes NBS activities directed toward the development of

methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period included the determination of the reasons for substantial differences in measurements of transistor delay time, a device characteristic frequently used as a screen in radiation hardness assurance tests, as measured with different instruments or with the same instrument at different frequencies; identification of an energy level model for gold-doped silicon that yields a calculated dependence of resistivity on gold concentration that agrees very well with experimental measurements on *p*-type gold-doped silicon; and finding of evidence that it does not appear to be necessary for an ultrasonic bonding tool to grip the wire and move it across the substrate metallization to make the bond. Work is continuing on measurement of resistivity of semiconductor crystals; study of gold-doped silicon; development of the infrared response technique; evaluation of wire bonds and die attachment; measurement of thermal properties of semiconductor devices, delay time and related carrier transport properties in junction devices, and noise properties of microwave diodes; and characterization of silicon nuclear radiation detectors. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN728. **Torsional instabilities in composite and composite-reinforced aluminum-alloy thin-walled cylinders,** D. E. Marlowe, Nat. Bur. Stand. (U.S.), Tech. Note 728, 77 pages (June 1972).

Key words: Aircraft structures; boron/epoxy; composite materials; reinforced aluminum; stability; thin shells; torsion buckling.

The elastic buckling strength has been determined for thin-walled aluminum-alloy tubes fabricated with and without unidirectional boron/epoxy and glass/epoxy composite materials applied as reinforcement to their outer surfaces. Three boron/epoxy ply orientations were investigated. The results of these tests have been compared with the buckling strengths predicted by two analytical techniques. It was found that reinforcement of the metal tubes with an equal thickness of the composite material increased the buckling strength about threefold. The effect on buckling strength of the ply angles investigated is small when compared with the overall effect of adding the reinforcement. The analyses have approximately the same degree of accuracy as that generally attributed to Donnell's treatment of isotropic tubes.

TN729. **Design, construction, and testing of a new high accuracy spectrophotometer,** K. D. Mielenz and K. L. Eckerle, Nat. Bur. Stand. (U.S.), Tech. Note 729, 60 pages (June 1972).

Key words: Beam non-uniformity; circular entrance and exit apertures; high accuracy spectrophotometer; linearity; parabolic mirrors; stray radiant energy; transmittance.

A new spectrophotometer is described which has an accuracy of approximately 0.0001 transmittance units. The spectrophotometer utilizes a collimated beam in the sample area. This is accomplished by means of off-axis parabolic mirrors in the monochromator and sample compartment. Also, circular holes are used as entrance and exit apertures in the monochromator. All components of this spectrophotometer were chosen to achieve maximum accuracy. The result of this work is a "state of the art" instrument. The instrument was tested to evaluate its performance. Systematic errors such as detector non-linearity, stray radiant energy, and beam non-uniformity are measured. A correction for non-linearity of the photomultiplier and electronics is applied.

TN730. **Manual and automated fingerprint registration,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 730, 26 pages (June 1972).

Key words: Computerized-fingerprint-identification; fingerprint; pattern-recognition.

A method is described for manually positioning a fingerprint so that manually read minutiae data can be searched by computer against a file of fingerprint data that has been previously read by machine. A procedure is also described whereby a computer can utilize machine-read ridge-direction data in manipulating minutiae data to effect a registration of the fingerprint prior to filing its minutiae data.

TN731. **Calibration of secondary standard magnetic tape cassettes (computer amplitude reference) Phase I,** S. B. Geller and P. A. Mantek, Nat. Bur. Stand. (U.S.), Tech. Note 731, 60 pages (July 1972).

Key words: Cassette tapes; cassette transport; computer amplitude reference; magnetic tape cassette; secondary standard; standard reference material; unrecorded references.

This Technical Note discusses a method for developing and maintaining a reference system which will produce NBS Secondary Standard Magnetic Tape Cassettes (Computer Amplitude Reference). It describes both centerline tape search procedures and an interim signal amplitude measurement system for the reference magnetic tape cassette candidates. The results of the initial experiments with cassette tapes and transports are given.

TN732. **A computer terminal network for transparent stimulation of the user of an on-line retrieval system,** S. Treu, Nat. Bur. Stand. (U.S.), Tech. Note 732, 39 pages (July 1972).

Key words: Computer terminal network; human characteristics; interactive information retrieval; man-computer interface; transparent stimulation; unobtrusive monitoring.

A computer terminal network to enable "transparent stimulation" of the user of an on-line retrieval system has been designed, implemented, and pilot tested. Its basic purpose is to provide a suitable and effective framework and methodology for experimental identification/validation of those human characteristics which should be recognized/reinforced in man-computer interface design. The rationale behind the transparent stimulation approach is presented and the methodology employed for such real-time, unobtrusive scanning and manipulation of the man-computer dialogue is described. A general overview of the hardware and software features of the implemented stimulation network is included.

TN733. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report January 1 to March 31, 1972,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 733, 59 pages (Sept. 1972).

Key words: Aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; nuclear radiation detectors; probe techniques (a-c); resistivity; ribbon wire bonding; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; thermographic measurements; ultrasonic bonding; wire bonds.

This quarterly progress report, fifteenth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting

period include development of a procedure to correct for the substantial differences of transistor delay time, a device characteristic frequently used as a screen in radiation hardness assurance tests, as measured with different instruments or with the same instrument at different frequencies; association of infrared response spectra of poor quality germanium gamma-ray detectors with spectra of detectors fabricated from portions of a good crystal that had been degraded in known ways; and confirmation of the excellent quality and cosmetic appearance of ultrasonic bonds made with aluminum ribbon wire. Work is continuing on measurement of resistivity of semiconductor crystals; study of gold-doped silicon; development of the infrared response technique; evaluation of wire bonds and die attachment; and measurement of thermal properties of semiconductor devices, delay time and related carrier transport properties in junction devices, and noise properties of microwave diodes. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN734. **OMNITAB II. Segmentation structure for the SCOPE operating system,** S. T. Peavy and R. N. Varner, Nat. Bur. Stand. (U.S.), Tech. Note 734, 25 pages (June 1972).

Key words: ANSI FORTRAN; general-purpose computer program; implementation of OMNITAB II; links; OMNITAB II; overlay procedures; SCOPE operating system; segmentation.

OMNITAB II is an interpretive system developed and maintained by the National Bureau of Standards to enable scientists to use a large computer easily, effectively and accurately for numerical, statistical and data analysis without prior computer experience. The system is as machine independent as possible, making implementation relatively easy. Since OMNITAB II has a large memory requirement, segmentation and overlay are virtually essential.

Overlay procedures are dependent upon the operating system of the computer. Changes are necessary to the OMNITAB II program when the overlay procedure requires specific overlay CALL statements to external procedures in other overlay links. This Technical Note describes a method of segmentation and overlay for a particular operating system (CDC-6000 series). The method can readily be adapted to other operating systems with modifications to the control statements.

TN735. **The effects of magnetic fields on magnetic storage media used in computers,** S. B. Geller, Nat. Bur. Stand. (U.S.), Tech. Note 735, 35 pages (July 1972).

Key words: Erasure, magnetic media; erasure, permanent magnet; erasure, shielding against; erasure, signal loss due to; magnet fields, erasure with; magnetic media, computer; magnetic media, information damage; permanent magnet, erasure with; permanent magnets; shielding.

Experiments have been performed with different types of magnets to determine their effects on the information stored on magnetic storage media. The test results that were obtained with recorded computer tapes are discussed and guidelines are suggested to computer installation managers for protecting their recorded tapes, disks and drums against unwarranted erasure by magnetic fields. The effects of other forms of energy on recorded magnetic media are briefly considered.

TN736. **Carrier lifetime measurement by the photoconductive decay method,** R. L. Mattis and A. J. Baroody, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 736, 52 pages (Sept. 1972).

Key words: Carrier lifetime; germanium; photoconductive decay; silicon.

The photoconductive decay (PCD) method of carrier lifetim measurement is discussed with emphasis on experimental an analytical work done at NBS. The relationship betwee photoconductive decay time τ_{PCD}, bulk decay time τ_B, an lifetime is described briefly and the PCD method is summarize The determination of τ_B from τ_{PCD} and the influence of highe modes of recombination are discussed.

Experimental data, supported by theoretical consideration are presented to demonstrate the dependence of τ_{PCD} on exces carrier density, the type of light source, specimen homogeneity filter thickness, and temperature. The dependences of τ_{PCD} on ex cess carrier density and temperature are consequences of th statistics of the recombination process. Measurements mad with chopped light excitation are shown to be less in error due t higher modes of recombination than are measurements mad with pulsed light excitation. The presence of inhomogeneities i verified in two crystals. Use of a filter is also shown to reduce th influence of higher modes. An unexpected reduction in τ_{PCD} wit increasing filter thickness is shown to be caused by an in homogeneity.

Other experimental conditions are discussed as they affect th measurement of τ_{PCD}. It is shown that the light turnoff must b sufficiently fast and the series resistance sufficiently large tha they do not interfere with the measurement. Equations ar developed whereby the specimen current and illumination pat tern can be chosen such that carrier sweep-out at the ends of th specimen and ohmic heating are avoided. The end contacts mus be sufficiently ohmic that excessive contact resistance does no interfere with the measurement.

Trapping is defined and the means for identifying it ar discussed briefly. The PCD method is inappropriate for deter mining minority carrier lifetime when trapping is present o under other circumstances when the hole and electron lifetime are unequal.

TN737. **Interior/exterior noise levels of over-the-road trucks: re port of tests,** W. A. Leasure, Jr., T. L. Quindry, D. E Mathews, and J. M. Heinen, Nat. Bur. Stand. (U.S.), Tech Note 737, 317 pages (Sept. 1972).

Key words: Acoustics; noise measurement; noise (sound); truck noise (exterior); truck noise (interior); trucks.

This report presents the results of interior and exterior nois measurements which were made on a representative sample o fifteen over-the-road trucks under various operational modes In-cab measurements were made six inches from the right an left ears of the driver with windows open and closed. Simultane ous exterior measurements were made utilizing a six-microphon array. Graphic histories of A-weighted sound level versus tim are presented for all test conditions and microphone locations The National Bureau of Standards made the field measurement and tabulated the data; however, interpretation of the results i the responsibility of the Department of Transportation and th American Trucking Associations—the joint sponsors of the stu dy. These data supplement the limited in-cab data available i the public domain and will form part of public Docket No. MC 22 Advanced Notice of Proposed Rule Making concerning vehi cle interior noise levels which was issued by the Bureau of Moto Carrier Safety, Department of Transportation, in response t Federal Regulations concerning occupational noise exposure.

TN738. **Subroutine for the calculation of CODEN check charac ters,** D. Garvin, Nat. Bur. Stand. (U.S.), Tech. Note 738, 12 pages (Sept. 1972).

Key words: Check characters; CODEN; computer pro gram; journal abbreviations.

A FORTRAN subroutine is described that computes the check character for an ASTM CODEN for Journal Titles. This routine, written for input in Hollerith characters, is adaptable to other coding schemes. A listing of the routine is provided.

TN739. **A universal dropout tester for magnetic storage media,** S. B. Geller, Nat. Bur. Stand. (U.S.), Tech. Note 739, 32 pages (Sept. 1972).

Key words: Dropouts, cassette tapes; dropouts, computer magnetic tapes; dropouts, instrumentation magnetic tapes; dropouts, measurement system; magnetic storage media; signal amplitude, dropouts.

This Technical Note describes a signal dropout detection and counting system which was designed to make measurements on 1/2 inch magnetic computer tape, magnetic instrumentation tapes and magnetic cassette tapes as required by existing and potential Federal Specifications. The calibration and operational procedures for the system are described in detail.

TN740. **SETAB: An edit insert program for automatic typesetting of spectroscopic and other computerized tables,** R. C. Thompson and J. Hilsenrath, Nat. Bur. Stand. (U.S.), Tech. Note 740, 30 pages (Dec. 1973) 55 cents, SD Catalog No. C13.46: 740.

Key words: Automatic typesetting; computer-assisted typesetting; edit insertion program; FORTRAN program; phototypesetting of spectroscopic tables; typesetting of tables.

SETAB is a FORTRAN program which accepts a card deck or FORTRAN records on magnetic tape and inserts the appropriate flags and shift symbols required by many programs associated with phototypesetting devices. The program is specialized to the particular application, the phototypesetter and typography programs, and to the desired typefaces by means of parameter cards supplied at run time. Examples are shown of spectroscopic tables typeset on the Linofilm phototypesetter at the Government Printing Office using the Autoset Typography Program. The program has also been used for tables of other types of data. The program can handle any records which can be read by a FORTRAN "READ" statement under "A" format control. The original record can be divided into as many as 40 fields and these fields can be combined in any order with any of 26 strings in front of or between the pieces. The program will, on a signal, replace a field by another field or by a combination of fields and strings. The output lines are blocked and paged via the insertion of the required strings between blocks and pages.

TN741. **Unassigned.**

TN742. **United States and Canadian fabric flammability standards,** R. G. Katz, Nat. Bur. Stand. (U.S.), Tech. Note 742, 59 pages (Oct. 1972).

Key words: Blankets; Canada; carpets; clothing; fabric flammability testing; fabrics; Flammable Fabrics Act; Hazardous Products Act; mattresses; sleepwear; standards; United States.

Current fabric flammability standards of the United States and Canada are described. The 1967 amendment to the Flammable Fabrics Act of 1953 gave impetus to basic and applied research in the United States and to the development of new test methods and standards for fabric products. Commercial Standard 191-53, the 45-degree angle test, applies to most clothing items, but a new stringent vertical test was developed for children's sleepwear. A small flame source, i.e., a standard methenamine tablet, is used to test carpets and rugs, while a smoldering cigarette is the ignition source for a mattress standard. The test methods attempt to simulate actual conditions.

In 1970, Canada amended the Hazardous Products Act of 1969 to (a) ban from sale those products already declared dangerously flammable by the United States, and (b) ban from sale some berets and sweatshirts that did not meet the 45-degree angle test. Later amendments (1971) deleted the 1970 amendments and established a basic minimum flammability standard covering all textile products for consumer use. A more stringent standard was established for children's sleepwear and bedding (excluding mattresses, mattress pads and pillows) that use the same 45-degree angle test but with a time of flame spread of 7 seconds or less.

TN743. **Methods of measurement for semiconductor materials, process control, and devices, quarterly report April 1 to June 30, 1972,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 743, 57 pages (Dec. 1972).

Key words: Aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; generation centers; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; nuclear radiation detectors; probe techniques (a-c); recombination centers; resistivity; ribbon-wire bonding; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; trapping centers; ultrasonic bonding; wire bonds.

This quarterly progress report, sixteenth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include verification of the applicability of resolution of forces in interpreting pull test measurements on unannealed wire bonds on single-level substrates, completion of the feasibility study of ribbon-wire bonding with the important finding that ribbon-wire bonds can be made with a wider range of bonding parameters than round-wire bonds of the same strength, and development of test procedures in preparation for studies of high-frequency measurements of transistors on the wafer by means of probes. Work is continuing on measurement of resistivity of semiconductor crystals; study of gold-doped silicon; development of the infrared response technique; evaluation of wire bonds and die attachment; and measurement of thermal properties of semiconductor devices, delay time and related carrier transport properties in junction devices, and noise properties of microwave diodes. New work has been started on development of procedures for analysis of the characteristics of generation-recombination-trapping centers in silicon. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes.

TN744. **Disclosures on: New syntheses of perfluorostyrene and other highly fluorinated derivatives; temperature-, radiation-, and vacuum-resistant magnetic tape; conductometric titration cell; mill work positioner; process for fabricating superconducting microbridges; apparatus for displaying average wind vane or other shaft position; and document numbering machine responsive to a staple in a print area for printing in an alternate area,** D. Robbins and A. J. Englert, Editors, Nat. Bur. Stand. (U.S.), Tech. Note 744, 31 pages (Nov. 1972).

Key words: Conductometry; decoding matrix; fluoroolefins; integrator; magnetic sensing probe; magnetic tape; microbridge; numbering machine; perfluorostyrene; shaft position encoder; staple detector; superconducting; synthesis, chemical; titration; wind vane; work positioner.

This Note describes and illustrates seven developments that are believed to embody interesting and unusual solutions to current problems in their fields.

TN745. **Neutron dose and fluence distributions in an infinite air medium,** G. L. Simmons and C. M. Eisenhauer, Nat. Bur. Stand. (U.S.), Tech. Note 745, 39 pages (Jan. 1973) 65 cents, SD Catalog No. C13.46:745.

Key words: Benchmark problems; dose distributions; moments method; neutron penetration; shielding; weapons radiation.

The moments method is applied to the problem of calculating the neutron dose and fluence distributions in an infinite medium of air. These calculations are compared with Monte Carlo and Discrete Ordinates (S_n) results. Simple parametric representations for the distributions are given which facilitate the calculation of dose and flux distributions in air with a different density.

TN746. **Estimates of the nature and extent of lead paint poisoning in the United States,** J. F. Gilsinn, Nat. Bur. Stand. (U.S.), Tech. Note 746, 163 pages (Dec. 1972).

Key words: Childhood diseases; estimation; health problems; lead; lead paint; lead paint poisoning; lead poisoning; mathematical modeling; models; urban health problems.

This report evaluates the nationwide magnitude and extent of pediatric lead poisoning resulting from the ingestion of lead-based paint. Estimates are given of the number of children who have elevated blood lead levels (40 μg or more of lead per 100 ml of whole blood) in each of 241 Standard Metropolitan Statistical Areas throughout the country. The mathematical models used to obtain these estimates are documented together with the assumptions and data upon which those models are based. Partial validation of both models and assumptions is also reported.

TN747. **Critical evaluation of data in the physical sciences—A status report on the National Standard Reference Data System, June 1972,** S. A. Rossmassler, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 747, 79 pages (Nov. 1972).

Key words: Atomic and molecular data; chemical kinetics; colloid and surface properties; data systems design; information services; mechanical properties; nuclear data; standard reference data; solid state data; thermodynamic and transport properties.

This is a report on the status of the National Standard Reference Data System as of June 1972. Recent activities of the Office of Standard Reference Data are summarized and future plans are indicated. A complete list of data evaluation projects supported by the Office of Standard Reference Data during Fiscal Year 1972 is included; this list also includes projects which received financial support during an earlier fiscal year, and which are still actively involved in some aspect of data compilation and evaluation, or which are still preparing a product for publication. Progress in data processing and in information services is reviewed. The appendix includes a listing of continuing data centers in the United states and a list of publications resulting from the standard reference data program.

TN748. **An adjoint gamma-ray moments computer code, ADJ-MOM-I,** G. L. Simmons, Nat. Bur. Stand. (U.S.), Tech. Note 748, 23 pages (Feb. 1973) 30 cents, SD Catalog No. C13.46:748.

Key words: Adjoint; buildup factor; dosimetry; gamma-ray transport; moment methods; shielding.

In this paper we discuss a computer code for generating spatial-angular moments of the adjoint gamma-ray flux in an infinite medium. The equation for the flux moments is given and techniques used for the solution are described. Details of the input data and a sample problem are also supplied.

TN749. **The flammable fabrics program 1971. U.S. Department of Commerce report of activities under the Flammable Fabrics Act 1971,** Nat. Bur. Stand. (U.S.), Tech. Note 749, 92 pages (Dec. 1972).

Key words: Annual report to Congress; blankets; children's sleepwear; flammability; flammability reduction; mattresses; research; sampling plans; standards; test development; upholstered furniture.

This Annual Report to the Congress, required by the Flammable Fabrics Act, covers calendar year 1971. Specific flammability standards outputs were standards for children's sleepwear in sizes 0 through 6X, a proposed standard for mattresses, and a finding of possible need for amendment of the children's sleepwear standard to add sampling plans for the periodic testing by manufacturers of subject garments and materials. Research included studies, in-house and under contract, on subjects such as the contribution of floor covering systems to fire spread along building corridors and the parameters related to the burning of cotton/polyester blends and of multilayer fabrics. Studies of the feasibility of reducing flammability included the effects of treatments on combustion products and the effects of heavy metal ions on flammability. Test development, in addition to that basic to the standards developments already mentioned, included work on a blanket test, an upholstered furniture test, and on a general apparel test. A series of formal training sessions was initiated to supplement the continuing informal training, presentations, etc. Extensive cooperation was carried out with HEW, the public, industry, and voluntary standards groups.

TN750. **Matches and lighters in flammable fabric incidents: The magnitude of the problem,** J. A. Slater, B. Buchbinder, and H. Tovey, Nat. Bur. Stand. (U.S.), Tech. Note 750, 27 pages (Dec. 1972).

Key words: Fabric fires; FFACTS; fire injuries; flammable fabrics; ignition sources; lighters; matches.

Matches and lighters were a major factor in the 1,838 flammable fabric incidents studied for which ignition sources are known. They accounted for 430, almost one-fourth, of the ignitions and led to 375 injuries, of which 57 were fatal. Children and the elderly were the groups most frequently involved in fires started by matches or lighters. Nearly half the incidents involved children under age 11, and two-thirds of these were children under age 6. Forty-four of the 57 fatalities were children under age 11 or adults over 65. The highest fatality rate, 57 percent, was experienced by persons over age 65. The home was the predominant location of fires involving matches and lighters. Of the fabric items ignited by matches and lighters, garments were first to ignite four times as frequently as nonapparel items such as furnishings and bedding. Over one-third of the incidents involved intermediary materials in the ignition sequence. Match ignitions outnumbered lighter ignitions by 6 to 1. Among the 430 match and lighter incidents, fires involving children were overwhelmingly the result of playing with matches and lighters, whereas for persons over age 16, smoking was the single most prevalent activity at the time of ignition.

TN751. **Studies of calibration standards used in the Department of Defense Equipment Oil Analysis Program,** D. W. Golightly and J. L. Weber, Nat. Bur. Stand. (U.S.), Tech. Note 751, 48 pages (Jan. 1973) 75 cents, SD Catalog No. C13.46:751.

Key words: Calibration standards; concentration validity; flash point; lubricating oil; pour point; spectrometric analysis; stability; trace elements; viscosity.

At the request of the Naval Systems Air Command, Department of the Navy, studies have been conducted on organo-metallic calibration standards and diluent oil used in the Department

Defense Equipment Oil Analysis Program. Consultation on standards has been provided, and measurements of physical properties of base oil, concentrations of major elements in standards, concentrations of trace contaminants, and stability of solutions have been performed. Results of studies accomplished fiscal year 1972 are detailed in this report.

N752. **Directory of law enforcement and criminal justice associations and research centers,** B. J. Latka, Nat. Bur. Stand. (U.S.), Tech. Note 752, 49 pages (June 1973) 80 cents, SD Catalog No. C13.46:752.

Key words: Associations; criminal justice; directory, law enforcement; research centers.

This directory lists national, non-profit professional and volunteer social action associations and research centers which are active in the fields of law enforcement and criminal justice. The International and foreign organizations which are listed either have large number of American members, have a United States chapter, or are doing work which is applicable to the United States. The local organizations which are listed either cover several states or are of national interest. The organizations are listed alphabetically with a subject index included. The format of an entry is: title of organization; mailing address; officer; telephone number; year when founded; number of members, number of staff; description of purpose and activities; affiliations; publications, meetings.

N753. **NBS Special Foreign Currency Program in Yugoslavia 1971-72,** H. S. Peiser, S. E. Chappell, E. Horowitz, H. Yakowitz, and D. Bluebond, Nat. Bur. Stand. (U.S.), Tech. Note 753, 72 pages (Jan. 1973) 90 cents, SD Catalog No. C13.46:753.

Key words: Binational research cooperation; international scientific cooperation; physical science research administration; research planning; scientific research abstracts; Special Foreign Currency Program; Yugoslavia science and technology.

An overview is given of grants awarded by the National Bureau of Standards under the Special Foreign Currency Program (SFCP) in Yugoslavia, authorized by Public Law 480 and other legislation. Each grant is identified by title, principal investigator, institution in Yugoslavia, NBS monitor, and the monitor's organizational unit within NBS. The work is then described briefly under the three headings "Summary Description of Project Goals," "Results and Implications to Date" and "List of Publications that Resulted from the Project." To demonstrate the relevance of such grants to the programs of NBS, the grant descriptions are ordered by the elements of that Program Structure. The significance and purpose of the NBS/SFCP grant program are discussed in the Foreword, the Introduction and an Appendix. The NBS monitors and the program manager judge this grant program to have had a high benefit to cost ratio from the viewpoint of NBS.

N754. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report July 1 to September 30, 1972,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 754, 55 pages (Mar. 1973) 80 cents, SD Catalog No. C13.46:754.

Key words: Aluminum wire; base transit time; carrier lifetime; die attachment; electrical properties; epitaxial silicon; gamma-ray detectors; generation centers; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; nuclear radiation detectors; probe techniques (a-c); recombination centers; resistivity; ribbon wire bonding; semiconductor devices; semiconductor materials; semiconductor process control; silicon; thermal resistance; trapping centers; ultrasonic bonding; wire bonds.

This quarterly progress report, seventeenth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include design of a plan to provide standard silicon wafers for four-probe resistivity measurements for the industry, publication of a summary report on the photoconductive decay method for measuring carrier lifetime, publication of a comprehensive review of the field of wire bond fabrication and testing, and successful completion of organizational activity leading to the establishment of a new group on quality and hardness assurance in ASTM Committee F-1 on Electronics. Work is continuing on measurement of resistivity of semiconductor crystals; characterization of generation-recombination-trapping centers in silicon; study of gold-doped silicon; development of the infrared response technique; evaluation of wire bonds and die attachment; and measurement of thermal properties of semiconductor devices, delay time and related carrier transport properties in junction devices, and noise properties of microwave diodes. New efforts were initiated in both the die attachment and wire bond evaluation tasks. Supplementary data concerning staff, standards committee activities, technical services, and publications are included as appendixes. A description of breakdown tracks, a primary failure mode of monolithic integrated circuits stressed with voltage pulses, is given in a separate appendix.

TN755. **Some aspects of the setting and hardening of gypsum plaster,** J. R. Clifton, Nat. Bur. Stand. (U.S.), Tech. Note 755, 33 pages (Jan. 1973) 55 cents, SD Catalog No. C13.46:755.

Key words: Colloidal theory; crystallization theory; gypsum; hydration; induction period; plaster of paris; setting mechanisms.

The mechanisms by which gypsum plaster sets and hardens have been investigated and the results generally are consistent with the crystallization theory. No evidence for the presence of colloidal intermediates has been found. The crystallization theory is modified to include, as an intermediate species, solvated calcium sulfate hemihydrate molecules. Evidence is presented that supports the belief that more than one reaction is responsible for the setting and hardening of gypsum plaster.

The roles of accelerators and retarders have been studied by calorimetric, differential thermal analysis, and scanning electron microscopic techniques. The cation is more effective than the anion in accelerating the setting and hardening of gypsum plasters; the catalytic order follows the sequence M^{+} M^{2+} M^{3+}. Small amounts of retarders can severely retard the setting and hardening processes.

Influences of temperature, impurities, and production conditions on the setting rates of gypsum plasters are discussed.

TN756. **A user's guide to the OMNITAB command "STATISTICAL ANALYSIS,"** H. H. Ku, Nat. Bur. Stand. (U.S.), Tech. Note 756, 44 pages (Mar. 1973) 75 cents, SD Catalog No. C13.46:756.

Key words: Computing, statistical; documentation for users; OMNITAB; statistics.

This Technical Note is the first of a series of interpretive notes for a number of commands in the OMNITAB system that have the automatic printout feature. Others planned in the series in-

clude commands FIT and POLYFIT, TWOWAY analysis, ONEWAY analysis, and CORRELATION.

These notes aim to be self-contained so that users may have sufficient information on hand for the understanding of the statistics computed and to use them for their immediate applications. Computation formulas are given in the text, and a number of statistical tables are reproduced in the Appendix for the convenience of users.

TN757. **The smoke density chamber method for evaluating the potential smoke generation of building materials,** T. G. Lee, Nat. Bur. Stand. (U.S.), Tech. Note 757, 20 pages (Jan. 1973) 45 cents, SD Catalog No. C13.46:757.

Key words: Building materials; fire; fire services; smoke; smoke density chamber; smoke potential; test method; visibility.

The paper reviews the Smoke Density Chamber Test Method and illustrates its use and application to assess smoke generation of building materials in fire situations. It shows how test results may aid the Fire Services and code authorities in evaluating and reducing the potential light-obscuration hazard of smoke in buildings. An example is given for calculating visibility in a simplified fire situation involving material of known smoke generation. The smoke generation of some common interior finish and construction materials is given.

TN758. **NBS reactor: Summary of activities October 1971 to September 1972,** R. S. Carter, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 758, 140 pages (Mar. 1973) $2.10, SD Catalog No. C13.46:758.

Key words: Activation analysis; crystal structure; diffraction; isotopes; molecular dynamics; neutron; nuclear reactor; radiation.

This report summarizes all those programs which depend on the NBS reactor. It covers the period from October 1971 through September 1972. The programs range from the use of neutron beams to study the structure and dynamics of materials through nuclear physics and neutron standards to sample irradiations for activation analysis, isotope production, and radiation effects studies.

TN759. **The NBS lead paint poisoning project: Housing and other aspects,** H. W. Berger, Nat. Bur. Stand. (U.S.), Tech. Note 759, 25 pages (Feb. 1973) 30 cents, SD Catalog No. C13.46:759.

Key words: Hazard elimination; lead analysis; lead paint; lead poisoning.

The National Bureau of Standards is providing technical support required by the Department of Housing and Urban Development to carry out its research responsibilities under PL 91-695, The Lead Based Paint Poisoning Prevention Act. The program at NBS has involved three major areas of research: (1) an estimation of the numbers of children at risk and with excessive body burdens of lead and the geographical distribution of those children; (2) the capabilities and characteristics of analytical methods for the detection of lead in paint and other building materials; and (3) the identification and evaluation of materials, techniques and systems for removing or eliminating the lead paint hazard from housing. This paper is a brief presentation of the activities and conclusions of NBS in the areas listed above.

TN760. **Description of the magnetic tape version of the Bulletin of Thermodynamics and Thermochemistry, No. 14 (1971),** R. McClenon, W. H. Evans, D. Garvin, and B. C. Duncan, Nat. Bur. Stand. (U.S.), Tech. Note 760, 51 pages (Mar. 1973) 75 cents, SD Catalog No. C13.46:760.

Key words: Bibliography; chemical thermodynamics; extended character codes; information retrieval; magnetic tape.

The substance-property index and bibliography sections of the Bulletin of Thermodynamics and Thermochemistry, No. 14 (May 1971) have been converted to a magnetic tape version designed for computerized searching written in an extended form of the American National Standard Code for Information Interchange (X 3.4-1968). In this version each substance-property entry has been supplemented by a searching key. This report describes the magnetic tape version.

TN761. **Project SOAP: A systems approach to biomedical research program management—A case study,** R. S. Cutler, Nat. Bur. Stand. (U.S.), Tech. Note 761, 75 pages (Apr. 1973) 95 cents, SD Catalog No. C13.46:761.

Key words: Biomedical research; "health relevance"; program planning and budgeting; R&D management; systems analysis; systems approach.

This case study describes the activities of an interagency task group that applied systems analysis to improve management controls within a biomedical research agency of the federal government. The results were the formulation and implementation of a discipline for program management, which explicitly makes use of multiple criteria in arriving at resource allocation decisions.

The text details the necessary preliminary analysis describing operational activities, information flows, and key decision points within the organization. It goes on to identify the techniques employed and the difficulties encountered while attempting to improve the decision-making process for selecting research projects, under conditions of reduced funding. In particular, a comparison is made between: (1) the agency's traditional single criterion "peer review" judgment for determining budget priorities, and (2) the multiple-criteria judgments required to effect more positive management control. The systematic use of separate "scientific merit" and "health relevance" ratings is compared with the organization's actual experience. The criteria used by various participants in the decision process are analyzed, and a dollar allocation "investment" procedure based on these findings is developed.

A procedure which organizes relevant information for research program planning and evaluation is presented, and extension of this recommended procedure to wider use by science administrators elsewhere in government is discussed.

TN762. **Tabulation of voluntary standards and certification programs for consumer products,** S. J. Chumas, Nat. Bur. Stand. (U.S.), Tech. Note 762, 119 pages (Mar. 1973) $1.25, SD Catalog No. C13.46:762.

Key words: Certification programs; consumer products; household products; industry standards; international recommendations; national standards; product standards; recommended practices; specifications; test methods.

This tabulation is a revised and enlarged version of NBS Technical Note 705, "Tabulation of Voluntary National Standards, Industry Standards, International Recommendations and Certification Programs for Consumer Products," issued December 1971.

Technical Note 705 was a revision of the Draft Tabulation compiled by the American National Standards Institute and issued in April 1970. The categories and products covered in the tabulation were originally based on those listed in the Consumer Product Safety Index (CPSI) of the National Commission on Product Safety, published in July 1970. The products and categories in the current revision are based on those developed

for the National Electronic Injury Surveillance System (NEISS) of the Food and Drug Administration. The NEISS listings are an expansion and revision of the CPSI. NEISS product areas were slightly altered to conform to the scope of this tabulation.

The tabulation lists over 700 product areas and over 1000 standards' titles covering products found in and around the home. (The major consumer product areas not included are foods, beverages, and drugs.) The tabulation also indicates the applicable voluntary national, industrial, and international standards which deal primarily with either safety or performance or both aspects of the products listed. For some of the product areas, there are no applicable standards. Available information on certification programs and standards under development, and the Standard Industrial Classification (SIC) numbers for the products are also provided. Supersedes NBS Technical Note 705.

TN763. **A set of debugging and monitoring facilities to improve the diagnostic capabilities of a compiler,** E. N. Fong, Nat. Bur. Stand. (U.S.), Tech. Note 763, 25 pages (Mar. 1973) 50 cents, SD Catalog No. C13.46:763.

Key words: Compiler; debugging; error diagnostic; high-level programming languages; monitoring; procedural-oriented languages.

Increasing concern with the quality of computer software today makes it important to evaluate critically the debugging facilities available in high-level languages. This paper presents a collection of program debugging and monitoring facilities to improve the diagnostic capabilities of a compiler. A distinction is made between debugging and monitoring facilities performed at compile time, at link/load time and at execution time. These facilities are described in terms of this breakdown with a conscious attempt to move the detection of errors from execution time to compile or link/load time, and to collect information when the information is available during the compilation process.

TN764. **An investigation of the stability of and insulation leakage in some high temperature resistance thermometers: An interim report,** S. D. Wood, Nat. Bur. Stand. (U.S.), Tech. Note 764, 31 pages (May 1973) 50 cents, SD Catalog No. C13.46:764.

Key words: Freezing point of zinc; high temperature resistance thermometer; insulation resistance; platinum resistance thermometer; resistance thermometer; stability; tungsten thermometer; zinc.

Data are presented concerning the stability of high temperature resistance thermometers. Two types of platinum and one type of tungsten thermometer were tested at 1065 °C and 960 °C. Some of the platinum thermometers were also tested at 900 °C and at the freezing point of zinc. Results of tests are also given on the insulation resistance of sensor supports and lead assemblies for the two types of platinum thermometers. A new design for a zinc-point cell is discussed briefly. Suggestions for future work are indicated.

TN765. **Low temperature thermometry: Interim report,** G. Cataland and H. H. Plumb, Nat. Bur. Stand. (U.S.), Tech. Note 765, 23 pages (May 1973) 40 cents, SD Catalog No. C13.46:765.

Key words: Acoustical thermometer; calibrator; germanium thermometers; heat conduction; NBS P2-20 (1965) scale; "speed of sound" isotherms; viscosity.

Earlier acoustical thermometer "speed of sound" isotherms are compared with recent measurements. Where systematic deviations had appeared in "smoothing" through acoustically derived temperatures via germanium thermometers, a possible solution has emerged; more precise temperature control of the acoustical thermometer is desirable and has been realized. A cursory examination of the applicability of the Helmholtz-Kirchhoff equation was made with a modified sonic chamber. Measurements with the modified instrument have shown no changes in the experimental results.

The maintenance of the NBS P2-20 (1965) scale is described. A new calibration apparatus was constructed to accommodate more germanium thermometers thus reducing the calibration cost per thermometer during a calibration run.

TN766. **A gamma ray moments computer code, GAMMOM-I,** C. M. Eisenhauer, G. L. Simmons, and L. V. Spencer, Nat. Bur. Stand. (U.S.), Tech. Note 766, 41 pages (Apr. 1973) 75 cents, SD Catalog No. C13.46:766.

Key words: Computer code; gamma rays; gamma ray transport; gauss quadrature; moments; shielding.

In this paper we describe a computer code for generating spatial-angular moments of gamma ray energy fluence in an infinite medium. The equation for moments of the energy fluence is given and the techniques used for the solution are discussed. The structure of the code and of the main subroutines is also given. Details of the input and output data are presented and the printout from a sample problem is included.

TN767. **Microelectronic interconnection bonding with ribbon wire,** H. K. Kessler and A. H. Sher, Nat. Bur. Stand. (U.S.), Tech. Note 767, 31 pages (Apr. 1973) 50 cents, SD Catalog No. C13.46:767.

Key words: Aluminum wire; bonding; fabrication (wire bonds); microelectronics; ribbon wire; round wire; testing (wire bond); ultrasonic bonding; wire bond.

The feasibility of using aluminum ribbon wire for ultrasonic bonding of semiconductor microelectronic interconnections was studied, and several advantages over the use of round wire of equivalent cross-sectional area were found. Ribbon wire bonds exhibited little deformation or heel damage, and a greater percentage of bonds of a certain quality (as judged by pull strength and appearance) could be made over much greater ranges of the bonding machine parameters, time and tool tip displacement, using ribbon wire than was possible with round wire. The ease of positioning ribbon wire was indicated by making multiple ribbon wire bonds side-by-side on a 5-mil square pad, or by stacking up to four bonds one on top of another. However, bonding with harder than normal wire, previously thought to offer certain advantages with respect to higher bond tensile strength, yielded inconsistent results.

TN768. **Nonmetallic coatings for concrete reinforcing bars. Coating materials,** J. R. Clifton, H. F. Beeghly, and R. G. Mathey, Nat. Bur. Stand. (U.S.), Tech. Note 768, 40 pages (Apr. 1973) 65 cents, SD Catalog No. C13.46:768.

Key words: Chlorides; concrete; corrosion; epoxy coatings; organic coating; steel reinforcing bars.

This work was undertaken in order to determine the feasibility of using organic coatings, especially epoxies, to protect steel reinforcing bars embedded in concrete from accelerated corrosion attributed to the depassivation of steel by chloride ions.

Coatings have been evaluated on the basis of their chemical and physical durabilities as well as their protective qualities. In this study, attention has also been directed to the following: application methods; surface preparation of the steel reinforcing bar; and site of application.

TN769. **A rigorous correction procedure for quantitative electron probe microanalysis (COR 2),** J. Hénoc, K. F. J. Heinrich, and R. L. Myklebust, Nat. Bur. Stand. (U.S.), Tech. Note 769, 132 pages (Aug. 1973) $2.10, SD Catalog No. C13.46:769.

Key words: Continuum fluorescence; data reduction; electron probe microanalysis; fluorescence correction; quantitative analysis.

This publication describes a rigorous data reduction procedure for quantitative electron probe microanalysis, which avoids simplifications present in conventional schemes. In addition, the program contains a correction for fluorescence due to the continuum, and separate computation of the fluorescent effects of each exciting primary x-ray line. Constants characteristic of elements are stored in a permanent data file, and the constants and parameters needed for the calculation of mass absorption coefficients are contained in a sub-program. These provisions and decision-making sections in the development of the fluorescence corrections reduce the required input considerably.

TN770. **Hazard elimination procedures for leaded paints in housing,** D. Waksman, L. F. Skoda, and E. J. Clark, Nat. Bur. Stand. (U.S.), Tech Note 770, 99 pages (May 1973) $1.25, SD Catalog No. C13.46:770.

Key words: Building material; housing; leaded paint; lead hazard elimination methods; lead paint poisoning; performance attributes.

Methods currently used to control the hazard caused by leaded paints in housing vary in effectiveness from complete elimination of the hazard to a minimal effort that runs a high risk for recurrence of the hazard. A series of guidelines has been drawn up to acquaint municipal planners and other decision makers with the factors that should be considered in implementing a hazard elimination program. Formats are presented to describe attributes of the various methods that should be considered.

TN771. **Some experiments on the stirring of viscous liquids,** A. Napolitano, Nat. Bur. Stand. (U.S.), Tech. Note 771, 60 pages (May 1973) 85 cents, SD Catalog No. C13.46:771.

Key words: Agitators; borosilicate glass; glass melt; glass tank; liquids; stirrer; viscosity.

The stirring actions of several designs of small stirrers were observed and photographed in transparent viscous model liquids. The fluidity of the liquids was comparable to that of a molten borosilicate glass at fining temperatures. The most efficient features of one or more of these stirrers were incorporated into larger model stirrers and observed under actual stirring conditions. As a result of these performance tests, a final design of stirrer was selected and fabricated of platinum-rhodium metal and used in an experimental glass tank. The design of one of the pots in the experimental glass tank was modified to obtain the maximum stirring action with the selected stirrer.

TN772. **A performance comparison of labeling algorithms for calculating shortest path trees,** J. Gilsinn and C. Witzgall, Nat. Bur. Stand. (U.S.), Tech. Note 772, 92 pages (May 1973) $1.25, SD Catalog No. C13.46:772.

Key words: Algorithms; networks; paths; shortest-paths; trees.

Many applications in transportation and communication require the calculation of shortest routes between points in a network, and several algorithms for the solution of this problem exist in the literature. This paper examines one class of such algorithms, that which calculates a shortest route from one point in the network to all other intersection points. Computer da handling techniques which can be used to improve the two bas algorithms in this class are investigated. Results of computer tir ing runs on various types and sizes of networks are compare and the differences, sometimes of an order of magnitude, a analyzed. Detailed flowcharts and computer programs of t tested algorithms are also included.

TN773. **Methods of measurement for semiconductor materia process control, and devices. Quarterly report, October 1 December 31, 1972,** W. M. Bullis, Editor, Nat. Bur. Stan (U.S.), Tech. Note 773, 56 pages (June 1973) 80 cents, S Catalog No. C13.46:773.

Key words: Base transit time; carrier lifetime; delay tim die attachment; electrical properties; electronics; epitaxi silicon; four-probe method; generation centers; germaniu gold-doped silicon; infrared response; methods of measur ment; microelectronics; microwave diodes; probi techniques (a-c); pull test; recombination centers; resisti ty; resistivity standards; semiconductor devices; semico ductor materials; semiconductor process control; silicon; parameters; switching transients; thermal resistance; the mally stimulated measurements; trapping centers; wi bonds.

This quarterly progress report, eighteenth of a serie describes NBS activities directed toward the development methods of measurement for semiconductor materials, proce control, and devices. Significant accomplishments during this r porting period include (1) completion of the investigation of t effects of current, probe force, and surface condition on the me surement of resistivity of bulk silicon wafers by the four-pro method, (2) establishment of operating conditions appropria for determining the sensitivity of transient thermal respon measurements to voids in transistor die attachment, and (3) i itiation of an interlaboratory comparison of transistor scatteri parameter measurements. Because of the general applicability the first of these, details are presented in a separate appendi Work is continuing on measurement of resistivity of semicondu tor crystals; characterization of generation-recombinatio trapping centers in silicon; study of gold-doped silicon; develo ment of the infrared response technique; evaluation of wi bonds and die attachment; measurement of thermal properties semiconductor devices; determination of S-parameters, del time, and related carrier transport properties in junction device development of a-c probing techniques; and characterization noise and conversion loss of microwave detector diodes. Suppl mentary data concerning staff, standards committee activitie technical services, and publications are included as appendice

TN774. **Fire service location-allocation models,** D. Colner and J Gilsinn, Nat. Bur. Stand. (U.S.), Tech. Note 774, 46 pag (June 1973) 75 cents, SD Catalog No. C13.46:774.

Key words: Algorithms; fire station location; heuristics; l cation-allocation models; location analysis; resource alloc tion analysis; transportation network analysis.

This paper compiles the various types of location-allocati models which analyze the impact of varying the number and l cation of fire stations. The assumptions of each model, the rel tionships between models, and possible heuristics and algorithn are discussed. In addition, a methodology of spatial concep analogous to those used in transportation planning is presente

TN775. **Coordinated evaluation system (CES) project, moc documentation for building regulation,** R. D. Dikkers, N Bur. Stand. (U.S.), Tech. Note 775 (16 pages) 35 cents, S

Catalog No. C13.46:775.

Key words: Building regulation; evaluation; inspection; manufactured building; mobile homes; model documents; state-of-art study.

Background information, objectives and the current status February 1973) of various tasks and reports pertaining to the Coordinated Evaluation System (CES) project are described. The goal of the CES Project is to develop model informational documentation that will assist state building regulatory agencies n establishing a coordinated and uniform evaluation, approval and inspection system. The model documentation will be related o the following building regulatory functions: (1) data submittal, 2) evaluation, (3) approval, (4) compliance assurance (inspection), (5) installation, and (6) owner information.

TN776. **A new method for generating waterdrops of specified mass,** J. E. Potzick, Nat. Bur. Stand. (U.S.), Tech. Note 776, 12 pages (May 1973) 35 cents, SD Catalog No. C13.46:776.

Key words: Drop generator; liquid drop; waterdrop.

A waterdrop generator has been constructed, based on the mechanical resonance of a vibrating waterdrop, which can enerate drops of 1.5 to 37 mg with standard deviations in the ange of 0.1 percent to 10 percent of drop mass. Drop mass over his range and drop interval are remotely controlled.

TN777. **Cost analysis of blood banking alternatives,** T. Miller, M. King, J. Flannagan, E. Nilsson, and B. Lemieux, Nat. Bur. Stand. (U.S.), Tech. Note 777, 121 pages (Sept. 1973) $1.35, SD Catalog No. C.13.46:777.

Key words: Blood banks; blood utilization statistics; cost benefit analysis; donor profiles; peer review; regulatory activities; sensitivity analysis.

This report provides a description of the current blood banking ystem and of the collection and derivation of quantitative information concerning system operation and blood cost. A easonably accurate but somewhat incomplete profile of practices, attitudes, and likely costs of present and alternative ystems has been developed. Among the topics presented are: 1) discussion of the blood collection process including statistics n present use and future needs; 2) information relating to donor notivation, attitudes and incentives; 3) a brief summary of demonstration programs in the U.S. and national blood programs n other countries which provides some insight concerning neans for improving blood quality and availability; 4) a description of blood processing, storage and distribution procedures; 5) narrative and statistical information relating to blood utilization practices; 6) discussions of post transfusion reactions and frozen blood programs; 7) a discussion of current governmental and professional standards, regulations and controls which influence many, but not all, concerns involved in blood collection and processing.

This information serves as the basis for the selection of alternatives analyzed in a cost effectiveness analysis of eight apparently viable alternatives to the current system. Because of the possible variation which might be ascribed to many of the parameters used as a basis for costing alternatives, the sensitivity analysis is crucial in the comparison of alternatives.

TN778. **Guidelines for selection of and use of foam polyurethane roofing systems,** W. C. Cullen and W. J. Rossiter, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 778, 46 pages (May 1973) 75 cents, SD Catalog No. C13.46:778.

Key words: Durability; fire safety; performance guidelines; protective coatings; rigid polyurethane; roofing.

The use of spray-in-place polyurethane foam for roofing application in the United States is increasing at a rapid rate. Little unbiased information is available to guide the user in the specification, selection, application, and performance of this innovative roofing system. This report describes the current state-of-the-art of rigid polyurethane technology as applied to roofing systems. The performance parameters as observed during the field survey are discussed in terms of protective coatings, fire safety, durability and problem areas. Guidelines to assist the supplier and user alike in the use and selection of polyurethane foam roofing systems are given. Finally, a performance specification for spray-in-place polyurethane foam roofing system is suggested.

TN779. **Data communications system throughput performance using high speed terminals on the dial telephone network,** D. S. Grubb, Nat. Bur. Stand. (U.S.), Tech. Note 779, 40 pages (May 1973) 65 cents, SD Catalog No. C13.46:779.

Key words: Data communications; modems; terminals; throughput; TRIB.

Throughput performance of high speed data terminals using the dial telephone network is calculated for signaling rate of 1200 to 4800 bits per second using the ANSI X3.28-1971 control procedures and measured in terms of the proposed ANSI strand TRIB described in X3S35/80. The performance calculations are shown graphically with TRIB as a function of block length, error rates of the telephone connection, signaling rate and telephone line delays. Error rates are based on a published survey involving several hundred telephone connections to geographically distributed parts of the United States.

TN780. **Controlled accessibility bibliography,** S. K. Reed and M. M. Gray, Nat. Bur. Stand. (U.S.), Tech. Note 780, 15 pages (June 1973) 35 cents, SD Catalog No. C13.46:780.

Key words: Confidentiality; controlled accessibility; data integrity; data security; security.

A bibliography of 96 references on controlled accessibility has been compiled. The purpose in compiling this limited bibliography was to free the effort to solve the problems of controlled accessibility from domination by discussion of the issues of privacy. Insofar as possible, except when the two subjects are referred to in the same work or for overriding historical considerations, references dealing with privacy have not been included.

TN781. **A study of six university-based information systems,** B. Marron, E. Fong, D. W. Fife, and K. Rankin, Nat. Bur. Stand. (U.S.), Tech. Note 781, 98 pages (June 1973) $1.25, SD Catalog No. C13.46:781.

Key words: Computer-based systems; information systems, university; university computer systems.

A methodology for categorically describing computer-based information systems was developed and applied to six university-based, NSF-supported, systems. The Systems under study all operate as retail information centers primarily serving campus communities by accessing large commercially-available data bases using 3d generation computer configurations. The systems vary in design philosophy, mode of user service, transferability characteristics, and operational status. A summary matrix is included.

TN782. **Application of systems analysis to the operation of a fire department,** E. K. Nilsson, J. A. Swartz, and M. Westfall, Nat. Bur. Stand. (U.S.), Tech. Note 782, 52 pages (June 1974) SD Catalog No. C13.46:782.

Key words: Alexandria; fire department; location; operations research; resource allocation; simulation; systems analysis.

Rising labor costs and increasing competition for tax dollars to provide urban services demand that a more precise methodology be used in the management of fire departments. A pilot program was conducted with the cooperation of the Alexandria, Va. Fire Department to evaluate the applicability and usefulness of selected Operations Research tools. These tools, in the form of computer models, were modified and adapted to assure that they could be implemented to provide information which would facilitate fire department management. In this effort queuing, facility location, and simulation models were applied to sample data extracted from the historical records of the Alexandria Fire Department. It was established that such models do provide valuable information which may assist managerial decisions. This paper describes the city of Alexandria and its fire department, the O.R. models, output from their application, and evaluations of the output.

TN783. **Durability and maintenance as related to the selection of flooring,** W. C. Wolfe, R. F. Roberts, and M. Russell, Nat. Bur. Stand. (U.S.), Tech. Note 783, 68 pages (Aug. 1973) 90 cents, SD Catalog No. C13.46:783.

Key words: Carpets; durability; economics; field studies; flooring; floor coverings; life-cost; maintenance; user needs.

This report is addressed to the problem of selection and maintenance of flooring to the best advantage in terms of durability, type and severity of service, appearance, comfort, and safety. The selection of flooring is discussed with respect to service life, maintenance, obsolescence, and trade-off advantages. Two articles by maintenance administrators include information and discussion helpful in determining maintenance cost, trade-offs, and selection of flooring for different types of service. Field observations and preliminary field tests by the National Bureau of Standards indicate areas in which research is needed, as in laboratory tests for wear and slip resistance. Observations and field tests are impracticable to use for procurement.

This report is helpful in the selection and maintenance of flooring and floor finishes. More important, it points up areas in which research is needed to develop information for this purpose.

TN784. **Unassigned.**

TN785. **Scanning electron microscope examination of wire bonds from high-reliability devices,** K. O. Leedy, Nat. Bur. Stand. (U.S.), Tech. Note 785, 35 pages (Aug. 1973) 55 cents, SD Catalog No. C13.46:785.

Key words: Aluminum wire; high reliability; integrated circuit; metallization; scanning electron microscope; transistor; ultrasonic bonding; wire bonding.

An examination with a scanning electron microscope was made of the wire bonds of over 75 high-reliability microelectronic devices. The device interconnects were ultrasonically bonded aluminum wires. Of primary interest were the bonds themselves; their appearance and its significance are described. Also described is the appearance of the metallization and the wire. Comments and explanations are given where the phenomena are understood. Although the devices studied had passed preliminary electrical tests and pre-encapsulation visual examinations, many potential reliability problems were identified such as weak bonds, electrical shorts and contamination.

TN786. **Methods for testing wire-bond electrical connections,** H. A. Schafft, Nat. Bur. Stand. (U.S.), Tech. Note 786, 23 pages (Nov. 1973) 50 cents, SD Catalog No. C13.46:786.

Key words: Bonding; electrical connection; failure (wire bond); integrated circuits; microelectronics; reliability; semiconductor devices; testing (wire bond); wire bond.

A significant fraction of the failures that occur in integrated circuits are due to failures of the wire-bond electrical connections that are used. Therefore, a critical area for reliability improvement is in the methods for testing and evaluating wire bonds. Several of these methods are surveyed. In particular, analyses with regard to the stress that the test imposes on the wire bond in the pull, centrifuge, mechanical shock, vibration and temperature cycling tests are presented and used in discussing the capabilities and limitations of these methods.

TN787. **Heuristic cost optimization of the Federal Telpak network,** R. G. Saltman, G. R. Bolotsky, and Z. G. Ruthberg, Nat. Bur. Stand. (U.S.), Tech. Note 787, 52 pages (June 1973) 80 cents, SD Catalog No. C13.46:787.

Key words: Communications network; computer program; heuristic; minimum cost; network configuration; optimization; Telpak rate structure.

A heuristic method of optimizing the design of a very large communications network is described. The procedure is employed to configure the routes of 5552 communications service requests involving 1633 nodes. A FORTRAN IV program was developed to solve for actual needs of the Defense Communications Agency for leased-line service employing the Telpak tariff structure.

TN788. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report January 1 to March 31, 1973,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 788, 79 pages (Aug. 1973) 95 cents, SD Catalog No. C13.46:788.

Key words: Base transit time; carrier lifetime; delay time; die attachment; electrical properties; electronics; epitaxial silicon; four-probe method; generation centers; germanium; gold-doped silicon; infrared response; methods of measurement; microelectronics; microwave diodes; probing techniques (a-c); pull test; recombination centers; resistivity; resistivity standards; semiconductor devices; semiconductor materials; semiconductor process control; silicon; S parameters; switching transients; thermal resistance; thermally stimulated properties; trapping centers; wire bonds.

This quarterly progress report, nineteenth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include (1) development of a comprehensive large-area test pattern for evaluating planar junction structures, (2) completion of experimental work on the evaluation of the destructive, double-bond pull test for wire bonds, (3) initiation of a scanning electron microscope facility, and (4) completion of the investigation of the mechanism of emitter-base junction reverse breakdown during rapid switching of transistors. Because of the general applicability of the last of these, details are presented in a separate appendix. Work is continuing on measurement of resistivity of semiconductor crystals; characterization of generation-recombination-trapping centers in silicon; study of gold doped silicon; development of the infrared response technique; evaluation of wire bonds and die attachment; measurement of thermal properties of semiconductor devices; determination of S-parameters, delay time, and related carrier transport properties in junction devices; development of a-c probing techniques; and characterization of noise and conversion loss of microwave detector diodes. Supplementary data concerning staff, standard committee activities, technical services, and publications are included as appendices.

TN789. **Technical options for energy conservation in buildings**

National Conference of States on Building Codes and Standards and National Bureau of Standards Joint Emergency Workshop on Energy Conservation in Buildings held at the U.S. Department of Commerce Washington, D.C., June 19, 1973, Nat. Bur. Stand. (U.S.), Tech. Note 789, 184 pages (July 1973) $2.35, SD Catalog No. C13.46:789.

Key words: Building design; energy conservation; mechanical systems.

The purpose of this report is to provide reference material on he technical options for energy conservation in buildings. It was prepared for the National Conference of States for Building Codes and Standards-National Bureau of Standards Joint Emergency Workshop on Energy Conservation in Buildings held at he U.S. Department of Commerce in Washington, D.C. on June 19, 1973.

This report describes actions pertinent to existing buildings and new buildings. Regarding existing buildings, principal topics include summer cooling, winter heating, and other energy conserving features—i.e., insulation, fenestration, lighting, appliances, domestic hot water, and human comfort. Suggested actions include those which can be accomplished voluntarily or without expense, and also actions which require some modest effort or expense on the part of the building owner or occupant.

Regarding new buildings, energy conservation actions are described that deal with building design and mechanical systems. The report concludes with a summary of mechanisms for implementation of such actions and criteria for use in evaluation of them.

TN789-1. **Emergency workshop on energy conservation in buildings,** S. A. Berry, Nat. Bur. Stand. (U.S.), Tech. Note 789-1, 31 pages (July 1975) SD Catalog No. C13.46:789-1.

Key words: building codes; buildings; energy conservation; standards.

This report contains the non-technical presentations given at the National Conference of States on Building Codes and Standards/National Bureau of Standards Joint Emergency Workshop on Energy Conservation in Buildings.

Presentations included in this document are those of other Federal Agencies, States, technical societies and industry organizations.

This document is a companion document to NBS Technical Note 789, "Technical Options for Energy Conservation in Buildings."

TN790. **MIDAS modular interactive data acquisition system—description and specification,** C. H. Pepenoe and M. S. Campbell, Nat. Bur. Stand. (U.S.), Tech. Note 790, 49 pages (Aug. 1973) 75 cents, SD Catalog No. C13.46:790.

Key words: Computer-controlled experiment; computer interfacing; data acquisition system; digital interface; instrumentation; laboratory automation; MIDAS; programmable controller.

The task of interfacing experiments to computers and data-logging systems should be made as painless as possible for the scientist. With this intent, MIDAS, a user-oriented, modular digital interface system based on CAMAC hardware and USASCII-bus data communication has been developed. MIDAS modules enable the experimenter to set up, program, modify and operate automated or computer-controlled experiments independently of the experts. Salient features of the concept are described and operating configurations discussed both with and without computer control. System interface requirements are specified in sufficient detail to enable one skilled in the art to design and construct modules operable within a MIDAS system.

TN791. **Dose calibrator pilot study,** S. B. Garfinkel and G. J. Hine, Nat. Bur. Stand. (U.S.), Tech. Note 791, 7 pages (Aug. 1973) 30 cents, SD Catalog No. C13.46:791.

Key words: Dose calibrators; indium-113m; molybdenum-99; nuclear medicine; radiopharmaceuticals; technetium-99m; tin-113.

Results of measurements of six sources in dose calibrators used in nuclear medicine facilities at eight hospitals in the Washington metropolitan area are given.

TN792. **Investigation of viscous flow in glass during phase separation,** J. H. Simmons, S. A. Mills, A. Napolitano, D. H. Blackburn, and W. K. Haller, Nat. Bur. Stand. (U.S.), Tech. Note 792, 43 pages (Sept. 1973) 65 cents, SD Catalog No. C13.46:792.

Key words: Glass; microstructure; phase separation; viscosity.

The isothermal viscosity of two borosilicate glasses, of which one is a commercial glass widely used for chemical glassware, shows a large increase (4 to 5 orders of magnitude) with heat-treatment time (ranging up to 100,000 min) near the annealing point. The two glasses have similar compositions, but differ greatly in their phase separation characteristics. Electron micrographs are used to analyze the development of microstructure during the suspected phase separation. In both glasses, it is found that the structure development is primarily responsible for the viscosity increase. An analysis of the data, and a theoretical interpretation of the effect are presented.

TN793. **Development of a procedure for measuring the noise of paper caps,** M. A. Cadoff, D. E. Mathews, and D. S. Blomquist, Nat. Bur. Stand. (U.S.), Tech. Note 793, 23 pages (Oct. 1973) 50 cents, SD Catalog No. C13.46:793.

Key words: Acoustics; cap guns; children; consumer safety; hearing damage; noise; paper caps; standard apparatus; toys.

In recent years, a great concern has been expressed for consumer protection and safety, especially for children. As an outgrowth of this concern, acoustical testing of potentially hazardous noise-producing toys has been carried out at the National Bureau of Standards for the Bureau of Product Safety (FDA) under the authority of the Toy Safety Act of 1969. This paper discusses in detail the testing work carried out on commercial cap guns and caps, which culminated in the development of a standard firing apparatus for testing paper caps. Engineering drawings of the standard apparatus are given as well as a recommended procedure for using this apparatus to test paper caps.

TN794. **NBS corridor fire tests: Energy and radiation models,** F. C. W. Fung, R. Suchomel, and P. L. Oglesby, Nat. Bur. Stand. (U.S.), Tech. Note 794, 127 pages (Oct. 1973) $1.40, SD Catalog No. C13.46:794.

Key words: Ceiling radiation; corridor fires; critical energy input; flame spread, calculation, and observations; floor covering evaluations; heat balances; heat transfer mechanisms; models, energy balance, radiation, and scaling.

The NBS corridor fire program is a continuing program to investigate the growth and spread of fire and smoke through a corridor when fire is initiated in an adjoining room. Due to recent fires involving floor coverings [1], and controversies over current floor covering flammability test methods, floor coverings have received special attention during the first phase of the cor-

ridor fire program. Results of the NBS program on corridor fires are presented under the unifying concepts of energy and radiation models. The major findings are: (1) One type of carpet fire hazard has been identified as the rapid flame spread over pile surface; (2) The dominant mechanism that causes this flame spread is energy transfer from ceiling radiation. This is substantiated by measurements and calculations; (3) Carpet evaluation by critical cumulative energy input into the corridor has been found to be feasible and informative in terms of heat transfer mechanisms; (4) Finally, a radiant panel test appears to be a promising approach to simulate the corridor environment for second generation flooring tests.

TN795. **Review of network management problems and issues,** A. J. Neumann, Nat. Bur. Stand. (U.S.), Tech. Note 795, 77 pages (Oct. 1973) $1.00, SD Catalog No. C13.46:795.

Key words: Academic computing; networks; network management; regional networks; research computing.

Computer networking is broadly considered including hardware, software, procedures and people. Networking encompasses many activities; such as, creation of network products, distribution processes, user activities, and supporting services like marketing, documentation, information services and maintenance. Network management covers both the establishment of networking operations and actual operation of the network facilities. It includes all management functions performed at such network nodes as computing centers, documentation facilities, and service distribution centers. In order to survey the problems facing development of network management, user requirements and system requirements are outlined in a qualitative manner. Examples of political, economic and legal constraints are summarized, such as the economic impact of extended networks on regional and local computing activities. Critical issues for networking management, and other areas of significant management concern are outlined. Organizational alternatives are conceived in terms of a four layer organization model. Conclusions deal with continuing problem areas, the need for a structural model for network management, critical experiments and tasks to be undertaken to further networking capabilities, and a suggestion to establish planning teams to initiate some of the initial steps required for further networking development.

TN796. **FRAME: An on-line correction procedure for quantitative electron probe microanalysis,** H. Yakowitz, R. L. Myklebust, and K. F. J. Heinrich, Nat. Bur. Stand. (U.S.), Tech. Note 796, 51 pages (Oct. 1973) 80 cents, SD Catalog No. C13.46:796.

Key words: Electron probe; mini-computer; on-line correction; quantitative microanalysis.

A procedure using a mini-computer for on-line correction of x-ray data from electron microprobe analysis has been developed. This program, called FRAME, allows mass fractions to be computed on-line by the ZAF approach. Besides x-ray intensities, the only input data required are the atomic numbers of the elements present, the analytical line being used, and the operating voltage. Other required parameters such as atomic weights and x-ray mass attenuation coefficients are stored or calculated by the program. FRAME is in FORTRAN IV, and requires about 4K of computer core. Results from FRAME are very close to those of COR2, which is considered to be the most accurate program available for quantitative electron probe microanalysis.

TN797. **Static language analysis,** G. Lyon, Nat. Bur. Stand. (U.S.), Tech. Note 797, 23 pages (Oct. 1973) 50 cents, SD Catalog No. C13.46:797.

Key words: Data archives; language use; programming aids; programming languages; source-statement analys syntax analysis.

Although many variants of programming languages exist, lit information is available on how language features are actua used by programmers. Several data collection schemes discussed here; each would provide empirical data on langua use. Some internal details are given for analyzers for FO TRAN and COBOL. In addition, a suggestion is made for a s cial systems option which would allow a compiler to conti ously record source statement characteristics or programs giv to it.

TN798. **Collaborative research program between NBS and Ind Scientific Institutions. Special foreign currency program 1 status,** H. S. Peiser, M. B. McNeil, and D. M. Bluebond, E tors, Nat. Bur. Stand. (U.S.), Tech. Note 798, 139 pa (Nov. 1973) $1.50, SD Catalog No. C13.46:798.

Key words: Binational research cooperation; internatio scientific cooperation; India science and technology; ph cal science research administration; research planni scientific research abstracts; Special Foreign Currency.

An overview is given of grants awarded by the National l reau of Standards under the Special Foreign Currency Progr in India, authorized by Public Law 480 and its amendme Each grant is identified by title, principal investigator, institut in India, NBS monitor charged with working in close techni touch with the project in India, and the monitor's organizatio unit within NBS. The relevant work is then described bri under the three headings "Summary Description of Proj Goals," "Results and Implications to Date," and "List of Pu cations that Resulted from the Project." To demonstrate wide use of such grants over the entire Program Structure NBS, the grant descriptions are ordered by the elements of t Program Structure. Editorial comment on the significance purpose of the NBS/SFCP grant program is confined to a Fo word and Introduction. The editors judge this grant program have had a high benefit to cost ratio from the viewpoint of NI

TN799. **User procedures standardization for network access,** J. Neumann, Nat. Bur. Stand. (U.S.), Tech. Note 799, pages (Oct. 1973) 70 cents, SD Catalog No. C13.46:799.

Key words: Network access procedures; networking; st dardization; user protocols.

User access procedures to information systems have beco of crucial importance with the advent of computer netwo which have opened new types of resources to a broad spectr of users. This report surveys user access protocols of representative systems. Functional access requirements are c lined, and implementation of access procedures is analyzed means of a common methodology.

Qualitative assessment of standardization possibilities iden standardization candidates such as: system and user signals, line user entries, system requests, and network wide catego of message content.

TN800. **Computer networking: Approaches to quality service surance,** R. B. Stillman, Nat. Bur. Stand. (U.S.), Tech. N 800, 26 pages (Jan. 1974) SD Catalog No. C13.46:800.

Key words: compiler; computer network; documentati dynamic software analysis; interpreter; quality control; s ware testing; software verification; static software analy structured programming; system errors; system p formance; theorem-proving.

The problem of quality service assurance in a (generaliz

computer networking environment is addressed. In the absence of any direct, well-defined, quantitative measure of service quality and reliability, error collection and analysis is the only basis for service quality control. Therefore, mechanisms are described which facilitate reporting of operational errors, documentation of error corrections, and collection of system performance data. Since techniques for hardware quality control are well known, these mechanisms focus on collecting data which can be used to assess and control software quality. Finally, specific network facilities are described which support research in the area of software quality, and potential areas of new research using the network are identified.

TN801. **Research considerations in computer networking to expand resource sharing,** D. W. Fife, Nat. Bur. Stand. (U.S.), Tech. Note 801, 24 pages (June 1974) SD Catalog No. C13.46:801.

Key words: computer networking research; computer network management; management evaluation; resource sharing.

Computer networking technology is adequately developed now to support research and experimentation to expand computing resource sharing. Whether progress will be made depends upon organizational initiative among multiple institutions, to pool personnel and capital so as to effectively address the major issues in management approach, support and software design that limit the feasible interdependence of computing operations. The organizational requirements are partially revealed by examining progressive stages of resource sharing in organizational and operational terms rather than such technical aspects as load sharing or program sharing that have been introduced in the past. Five stages are identified, ranging from simply establishing multiple service access to the advanced stage where multiple institutions organize for joint development of new resources. A preliminary evaluation framework for new management arrangements results when these stages are mapped against the four functional levels inherent in computer network management. Future needs for networking experimentation and research are briefly described, and other NBS technical results are identified in context.

TN802. **Network user information support,** A. J. Neumann, Nat. Bur. Stand. (U.S.), Tech. Note 802, 27 pages (Dec. 1973) 60 cents, SD Catalog No. C13.46:802.

Key words: Computers; consultation; documentation; information support; networks; on-line support; user needs; user support.

With increasing interest in the development of computer networks and the proliferation of remote entry capability from user terminals, user support takes on new dimensions. Some user characteristics are outlined as they affect user support. User support requirements are identified for training, terminal operation, and general information to aid in network operations. Support capabilities include on-line aids, information available on request, and tutorial information available at the terminal. User support also includes pertinent documentation and human consultation. Areas of future research are identified as: interactive language design, tutorial design, integration of hard-copy and on-line capabilities, and further development of user feedback capability.

TN803. **A guide to networking terminology,** A. J. Neumann, Nat. Bur. Stand. (U.S.), Tech. Note 803, 29 pages (Mar. 1974) SD Catalog No. C13.46:803.

Key words: computer networks; glossary; telecommunications; teleprocessing; terminology; vocabulary.

A selected set of terms and definitions relating to computer networking is presented in a coherent manner. An introduction gives the rationale for the glossary, defines the scope by a brief tutorial overview, and states the glossary format and conventions. The glossary is arranged alphabetically and contains about 140 definitions and associated terms. The sources of many terms are cited and modifiers indicate the status of definitions. A complete listing of source material is appended.

TN804. **Review of computer networking technology,** R. P. Blanc, Nat. Bur. Stand. (U.S.), Tech. Note 804, 135 pages (Jan. 1974) SD Catalog No. C13.46:804.

Key words: computer networks; computer-to-computer transfers; interactive terminals; minicomputer-based systems; network configuration; remote job entry; resource sharing.

This report gives a descriptive summary of the technical characteristics of existing computer networks, including data communication technology and configuration related to support of resource sharing services for a computer network. Included are discussions of terminal support capabilities for the communications network and a development of relevant network terminology. The report concludes with a comparative evaluation of existing technological approaches to networking.

TN805. **Network management survey,** I. W. Cotton, Nat. Bur. Stand. (U.S.), Tech. Note 805, 91 pages (Feb. 1974) SD Catalog No. C13.46:805.

Key words: computer network; management; network, network management.

This report presents the results of a study of management practices in different computer networks. Five networks were chosen as typical of different approaches to network implementation and management: Defense Advanced Research Projects Agency (ARPA) Network, MERIT Network, Triangle Universities Computation Center (TUCC), Oregon State Regional Network and Tymnet, a commercial network. A common format is employed to survey each network. While the report is not intended to be prescriptive, some empirical observations are presented for each topic covered.

TN806. **Methods of measurement for semiconductor materials, process control, and devices. Quarterly report April 1 to June 30, 1973,** W. M. Bullis, Editor, Nat. Bur. Stand. (U.S.), Tech. Note 806, 77 pages (Nov. 1973) $1.00, SD Catalog No. C13.46:806.

Key words: Beam leads; carrier lifetime; delay time; die attachment; electrical properties; electronics; epitaxial silicon; generation centers; gold-doped silicon; methods of measurement; microelectronics; microwave diodes; mobility; pull test; recombination centers; resistivity; resistivity standards; scanning electron microscopy; semiconductor devices; semiconductor materials; semiconductor process control; silicon; S-parameters; spreading resistance; thermal resistance; thermally stimulated properties; trapping centers; wire bonds.

This quarterly progress report, twentieth of a series, describes NBS activities directed toward the development of methods of measurement for semiconductor materials, process control, and devices. Significant accomplishments during this reporting period include (1) completion of an initial identification of the more important problems in process control for integrated circuit fabrication and assembly as a basis for and expanded effort to be conducted in cooperation with ARPA, (2) completion of preparations for making silicon bulk resistivity wafer standards available to the industry, and (3) undertaking of new work to establish the relationship between carrier mobility and impurity density in silicon and to investigate test patterns for use in

process control and evaluation. Because of the general applicability of the first of these, a summary of the findings is presented in a separate appendix. Work is continuing on measurement of resistivity of semiconductor crystals; characterization of generation-recombination-trapping centers, including gold, in silicon; evaluation of wire bonds and die attachment; study of scanning electron microscopy for wafer inspection and test; measurement of thermal properties of semiconductor devices; determination of S-parameters and delay time in junction devices; and characterization of noise and conversion loss of microwave detector diodes. Supplementary data concerning staff, standards committee activities, technical services, and publications are also included as appendices. This is the last report in this form; future reports in this series will appear under the title, Semiconductor Measurement Technology.

TN807. **Building performance in the 1972 Managua earthquake,** R. N. Wright and S. Kramer, Nat. Bur. Stand. (U.S.), Tech. Note 807, 155 pages (Nov. 1973) $1.60, SD Catalog No. C13.36:807.

Key words: Building codes; buildings; earthquakes; hazards; natural disasters; structures.

Following the Managua, Nicaragua, earthquake of Dec. 23, 1972, a team of engineers representing the U.S. Department of Commerce's National Bureau of Standards (NBS) and the National Academy of Engineering (NAE) performed field investigations in Managua, Nicaragua, from Dec. 26, 1972, to Jan. 4, 1973. The objectives were to assist the Nicaraguan government in surveying major buildings to determine whether each was suitable for emergency use, repairable, or appropriate for clearance. The team also viewed the patterns of successful performance and damage to identify needs for improvements in building practices for mitigation of earthquake hazards and opportunities for more detailed investigations which could provide information for future improvements in practices. In general, the damages cannot be attributed to unusual intensities of ground shaking or severity of surface faulting. Most damages appeared to result from deficiencies in building practices; deficiencies which had been exhibited many times before in previous earthquakes, deficiencies which would be avoided by implementation of up-to-date provisions for earthquake resistant design and construction. However, Managua did not employ a building code with seismic design requirements appropriate to its earthquake risk, and furthermore, did not have a building regulatory system capable of effective implementation of its building code provisions. This report documents the observations of damages by the NBS/NAE team and points out relationships to inadequacies in the building practices employed. Most of these inadequacies have been well known; however, the Managuan experience may serve as an incentive to improvement of building practices in many other areas which are subject to substantial earthquake risks and have not consistently accounted for these risks in their building codes and building regulatory system.

TN808. **Potential systems for lead hazard elimination: Evaluations and recommendations for use,** D. Waksman, J. B. Ferguson, M. Godette, and T. Reichard, Nat. Bur. Stand. (U.S.), Tech. Note 808, 192 pages (Dec. 1973) $1.95, SD Catalog No. C13.46:808.

Key words: Abrasion; adhesion; colorfastness; covering; flame spread; flash point; impact resistance; lead paint poisoning; materials; performance; properties; scratch resistance; smoke generation; toxic combustion products; toxicity; washability; water vapor permeance.

The National Bureau of Standards is providing technical support to the Department of Housing and Urban Development which is required by Public Law 91-695 (the Lead Paint Poisoning Prevention Act) to carry out a research program to evaluate and make recommendations regarding technology for the removal of the lead based paint hazard from the Nation's housing.

Potential hazard elimination methods have been identified by means of a survey of available technology. This report describes testing and evaluation methodologies used to determine (1) the suitability for use of a series of removal and lead barrier systems (2) the results of this evaluation, and (3) recommendations concerning the use of said systems.

Paint removal systems were evaluated in terms of the hazards that they present in the course of their use. Both the flammability and the toxicity of the solvents found in removers were considered. Covering systems were evaluated for their suitability for use as barrier layers over lead bearing paints in housing. The effectiveness of covering systems in protecting children from leaded paint, their fire hazard properties and functional properties which are related to their serviceability were considered in making this evaluation. The properties of the systems were assessed in terms of minimum acceptable performance levels and recommendations are given for their use in a field evaluation program.

TN809. **Government looks at privacy and security in computer systems. A summary of a conference held at the National Bureau of Standards, Gaithersburg, Maryland, November 19-20, 1973,** C. R. Renninger and D. K. Branstad, Eds., Nat. Bur. Stand. (U.S.), Tech. Note 809, 47 pages (Feb. 1974) SD Catalog No. C13.46:809.

Key words: computer systems, privacy and security; confidentiality; privacy; security.

This publication summarizes the proceedings of a conference held for the purpose of highlighting the needs and problems of Federal, State and local government in safeguarding individual privacy and protecting confidential data contained in computer systems from loss or misuse. The Conference was held at the National Bureau of Standards on November 19-20, 1973.

The origin of governmental problems is discussed in the context of the public's concern for privacy arising out of computer-based recordkeeping, the diverse legislative actions now being taken to safeguard privacy, the threats to the security of computer-based information systems and the technological problems associated with protecting against such threats. Useful distinctions are drawn between privacy, confidentiality and security to clarify the issues and allocate responsibilities for solving the problem among lawmakers, technologists and management.

Major needs are described. These include the need for cohesive Federal, State and local legislation, technological guidelines and standards for assuring uniform compliance with legislative requirements; management guidelines for identifying and evaluating threats to security; and improved technological mechanisms for controlling access to computer systems and networks. Cost implications of providing security measures are discussed.

TN810. **Fire incidents involving sleepwear worn by children ages 6-12,** J. A. Slater, Nat. Bur. Stand. (U.S.), Tech. Note 810, 23 pages (Dec. 1973) 50 cents, SD Catalog No. C13.46:810.

Key words: Accidents; burns; children; clothing fires; deaths; FFACTS; fire; flammable fabrics; injury; sleepwear; standards; statistics.

Sleepwear was the first fabric item ignited more frequently than any other item in over 1,900 fire incidents reported to the

ional Bureau of Standards Flammable Fabrics Accident e and Testing System (FFACTS). Information acquired e promulgation of the current sleepwear flammability stan- l protecting children of ages 0-5 indicates a problem of com- able magnitude exists for children of ages 6-12. Of 316 in- nts involving non-contaminated sleepwear that was first to te, about one-fourth involved children 0-5 years old and one- rth involved children 6-12 years old. For the 6-12 group, pwear ignited first more often than all other garment items bined. Females outnumbered males 4-to-1 in the 6-12 group, mostly to the involvement of nightgowns and kitchen ranges, most common ignition source for this age group. Five of the 2 year old children died and 52 of 74 victims were hospital- l. Almost all of the first-to-ignite sleepwear in this group was on. Data from Shriners Burns Institute and the National n Information Exchange provide further evidence of the in- vement of children ages 6-12 in garment fires. It is recom- nded that a new standard be issued covering sleepwear sizes rough 14 to effectively protect 6-12 year old children.

811. **Evaluation of the column connections used in a precast oncrete modular housing system,** F. Y. Yokel and T. W. eichard, Nat. Bur. Stand. (U.S.), Tech. Note 811, 63 pages Mar. 1974) SD Catalog No. C13.46:811.

Key words: building system; column connection; concrete triaxial strength; ductility; neoprene bearing pad; Operation Breakthrough; performance test; precast concrete; structural design.

The column connections used in a housing system employing cked precast concrete box modules were tested to evaluate ir structural performance. The system was proposed for con- uction in Operation Breakthrough, a research and demonstra- n program sponsored by the Department of Housing and ban Development. The system uses innovative structural sign concepts, which include: confinement of the concrete in vicinity of the column bearings by reinforcing ties in order to rease concrete compressive strength; neoprene pads between umn bearings in the upper stories; steel-neoprene-steel sand- ch in the lower stories; and a grouted dowel through the center the columns to provide resistance to tension and shear.

The test program included the following: tests to determine the ect of various bearing pads on the load capacity of the connec- n; tests to determine the load-deformation characteristics of neoprene pads; a test to determine the performance of a ver-story connection using a steel-neoprene-steel sandwich d a grouted dowel; and tests to evaluate the strength and duc- ty of the connections when subjected to a shear force. The test sults are presented and interpreted and the findings are sum- arized. Supersedes NBSIR 73-148 (PB 220366/7).

812. **Tensile behavior of boron/epoxy-reinforced 7075-T6 alu- minum alloy at elevated temperatures,** D. J. Chwirut and G. F. Sushinsky, Nat. Bur. Stand. (U.S.), Tech. Note 812, 31 pages Mar. 1974) SD Catalog No. C13.46:812.

Key words: aluminum alloy; boron/epoxy; co-cure; composite materials; fabrication process; load-deformation characteristics; residual stress; rule of mixtures; sandwich specimen; stress-strain curves; tensile properties.

Static tensile tests were performed on specimens of 7075-T6 minum alloy, 0° unidirectional boron/epoxy, and 7075-T6 minum alloy reinforced on the surface with 0° unidirectional ron/epoxy laminate, at four temperatures up to 300 °F (149). Analytical load-strain curves are formulated for the rein- ced-metal specimens using the rule of mixtures, assuming that longitudinal strains in the composite and the metal remain ial, and taking account of the residual stresses caused by the rication process. Two analytical curves are plotted for each reinforced-metal specimen, one based on the measured ply thickness of the composite, and one based on a nominal 0.005-in (0.13-mm) ply thickness. In general, the experimental load-strain curves fall between the two analytical curves for each specimen.

TN813. **NBS Reactor: Summary of activities July 1972 to June 1973,** R. S. Carter, Nat. Bur. Stand. (U.S.), Tech. Note 813, 135 pages (Feb. 1974) SD Catalog No. C13.46:813.

Key words: activation analysis; crystal structure; diffraction; isotopes; molecular dynamics; neutron; nuclear reactor; radiation.

This report summarizes all those programs which depend on the NBS reactor. It covers the period from July 1972 through June 1973. The programs range from the use of neutron beams to study the structure and dynamics of materials through nuclear physics and neutron standards to sample irradiations for activation analysis, isotope production and radiation effects studies.

TN814. **A mechanized information services catalog,** B. Marron, E. Fong, and D. Fife, Nat. Bur. Stand. (U.S.), Tech. Note 814, 56 pages (Feb. 1974) SD Catalog No. C13.46:814.

Key words: bibliographic data bases; computer-based systems; information services; information systems.

NBS is mechanizing a catalog of currently available information sources and services. Information from recent surveys of machine-readable, commercially-available bibliographic data bases, and the various current awareness, batch retrospective, and interactive retrospective services which can access them, has been correlated and converted into a machine-readable data base. A prototype searching capability has been established on an operational interactive retrieval system. Reasons for establishing the catalog and the choice of the initial information are detailed and the prototype implementation is described. Sample queries are included, as well as a to-date listing of the catalog. Plans for future development are discussed.

TN815. **Fire accidents involving the ignition of sleepwear worn by children under the age of three,** E. A. Tyrrell, Nat. Bur. Stand. (U.S.), Tech. Note 815, 23 pages (Feb. 1974) SD Catalog No. C13.46:815.

Key words: accidents; burn injuries; case histories; children's sleepwear; fabric fires; FFACTS; fires; flammable fabrics; garment fires; ignition sources; standards.

Accident case histories of children under age 3 involved in sleepwear fires are examined in detail. Of 434 persons involved in sleepwear ignition incidents in the NBS Flammable Fabrics Accident Case and Testing System as of January 1973, 101 were children under age 6; 22 of these were children under age 3. In 15 of these 22 accidents, the child was a victim of his own actions, while in 7 more accidents, the child played a passive role in the ignition sequence. Matches and kitchen ranges were the most frequent ignition sources found for this group of children. Seven of these small children died; the remaining 15 victims sustained burn injuries covering from one to 65 percent of their bodies. Most of the sleepwear items involved in these 22 accidents were made of cotton and 14 of these 22 items were pajamas. Children under age 3 were most frequently involved in fire accidents during the morning hours in the kitchen or bedroom. Only one child was under the supervision of an adult at the time of the accident. From the information found in the case history reports, an analysis of the severity of the injuries received by the victims was made and it was determined that the severity of the injuries received by one of the 3 infants under the age of one and 15 of the remaining 19 one- and two-year-olds probably would have been reduced if they had been afforded the protection of a flammability standard.

TN816. **Engineering and construction manual for an instrument**

to make burn hazard measurements in consumer products, L. A. Marzetta, Nat. Bur. Stand. (U.S.), Tech. Note 816, 48 pages (Feb. 1974) SD Catalog No. C13.46:816.

Key words: consumer products; contact temperature; thermesthesiometer; thermometry.

Surface temperature measurement alone is insufficient to establish the hazard of human contact with a hot or cold object. A metal surface is more likely to cause thermal injury than a plastic surface at the same temperature. An instrument equipped with a measuring probe has been developed for indicating the tissue temperature that would be experienced if human contact were made with the hot surface in question. The correct value of interface contact temperature can be read for a selected contact time without knowing the composition or temperature of the heated material under test.

A detailed set of instructions and drawings for assisting in the construction of the device is included in the manual. Several test procedures are described for use in checking the performance of the measuring probe and instrument.

TN817. **Kitchen ranges in fabric fires,** A. K. Vickers, Nat. Bur. Stand. (U.S.), Tech. Note 817, 23 pages (Apr. 1974) SD Catalog No. C13.46:817.

Key words: accidents; burns; FFACTS; flammable fabrics; garments; ignition sources; injuries; kitchen ranges.

Kitchen ranges played a major role in the 1616 fabric accident case histories recorded in the Flammable Fabrics Accident Case and Testing System as of May 1972. They accounted for 214 or 35 percent of the direct garment ignitions in FFACTS. Female victims outnumberd males by 3 to 1; females under 16 and over 65 were particularly heavily represented. Reaching over and leaning against the range caused the majority of the garment ignitions. Shirts, robes, pajamas, nightgowns and dresses were the most frequently ignited garments. Thirty-four victims died from injuries resulting from garment ignitions from ranges; 24 of these fatalities were people over 65 years old.

TN818. **Occupant behavior in building fires,** A. I. Rubin and A. Cohen, Nat. Bur. Stand. (U.S.), Tech. Note 818, 28 pages (Feb. 1974) SD Catalog No. C13.46:818.

Key words: disaster research; high rise building fires; occupant safety.

Fire safety in buildings is important in building design and the formulation of codes and standards. However, an examination of the information concerning the *needs* of occupants in fire emergencies (as opposed to ensuring a degree of structural integrity for the building) indicates that the scientific information base is woefully inadequate. The increasing prominence of high rise buildings having many occupants intensifies the need for better information about the behavior of occupants during fire emergencies. Fire researchers have indicated that it is often not feasible to evacuate buildings because of time constraints. Instead, designers use techniques such as safe areas within buildings and requiring people to respond differentially, based on their particular location. This approach emphasizes communications and warning systems to transmit messages. These systems such as loud noises or blinking lights should be designed to "take advantage" of the usual responses made by people. Occupants can actively be a part of the fire warning and fighting system instead of being unwilling victims. This possibility is pursued and a human factors approach is taken to suggest some means of better understanding the capabilities of occupants.

TN819. **A technical index of interactive information systems,** D. W. Fife, K. Rankin, E. Fong, J. C. Walker, and B. A. Marron, Nat. Bur. Stand. (U.S.), Tech. Note 819, 73 pages (Mar. 1974) SD Catalog No. C13.46:819.

Key words: bibliographic systems; computer programs computer syst ems; data base; data management; informa tion retrieval; information services; interactive system query language; software selection; text processing.

This report constitutes a reference to technical features an operational status of interactive information systems, i.e. thos providing a "conversational" usage mode to a "non-pro grammer" through a data terminal device. It is aimed at the ADI service manager, for his use in the state-of-the-art assessment preparatory to a detailed system selection process. It contains a index that describes 46 systems in terms of a list of over 5 technical features plus descriptive, identification, an background information. In addition, there are aids and exam ples contributing to the intended use of the index.

TN820. **Complete clear text representation of scientific document in machine-readable form,** B. C. Duncan and D. Garvin, Na Bur. Stand. (U.S.), Tech. Note 820, 55 pages (Feb. 1974) SI Catalog No. C13.46:820.

Key words: graphic character sets; information analysi centers; information interchange codes; recordin typewriters; scientific computer technology.

Science and technology use a large variety of symbols t represent physical properties, chemical formulas and mathemat cal expressions.

Data centers that codify and evaluate physical properties nee to use this conventional symbolism in their work. It is recom mended that these data centers adopt the symbols and terminol gy specified by the various International Unions both in manu operations and in the creation of machine-readable data bases.

It is demonstrated that these conventional symbols can b produced by modern communications devices that are compat ble with the international standard codes for information in terchange. A set of characters suitable for representing scientifi data and text is presented and proposed as an extension of th ISO information interchange code.

The use of this extended character code by computer oriente data centers at the National Bureau of Standards is describe The equipment needed for this level of performance and criteri for their selection are outlined.

TN821. **Photometric data variability of automotive lighting com ponents,** B. G. Simson and J. Mandel, Nat. Bur. Stand. (U.S. Tech. Note 821, 15 pages (Mar. 1974) SD Catalog N C13.46:821.

Key words: Federal Motor Vehicles Safety Standards; in terlaboratory test evaluation; motor vehicles; photometri testing; safety standards.

Four automotive lighting components were tested in thre commercial testing laboratories to estimate the degree photometric data repeatability and reproducibility. The laborat ries used the photometric testing techniques required by Feder Motor Vehicle Safety Standard No. 108. The precision of th test method was placed in a range of about 10 percent coefficie of variation. However, this value should be considered more an indication of existing conditions than as a predictive param ter.

TN822. **A review of Federal and military specifications for flo coverings,** W. C. Wolfe, Nat. Bur. Stand. (U.S.), Tech. No 822, 99 pages (Apr. 1974) SD Catalog No. C13.46:822.

Key words: carpets; floor coverings; government; pe formance; procurement; specifications; standards; test user needs.

In this manual, which is organized so as to aid ready reference, requirements and test methods in Federal and military specifications for flooring, or floor coverings are combined, indexed and reviewed. The manual covers carpet, resilient flooring, monolithic surfacings or seamless flooring, and polyurethane coatings related to seamless flooring. It also covers all serviceability requirements except those relating to flammability, fire safety and acoustical properties.

Physical and material requirements in Federal specifications for floor coverings are considered in separate sections. Military specifications for monolithic surfacings and Federal specifications for floor coverings and polyurethane coatings are summarized in comprehensive tables. Under each physical requirement, comments indicate whether it is a quality control or a performance requirement. Each comment is followed by a list of those Federal specifications which include the requirement and a brief description of the criteria and test methods in the specifications. Comments on materials requirements relate to their adequacy and applicability to the product for which they were written. Finally, recommendations are made for improvements in performance requirements which should be considered for inclusion in future flooring and floor covering specifications.

TN823. **Cryogenic Physics Section, summary of activities 1973,** R. J. Soulen, Jr., Ed., Nat. Bur. Stand. (U.S.), Tech. Note 823, 23 pages (Mar. 1974) SD Catalog No. C13.46:823.

Key words: Josephson junctions; noise thermometer; nuclear orientation; paramagnetism; superconductivity; temperature.

This report summarizes the research activities of the Cryogenic Physics Section which specifically relate to thermometry. The topics range from superconductive fixed points to nuclear orientation thermometry, as well as Josephson junction noise thermometry and paramagnetism.

TN824. **A laboratory study of some performance characteristics of an aluminum oxide humidity sensor,** S. Hasegawa, L. Greenspan, J. W. Little, and A. Wexler, Nat. Bur. Stand. (U.S.), Tech. Note 824, 28 pages (Mar. 1974) SD Catalog No. C13.46:824.

Key words: aluminum oxide sensor; humidity; humidity sensor; hygrometer; measurement of frost points; moisture measurement; water vapor measurement.

A laboratory study was made of the performance of aluminum oxide humidity sensors over a range of ambient temperatures from +20 °C to − 60 °C encompassing dew points from +18 °C to frost points of − 100 °C. Information was obtained on such characteristics as sensitivity, hysteresis, temperature effect, pressure-altitude effect and short-term and long-term repeatability. The sensors were found to be capable of detecting frost points as low as − 100 °C at ambient temperatures of − 40 °C and − 60 °C. It is estimated that the total uncertainty inherent in these sensors is approximately 4 °C.

TN825. **Properties of selected superconductive materials—1974 supplement,** B. W. Roberts, Nat. Bur. Stand. (U.S.), Tech. Note 825, 1974 Supplement, 88 pages (Apr. 1974) SD Catalog No. C13.46:825.

Key words: bibliography; composition; critical fields; critical temperature; crystallographic data; data compilation; low temperature; superconductive materials; superconductivity.

This report includes data on additional superconductive materials extracted from a portion of the world literature up to mid-1973. The data presented are new values and have not been selected or compared to values (except for selected values of the elements) previously assembled by the Superconductive Materials Data Center. The properties included are composition, critical temperature, critical magnetic field, crystal structure and the results of negative experiments. Special tabulations of high magnetic field materials with Type II behavior and materials with organic components are included. All entries are keyed to the literature and a list of reviews centered on superconductive materials is included. Extends NBS Technical Note 724.

TN826. **Cost-benefit analysis of computer graphics systems,** I. W. Cotton, Nat. Bur. Stand. (U.S.), Tech. Note 826, 47 pages (Apr. 1974) SD Catalog No. C13.46:826.

Key words: computer graphics; cost-benefit analysis; cost-effectiveness; economics; performance evaluation.

This report assesses the state-of-the-art in cost benefit analyses of computer graphics systems and suggests an approach for developing improved methodology. Cost-benefit analyses are distinguished from analyses of system performance in that the latter are directed at optimizing system performance at a given level of investment, while the former are directed at justifying the investment itself.

Computer graphic system design alternatives are first outlined. Then methods of analyzing the performance and costs of computer systems in general and graphic systems in particular are discussed. With this information it is shown how cost-effectiveness analyses may be performed. The next crucial step is to conduct benefit analysis, an ill-defined art. The results of benefit analysis must be combined with cost-effectiveness analysis in order to perform the desired cost-benefit analysis.

An experimental methodology is suggested for better performing benefit analyses of computer graphic systems. A more rigorous formulation of the cost-benefit procedure is then outlined. No attempt is made in this report to actually perform such an analysis.

TN827. **Controlled accessibility workshop report. A report of the NBS/ACM Workshop on Controlled Accessibility, Rancho Santa Fe, Calif., Dec. 10-13, 1972,** S. K. Reed and D. K. Branstad, Eds., Nat. Bur. Stand. (U.S.), Tech. Note 827, 86 pages (May 1974) SD Catalog No. C13.46:827.

Key words: access control; computer security; controlled accessibility; EDP management control; identification; measurement; security audit.

A report has been prepared of the NBS/ACM Workshop on Controlled Accessibility, December 1972, Rancho Santa Fe, Calif. The Workshop was divided into five separate working groups: access controls audit, EDP management controls, identification, and measurements. The report contains the introductory remarks outlining the purpose and goals of the Workshop, summaries of the discussions that took place in the working groups and the conclusions that were reached. A list of participants is included.

TN828. **Measures for air quality (1972-1973). Annual report-FY 1973,** J. R. McNesby, Nat. Bur. Stand. (U.S.), Tech. Note 828, 143 pages (May 1974) SD Catalog No. C13.46:828.

Key words: air pollution; measurement; standard reference material; water pollution.

This report is a project-by-project description of the Measures for Air Quality program covering the fiscal years 1972 and 1973. Participation in the program is bureau-wide but the program office operates out of the Institute for Materials Research. Although air pollution measurement science has formed the major thrust of the program, it has been extended in FY 73 to include the beginnings of a water pollution effort to respond to new needs, particularly those arising out of the requirements of the Federal Water Pollution Control Act of 1972. A report on the MAQ program for FY 72 was not issued. However, the project

reports in the current document include progress made during FY 72 for those FY 73 projects which were active in FY 72. Where a project was terminated at the end of FY 72 its description is included in the present document with appropriate notation.

In water pollution the situation is much more complex since there are many more pollutants in more types of water that will be subject to control under the Federal Water Pollution Control of 1972. When a pollutant is of concern in the discharge permit program, water quality standards, the toxic pollutant list and in the specimen bank program, the state of the measurement art is scrutinized at NBS and the need for development assessed.

TN829. **Multicommodity network plotting via program NETPLT,** Z. G. Ruthberg, G. R. Bolotsky, and W. Slater, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 829, 67 pages (June 1974) SD Catalog No. C13.46:829.

Key words: communication network; multicommodity network; network; network display; plotting algorithm; plotting program.

In the design and operation of complex networks, it is often an advantage to obtain a visual representation that readily allows for a quick appraisal of the network's current configuration or of its changed appearance due to variations of its nodes and links. The program NETPLT enables a user to plot the two leading characteristics of any multicommodity network: (1) nodes and links and (2) the multiple source-sink structure (multi-commodity property). The unique feature of NETPLT is its unambiguous planar representation of links. NETPLT uses an arc of a circle instead of the usual straight line, to represent a connector between a node pair (link).

TN830. **NBS cryogenic thermometry and the proposed cryogenic extension of the IPTS,** G. Cataland, R. P. Hudson, B. W. Mangum, H. Marshak, H. H. Plumb, J. F. Schooley, R. J. Soulen, Jr., and D. B. Utton, Nat. Bur. Stand. (U.S.), Tech. Note 830, 32 pages (May 1974) SD Catalog No. C13.46:830.

Key words: acoustical thermometry; γ-ray anisotropy thermometry; noise thermometry; nuclear magnetic resonance; nuclear quadrupole resonance; paramagnetism; superconductivity; temperature.

This article outlines a comprehensive and long-term program being carried out by NBS scientists of the Cryogenic Physics and Temperature Sections. The goals of the program are the extension of IPTS 68 below 13.81 K and the development of devices which make practical realizations of that scale convenient and reliable. We propose to contribute to international adoption of a thermodynamically accurate scale below 13.81 K by analyzing the results of three thermometers: the NBS Acoustical Thermometer (already in operation for several years), noise thermometry using the Josephson effect (recently developed), and γ-ray anisotropy thermometry (recently studied in detail at NBS). Such a temperature scale will most likely be disseminated by the use of certain superconductors as thermometric reference points. Practical interpolation devices will be based on the principles of nuclear and electronic paramagnetism, nuclear quadrupole resonance, and nuclear magnetic resonance. Details of operation, measurement schemes and experimental progress made to date are included in nine appendices.

TN831. **Introduction to liquid flow metering and calibration of liquid flowmeters,** L. O. Olsen, Nat. Bur. Stand. (U.S.), Tech. Note 831, 60 pages (June 1974) SD Catalog No. C13.46:831.

Key words: calibration; liquid flow; liquid flowmeters; metering.

These notes are intended to serve as an instruction manual for technicians and engineers engaged in metering liquids and calibrating liquid flowmeters. It is a condensed review of the properties of liquids and the mathematical relations required in this work. References to more complete sources of properties of liquids, theoretical relations and instructions for metering liquids are included. Separate chapters discuss liquids and their properties as they affect flow, the theory of incompressible flow of liquids and the measurements required in the metering of liquids. One chapter describes several different apparatus and their use in the calibration of liquid flowmeters. The last chapter contains brief descriptions of the many types of flowmeters such as differential pressure, positive displacement, electromagnetic and ultrasonic. It also includes a discussion of the physical principles involved in their design and use.

TN832. **Report on planning session on software engineering handbook,** S. L. Stewart, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 832, 18 pages (Nov. 1974) SD Catalog No. C13.46:832.

Key words: programming; quality software; software engineering.

This report from a planning committee sponsored by the National Bureau of Standards, the National Science Foundation, and the Association for Computing Machinery discusses the need for, coverage of, and audience for a proposed Software Engineering Handbook.

TN833. **Fire department ground ladders—results of a preliminary study,** H. P. Utech, Nat. Bur. Stand. (U.S.), Tech. Note 833, 82 pages (July 1974) SD Catalog No. C13.46:833.

Key words: aluminum; fire department; ladders; performance requirements; standards.

The key performance requirements for fire department ground ladders were determined. Existing ladder standards were reviewed and found to be unnecessarily restrictive in some areas and inadequate and unrealistic in others. Included in the report are metallurgical studies of three ladders that failed in service as well as a correlation of hardness with tensile and yield strength for 6061-T6 alloy.

TN834. **Information handling needs within the U.S. Patent Office,** S. Jeffery, Nat. Bur. Stand. (U.S.), Tech. Note 834, 17 pages (June 1974) SD Catalog No. C13.46:834.

Key words: administrative operations; data handling; data storage and retrieval; information handling technology; information processing; intellectual process; patent examination; Patent Office; patent storage; production statistics.

This paper examines aspects of the Patent Office's needs that make it different from other existing information retrieval systems. The paper than reviews current technology and assesses its ability to provide effective and economical tools to aid the Patent Office.

TN835. **Tabulation of published data on electron devices of the U.S.S.R. through December 1973,** C. P. Marsden, Nat. Bur. Stand. (U.S.), Tech. Note 835, 130 pages (Nov. 1974) SD Catalog No. C13.46:835.

Key words: electron devices; electron tubes; semiconductors; U.S.S.R.

This tabulation includes data on U.S.S.R. electron devices as collected from publications, mostly handbooks, published by the various ministries and institutes of the U.S.S.R. Information is given on all active devices ranging from receiving to microwave devices, semiconductor devices, and miscellaneous devices such as photographic flash tubes and thermistors. Supersedes NBS TN715.

TN836. **Detector actuated automatic sprinkler systems—a preliminary evaluation,** R. L. P. Custer, Nat. Bur. Stand. (U.S.), Tech. Note 836, 27 pages (July 1974) SD Catalog No. C13.46:836.

Key words: bedding fires; design criteria; detector actuated automatic sprinklers; detectors; levels of protection; life safety; sprinklers.

An investigation was conducted to evaluate the capabilities of a detector actuated automatic sprinkler system to protect individuals who are intimately associated with the first materials ignited such as bedding materials. Tests were conducted in a simulated nursing home bedroom. System response was evaluated for both smoldering and open flaming ignition sources. It was determined that barring electrical or mechanical failure the system could be nearly 100 percent effective with smoldering fires. The effectiveness with open flaming fires was difficult to evaluate. Although these fires were extinguished with minimum damage in times as short as 36 seconds the possible effects of flammable blankets and sleepwear were not tested. It was estimated that perhaps one third of the potential victims of open flaming fires might be saved. Although these tests were limited in scope, some tentative design criteria for detector actuated sprinkler systems are presented and possible alternatives offered.

TN837. **Barrier penetration tests,** R. T. Moore, Nat. Bur. Stand. (U.S.), Tech. Note 837, 191 pages (June 1974) SD Catalog No. C13.46:837.

Key words: barrier penetration; intrusion detection; intrusion resistance; physical security.

Sixteen structural barrier panels were tested to determine their resistance to forcible penetration through the use of readily available tooling. Thirteen of these represented experimental techniques to reinforce an existing structural barrier of low penetration resistance; the other three were designs which would be most appropriate to consider as replacement barriers. Minimum man-passable sized openings were made in the barriers in working times which averaged 7.85 minutes and ranged from 1.52 to 25.56 minutes. One of the replacement and two of the reinforcing designs showed superior cost-effectiveness.

Seven woven, wire-mesh security fence specimens were also tested for their intrusion deterrence capability. The test results indicate that the deterrent influence of unelectrified fences of the type tested is largely psychological rather than physical. All of the specimens could be penetrated in 0.14 minutes or less.

Samples of the acoustical and vibrational data produced during the penetration tests add to the growing body of data which are expected to be useful in the design and selection of electronic intrusion alarm equipments.

TN838. **The use of weather and climatological data in evaluating the durability of building components and materials,** L. W. Masters and W. C. Wolfe, Nat. Bur. Stand. (U.S.), Tech. Note 838, 101 pages (Aug. 1974) SD Catalog No. C13.46:838.

Key words: accelerated aging; building components and materials; climatological data; durability; environmental factors; long-term tests; short-term tests; weathering factors.

The durability of building components and materials is dependent, to a large extent, on the in-service environment to which they are subjected in service. Thus, the prediction of durability requires knowledge of the service environment.

Weathering factors, which comprise one group of environmental factors, are the subject of this report. The objectives of this report are to indicate how, in the present state of knowledge, weather and climate data can be used to aid in quantifying weathering factors so that durability tests for building components and materials may be designed.

TN839. **Fire detection: The state-of-the-art,** R. L. P. Custer and R. G. Bright, Nat. Bur. Stand. (U.S.), Tech. Note 839, 119 pages (June 1974) SD Catalog No. C13.46:839.

Key words: fire detection; fire detection code requirements; fire detector testing and standards; fire detectors; fire signatures.

The current state-of-the-art in fire detection technology is reviewed considering the nature of fire signatures, detection modes used, test methods, performance requirements and code requirements for fire detection. Present trends in standards development and recommendations for future work are included. An extensive bibliography is provided.

TN840. **Reference materials for collaborative tests of air quality methods,** R. H. Johns and J. K. Taylor, Nat. Bur. Stand. (U.S.), Tech. Note 840, 17 pages (Aug. 1974) SD Catalog No. C13.46:840.

Key words: air pollution; chemical analysis; Standard Reference Materials.

Reference materials and associated distribution apparatus were developed for seven ambient air contaminants and for two smokestack contaminants. These established the reference base for collaborative tests of ASTM procedures for ambient air quality and smokestack emissions carried out under a three-year program known as Project Threshold.

TN841. **Review of reverberant sound power measurement standard and recommendations for further research,** Nat. Bur. Stand. (U.S.), Tech. Note 841, 24 pages (Aug. 1974) SD Catalog No. C13.46:841.

Key words: acoustics; noise; reverberation room; sound power; statistical room acoustics.

This report presents a critical review of American National Standard S1.21-1972, "Methods for the Determination of Sound Power Levels of Small Sources in Reverberation Rooms." This standard, as now embodied, represents a major advance in the state-of-the-art of reverberation room measurement of sound power. This report was prepared in order to identify additional analytical and experimental information needed for further refinement of this standard. This report presents a detailed critique of specific items in the standard. Indications are given of both general research areas for statistical room acoustics and of specific research areas for improved reverberant room sound power measurements.

TN842. **Concepts in quality software design,** S. L. Stewart, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 842, 89 pages (Aug. 1974) SD Catalog No. C13.46:842.

Key words: control structures; GOTO-less programming; program validation; programming; proofs of correctness; referential transparency; software quality; structured programming; top-down programming.

A seminar series on quality software, sponsored by the Systems and Software Division, was held at the National Bureau of Standards during the summer of 1972. This Note includes five of these seminars in edited form. (I) A brief background provides motivation for studies in software quality. The authors mention some factors which influence software manufacture, and propose measures which might quantify concepts of "software quality." Several approaches to establishing program correctness receive attention. (II) Elements of top-down programming are sketched out and then examined in detail. An extended critique of another

top-down experiment provides example material. (III) Powers of various structured control constructs are compared within a framework of weak and strong program equivalence. Results include a demonstration that Dijkstra's D-programs are strongly equivalent to programs built from functions and one-input/two-output predicates. (IV) After a review of Quine's notion of referential transparency, the author examines elements of good and bad programming practice. In addition, a table of programming proverbs provides guidance to a programmer, and should be especially useful to a novice. (V) Discussions on problem and program specification provide an introduction to a review of proof-of-correctness techniques. Then, noting some practical limitations on proving correctness, the author goes on to examine selected facets of program synthesis.

TN843. **A technical guide to computer-communications interface standards,** A. J. Neumann, B. G. Lucas, J. C. Walker, and D. W. Fife, Nat. Bur. Stand. (U.S.), Tech. Note 843, 111 pages (Aug. 1974) SD Catalog No. C13.46:843.

Key words: ADP standards; communications disciplines; computer networks; data communications.

A technical summary and guide is given for existing and forthcoming Federal and National standards on data communications pertinent to computer networking. Selected international standards and industry practices are included for completeness. Prepared to assist the application of standards within the World Wide Military Command and Control System, this handbook should be useful to all ADP system designers interested in uniform data terminal interfaces, character sets and codes, keyboard arrangements, and communications line disciplines for effective message exchange between computers.

TN844. **Designs for the calibration of small groups of standards in the presence of drift,** J. M. Cameron and G. E. Hailes, Nat. Bur. Stand. (U.S.), Tech. Note 844, 35 pages (Aug. 1974) SD Catalog No. C13.46:844.

Key words: calibration; calibration design; experiment design; instrumental drift; measurement process; statistical analysis; trend elimination.

The process of calibrating a small number of "unknown" standards relative to one or two reference standards involved determining differences among the group of objects. Drift, due most often to temperature effects, or a "left-right" polarity effect can bias both the values assigned to the objects and the estimate of the effect of random errors. This note presents schedules of measurements of differences that eliminate the bias from these sources in the assigned value and variances at the same time gives estimates of the magnitude of these extraneous components. The use of these designs in measurement process control is discussed and a computer program in BASIC is presented.

TN845. **Cost analysis for computer communications,** R. P. Blanc, Nat. Bur. Stand. (U.S.), Tech. Note 845, 40 pages (Sept. 1974) SD Catalog No. C13.46:845.

Key words: computer networking; cost study; interactive terminals; value-added networks.

This report summarizes a communication cost study relevant to the needs of the NSF Networking for Science Program. The primary purpose of this report is to provide an approximation to the communications costs of connecting a specified number of host computers in selected locations with a specified number of interactive user terminals. Cost factors from existing, proposed, and modeled value-added networks are applied to hypothetical traffic demands to arrive at cost estimates.

TN847. **Dataplot 70: Fortran-callable plotting routines,** C. V. Young and P. G. Stein, Nat. Bur. Stand. (U.S.), Tech. Note 847, 32 pages (Oct. 1974) SD Catalog No. C13.46:847.

Key words: digital plotter; graph; graphics; minicomputer plotter.

A description is given of Dataplot 70, a program which enables plotting 1) lines between pairs of X-Y coordinates and 2) a string of ASCII characters at a given X-Y coordinate on the electrostatic printer/plotter. Detailed instructions are provided enabling the user to 1) convert data to plotter format, 2) draw axis, 3) label axis, 4) scale data, 5) handle arrays, 6) produce symbols at end points, and 7) offset the origin. Hardware and software requirements as well as loading and operating instructions are given.

A sample FORTRAN calling program is included and each instruction is explained in detail. The output of the calling program is shown. Error messages produced by Dataplot 70 are explained.

TN848. **A bibliography of the Russian reference data holdings of the library of the Office of Standard Reference Data,** G. B. Sherwood and H. J. White, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 848, 20 pages (Sept. 1974) SD Catalog No. C13.46:848.

Key words: bibliography; reference data; Russian literature.

This text presents a listing of the Russian reference data holdings of the library of the Office of Standard Reference Data of the National Bureau of Standards as of March 1974. In addition to the bibliographic listing, information on the status of translations into English is given where available.

TN849. **A FORTRAN analyzer,** G. Lyon and R. B. Stillman, Nat. Bur. Stand. (U.S.), Tech. Note 849, 28 pages (Oct. 1974) SD Catalog No. C13.46:849.

Key words: computation and flow analysis; FORTRAN language use; programming aids; syntax analysis.

Details of a FORTRAN analysis package are presented. Examples illustrate a current operational level which gathers FORTRAN statement and frequency-of-execution statistics. Arguments support a simple technique for monitoring FORTRAN executions.

TN850. **Gasoline and gasoline container fire incidents,** E. A. Tyrell, Nat. Bur. Stand. (U.S.), Tech. Note 850, 34 pages (Jan. 1975) SD Catalog No. C13.46:850.

Key words: accidents; FFACTS; gasoline; gasoline containers; gasoline incidents; gasoline-related fires; ignition causing activities; ignition sources; volatile flammal liquids; volatile flammable liquids incidents.

Gasoline was involved in 72 percent of the 645 volatile flammable liquids fire incidents found in the NBS Flammable Fabrics Accident Case and Testing System as of December 1973. These gasoline incidents, particularly those that were container-related, were studied in detail. Male victims out-numbered females approximately 5 to 1. Both males and females, ages 6-7 were injured more frequently than would have been expected if the incidents for each sex had been distributed uniformly over age groups. Starting or tending an open fire caused ignitions most frequently and involved primarily males ages 13-45. Children were injured most from knocking over or dropping a container of gasoline close to an ignition source and playing with gasoline near an ignition source. Matches were the most frequent ignition source. Containers ranged from large gasoline cans to kitchen measuring cups, although gasoline cans were reported most often. The youngest children were involved most with some of the largest containers. The remaining victims were involved primarily with smaller, more easily managed containers. There was no indication that the gasoline containers, by themselves, contributed substantially to these incidents. The problem was one of human error—misuse or abuse of the gasoline, the container or both.

TN851. **Computer system capacity fundamentals,** D. J. Kuck, Nat. Bur. Stand. (U.S.), Tech. Note 851, 25 pages (Oct. 1974) SD Catalog No. C13.46:851.

Key words: capacity; computer; evaluation; measurement; performance.

A framework for the study of computer capacity is given by means of a definition of capacity in terms of speeds of various parts of a comuter as well as memory size. The calculation of theoretical capacity is given for several combinations of processor, memory, and I/O bandwidth for both overlapped and nonoverlapped machines. The tradeoff between primary memory size and I/O bandwidth is discussed in terms of the new definition.

TN852. **A study of wind pressures on a single-family dwelling in model and full scale,** R. D. Marshall, Nat. Bur. Stand. (U.S.), Tech. Note 852, 40 pages (Oct. 1974) SD Catalog No. C13.46:852.

Key words: aerodynamics; boundary layers; buildings; codes and standards; wind loads; wind tunnels.

Wind pressures measured on a single-family dwelling are compared with results obtained from a 1:80 scale model placed in a turbulent boundary layer. It is shown that the fluctuating components of surface pressures far exceed the mean or steady pressures and are well correlated over sizeable roof areas. The consistently low fluctuating pressure coefficients obtained from the wind tunnel model are attributed to improper simulation of the lower portion of the atmospheric boundary layer. Comparisons between actual loads and specified design loads suggest that certain current provisions are marginal for tributary areas and excessive for localized areas such as ridges, eaves and corners. A procedure for expressing loads on both localized and extended roof areas in terms of mean pressure coefficients and a peak factor is described.

TN853. **State building regulatory programs for mobile homes and manufactured buildings—a summary,** P. W. Cooke, H. K. Tejuja, R. D. Dikkers, and L. P. Zelenka, Nat. Bur. Stand. (U.S.), Tech. Note 853, 35 pages (Sept. 1974) SD Catalog No. C13.46:853.

Key words: building regulation; enforcement; evaluation; inspection; legislation; manufactured building; mobile homes; rules and regulations; state-of-the-art study.

Information describing State mobile home and manufactured building regulatory programs are presented in two series of summary tables. The tables provide information on salient elements of the enabling legislation and the administrative rules and regulations promulgated for each State program. Other features of the various enforcement programs, including the status of reciprocity for the interstate acceptance of mobile homes and manufactured buildings are also enumerated.

TN854. **A system of Fortran IV computer programs for crystal structure computations,** L. W. Finger and E. Prince, Nat. Bur. Stand. (U.S.), Tech. Note 854, 133 pages (Feb. 1975) SD Catalog No. C13.46:854.

Key words: computer programs; contour plotting; constrained refinement; crystallographic calculations; Fourier section; Fourier synthesis; least squares.

This report gives detailed descriptions and instructions for use of a system of programs for crystallographic calculations, including least-squares refinement with generalized systems of constraints, calculation of bond distances and angles with errors, Fourier synthesis, plotting of contours in Fourier maps, and preparation of structure factor tables for publication.

TN855. **An experimental technique for the evaluation of thermal transient effects on piezoelectric accelerometers,** C. F. Vezzetti and P. S. Lederer, Nat. Bur. Stand. (U.S.), Tech. Note 855, 48 pages (Jan. 1975) SD Catalog No. C13.46:855.

Key words: accelerometer; performance characteristics; piezoelectric; test method; thermal radiation; thermal transient; zero shift.

A simple, inexpensive method was developed for determining the effects of thermal transients on the zero output and sensitivity of piezoelectric accelerometers. Thermal transient stimuli are generated by an incandescent lamp and can be made to heat the top or side of the test accelerometer. Fourteen commercial accelerometers were tested using this technique. Zero shifts with magnitudes as high as 640 g_n* were observed. Zero shifts up to 2 percent of full-scale resulted from one-second duration transients, and up to 7 percent of full-scale from fifteen-second transients. These results were obtained at a radiation power density of 1.8 W/cm². No changes of accelerometer sensitivity exceeding experimental uncertainties were noted as a result of the thermal transients used.

TN856. **Note on a vibratory phenomenon arising in transducer calibration,** R. Kraft, Nat. Bur. Stand. (U.S.), Tech. Note 856, 13 pages (Feb. 1975) SD Catalog No. C13.46:856.

Key words: boundary initial problems; measurement; pressure transducer; transducer calibration; vibration.

By making appropriate physical approximations and idealizations a theoretical explanation is found for a vibratory phenomenon observed in calibrating pressure transducers inside thin liquid filled cylinders. The theoretical explanation requires proving the equivalence of two boundary initial problems which define the vibratory phenomenon. A short, general and complete proof of this equivalence is given.

TN857. **Real-time acquisition and processing of fluorimetry data,** P. S. Shoenfeld, Nat. Bur. Stand. (U.S.), Tech. Note 857, 45 pages (June 1975) SD Catalog No. C13.46:857.

Key words: analytical chemistry; computers; data acquisition; data processing; fluorimetry; laboratory automation; real-time.

The National Bureau of Standards Analytical Chemistry Division uses a centralized computer system to automate a number of experiments. Computer software for a fluorimetry application is described in this report. The file and program structure used is quite general and can be applied to other experiments as well.

TN858. **A program for survey of fire loads and live loads in office buildings,** C. Culver and J. Kushner, Nat. Bur. Stand. (U.S.), Tech. Note 858, 229 pages (May 1975) SD Catalog No. 13.46:858.

Key words: buildings; fire loads; occupancy live loads; load surveys; structural engineering; survey techniques.

The development of a survey program for determining the fire loads and live loads in office buildings is described. Considerations involved in planning the program which is directed toward establishing the factors affecting the loads in buildings are presented. The type of data to be collected and a data collection technique which utilizes visually observed information on the characteristics of building content items to determine weight are discussed. Procedures employed to select buildings to be included in a nation-wide office building load survey being conducted by the National Bureau of Standards and a sampling plan for selecting rooms to be surveyed in these buildings are also discussed.

TN859. **Literature search: Law enforcement facilities—planning, design, construction,** R. Kapsch and J. Stroik, Eds., Nat. Bur.

Stand. (U.S.), Tech. Note 859, 221 pages (Nov. 1975) SD Catalog No. C13.46:859.

Key words: architecture; bibliography; building; construction; design; law enforcement facilities.

Citations and abstracts are provided on literature concerning the planning, design, and construction of law enforcement facilities in the United States and in foreign countries. In addition, plans of 21 select law enforcement facilities are included.

TN860. **NBS reactor: Summary of activities July 1973 to June 1974,** R. S. Carter, Nat. Bur. Stand. (U.S.), Tech. Note 860, 143 pages (Apr. 1975) SD Catalog No. C13.46:860.

Key words: activation analysis; crystal structure; diffraction; isotopes; molecular dynamics; neutron; nuclear reactor; radiation; radiography.

This report summarizes all those programs which depend on the NBS reactor. It covers the period from July 1973 through June 1974. The programs range from the use of neutron beams to study the structure and dynamics of materials through nuclear physics, and neutron standards and neutron radiography to sample irradiations for activation analysis, isotope production and radiation effects studies.

TN861. **A survey for the collection of professional opinion on selected fire protection engineering topics,** G. A. Harrison and J. L. Houser, Nat. Bur. Stand. (U.S.), Tech. Note 861, 30 pages (Mar. 1975) SD Catalog No. C13.46:861.

Key words: building construction; detectors; flame spread; furnishings; interior finishes; noncombustible; smoke development; sprinklers; survey.

A questionnaire survey on selected fire protection engineering topics was sent to 422 persons from every state and major city in the United States and, also, parts of Canada. The surveyed included architects, engineers, insurance and government representatives, academics, and fire services personnel. One hundred and eighty-six questionnaires were returned, a 46.2 percent return rate. This return rate is more than double the National average on survey returns. The questionnaire covered topics such as the adequacy of the term "noncombustible" as contained in the National Fire Protection Association's National Fire Code, hazards of fire loading concepts, code regulation and enforcement, furnishings, sprinkler systems and smoke detectors. In addition to the questionnaire data, many of the surveyed took the time to write in various unsolicited comments.

Although this survey does not represent a statistical study approach, it is the best effort to date to gather and document the current professional thinking on fire protection matters. When the data permitted, obvious and significant group thought ideas and patterns are documented. The objective of this survey is to collect and document professional opinions on selected fire protection engineering topics for the purpose of determining current professional thinking, and indications of future trends of thought.

TN862. **Application of ion beam milling to the characterization of cracks in metals,** L. K. Ives, A. Harper, and A. W. Ruff, Nat. Bur. Stand. (U.S.), Tech. Note 862, 29 pages (Apr. 1975) SD Catalog No. C13.46:862.

Key words: cracks; flaws; ion beam milling; metals; microscopy; surfaces.

The technique of ion beam milling coupled with subsequent optical and scanning electron microscopy has been applied as a means of detecting and characterizing small surface intersecting cracks. Two types of cracked specimens involving different metals were studied. Various orientations of the crack plane, crack direction, and ion beam were explored. The technique is capable of increasing the sensitivity for detection of small cracks and also removing distorted surface layers and revealing the crack more accurately.

TN863. **Fatigue tests of bituminous membrane roofing specimens,** G. F. Sushinsky and R. G. Mathey, Nat. Bur. Stand. (U.S.), Tech. Note 863, 32 pages (Apr. 1975) SD Catalog No. C13.46:863.

Key words: bituminous roof membranes; fatigue testing; flexural fatigue; performance criteria; roofing; temperature effects; tensile fatigue; test methods.

Tensile and flexural fatigue tests were performed on built-up roof membrane specimens (ASTM Designation: D2523-70) fabricated from four different material systems. The tensile fatigue tests were run under cyclic load control conditions while specimens tested in flexural fatigue were run under cyclic mid-span displacement control. Tests were run at ambient laboratory conditions, generally 70 ± 2 °F (21 ± 1 °C), and at 0 ± 2 °F (-18 ± 1 °C). Curves based on the experimental results are plotted relating the peak load or displacement to the median fatigue lifetimes for specimens fabricated from each material. Performance criteria for roof membranes subject to fatigue loading are recommended.

TN864. **Cost recovery in pricing and capacity decisions for automated information systems,** J. A. Dei Rossi, Nat. Bur. Stand. (U.S.), Tech. Note 864, 60 pages (Apr. 1975) SD Catalog No. C13.46:864.

Key words: automated information retrieval; cost benefit; public good; scientific and technical information; semi-public good; subsidization; total cost recovery; user charges.

This paper examines the cost-benefit implications of alternative pricing and capacity investment decisions for automated scientific and technical information retrieval systems. Two typical systems are examined and numerical examples presented. In the first system, search requests are entered on-site. The numerical examples show how setting price to maximize net social benefit precludes total cost recovery and implies subsidization. In the second hypothetical system, search requests are entered from remote access terminals. Allowance is made for random arrival rates, and distinction is made between system charges to users and other user incurred costs. With these refinements, the numerical examples show how, for certain ranges of output, total cost recovery is consistent with the maximization of net social benefit. The paper then examines the "public good" attributes of scientific and technical information retrieval systems and concludes that such systems can be viewed as "semi-public goods," since the information stored has the characteristics of a public good while access to this information has the characteristic of a private good. Based on the public good considerations and the numerical examples, the paper concludes that subsidization for the fixed costs is warranted to the extent that all reasonable alternatives which maximize net social benefit preclude total cost recovery.

TN865. **Critical electrical measurement needs and standards for modern electronic instrumentation,** P. Richman, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 865, 74 pages (May 1975) SD Catalog No. C13.46:865.

Key words: data conversion; dynamic measurements; electrical measurements; electronic instrumentation; signal conditioning; systems; time domain.

Recognizing the proliferation of sophisticated modern electronic instrumentation in the field of electrical measurement, the Electricity Division of the National Bureau of Standards

recently initiated a new program in the general area of dynamic measurements and standards in support of such instrumentation. Recognizing further that the vastness and complexity of the field would require, at the earliest stages of the program, identification of the most critical problem areas, the Electricity Division held a workshop on 23 and 24 September, 1974, at the Bureau's Gaithersburg site, to assist it in ascertaining just what these areas in fact were. The basic idea of the Workshop was to bring together a broadly representative group of some twenty-five leading manufacturers and prime users, working in a free and open atmosphere, in order to have them delineate the present and future critical support needs in the field of dynamic electrical measurements for modern electronic instrumentation, with emphasis on physical standards, standardized measurement methods, new calibration and measurement assurance services, relevant data, and most important, new measurement methodologies. The overall objectives of the Workshop were generally met, and a number of significant specific programs and projects consistent with the mission of the Electricity Division were identified.

TN866. **Chemical kinetic and photochemical data for modelling atmospheric chemistry,** R. F. Hampson, Jr., and D. Garvin, Eds., Nat. Bur. Stand. (U.S.), Tech. Note 866, 118 pages (June 1975) SD Catalog No. C13.46:866.

Key words: atmospheric chemistry; chemical kinetics; data evaluation; gas phase; photoabsorption cross section; photochemistry; quantum yield; rate constant.

A table of data for gas phase chemical reactions and photochemistry of neutral species is presented. Specifically, it gives preferred values for reaction rate constants, photoabsorption cross sections, and quantum yields of primary photochemical processes and also cites recent experimental work. It is intended to provide the basic physical chemical data needed as input data for calculations modelling atmospheric chemistry. An auxiliary table of thermochemical data for the pertinent chemical species is given in the appendix.

TN867. **Relationship of garment characteristics and other variables to fire injury severity,** L. B. Buchbinder, Nat. Bur. Stand. (U.S.), Tech. Note 867, 41 pages (June 1975) SD Catalog No. C13.46:867.

Key words: accident patterns; apparel; apparel fires; burn injury; FFACTS; fire; flammable fabrics; flammable liquids; garment fires; garment parameters; injury severity; victim's activity; victim's reactions.

This final report on an in-depth study of apparel fire accident variables focuses on the physical parameters of fabrics and garments involved in apparel fires and the relationship between these parameters and injury severity. Interactions between accident variables are summarized and recommendations for remedial action and further research are included. Garments involved in apparel fire accidents were classified by degree of fit and amount of the body covered. Fires in which the garment configurations involved covered over half the body (the dress/shift and pants/top configurations) were shown to be associated with more extensive burn injuries than fires involving configurations covering smaller areas (loose tops, fitted pants, and loose pants). Degree of fit could not be shown to be directly related to injury severity. Within garment configuration classifications, age was shown to be a major determinant of injury severity, with victims over 65 years of age receiving a significantly higher percentage of severe burns than those in the 21-65 age group. In accidents involving loose tops, fitted pants, and loose pants the presence of flammable liquids in the accident sequence appeared to be the dominant factor in determining injury level. In addition, when accidents involved flammable liquids, (1) the fabrics involved tended to be heavier, (2) the fit of the garment at point of ignition was closer, and (3) the proportion of cellulosic/synthetic blend and 100 percent synthetic fabrics was higher than in accidents which did not involve flammable liquids. Because of the many human and physical variables shown to be associated with an apparel fire accident, the author suggests a broad fire prevention program which includes both product regulation and public education.

TN868. **Statistical analysis of extreme winds,** E. Simiu and J. J. Filliben, Nat. Bur. Stand. (U.S.), Tech. Note 868, 52 pages (June 1975) SD Catalog No. C13.46:868.

Key words: building codes; extreme value distributions; hurricanes; probability distribution functions; reliability; risk; statistical analysis; storms; structural engineering; wind loads; wind speeds.

With a view to assessing the validity of current probabilistic approaches to the definition of design wind speeds, a study was undertaken of extreme wind speeds based on records taken at 21 U.S. weather stations. For the purpose of analyzing extreme value data, a computer program was developed, which is described herein. The following results were obtained: (1) the assumption that a single probability distribution is universally applicable to all extreme wind data sets in a given type of climate was not confirmed, and (2) predictions of 100-year wind speeds based on overlapping 20-year sets of data taken at the same station differed between themselves by as much as 100 percent. Similar predictions for 1000-year winds differed by as much as a few hundred percent. Since wind pressures are proportional to the square of the wind speeds, errors of such magnitude are unacceptably high for structural design purposes. It is therefore suggested that while, in principle, probabilistic methods provide the most rational approach to specifying design wind speeds, it is of the utmost importance that the possible errors inherent in this approach be carefully taken into account.

TN869. **Temperature section activity summary, 1974,** J. F. Schooley, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 869, 28 pages (June 1975) SD Catalog No. C13.46:869.

Key words: annual report; calibrations; progress report; standards; temperature scale; thermometry.

This report summarizes the progress in calendar 1974 of the technical program of the temperature section of the Heat Division, Institute for Basic Standards. Separate sections of the report are devoted to the various projects, to highlights of the year's activities, and to other agency interactions.

TN870. **Sampling techniques for electric power measurement,** R. S. Turgel, Nat. Bur. Stand. (U.S.), Tech. Note 870, 35 pages (June 1975) SD Catalog No. C13.46:870.

Key words: analog-to-digital conversion; digital; electricity; electric power; measurement; sampling; simulation; wattmeter.

A system is described that determines average electric power by periodically sampling current and voltage waveforms and calculating the result from digitized values of measured instantaneous currents and voltages. System performance is modeled on a digital computer to investigate the effects of noise, harmonics and sampling time errors on the result of a simulated power measurement. With 15 bit analog-to-digital conversion and 512 measured sample points an accuracy of 0.01 percent can theoretically be obtained from dc up to 5 kHz.

TN871. **Geometrical calibration of the NBS electron scattering apparatus,** S. Penner, S. P. Fivozinsky, J. W. Lightbody, Jr., L. S. Cardman, and W. P. Trower, Nat. Bur. Stand. (U.S.), Tech. Note 871, 79 pages (June 1975) SD Catalog No. C13.46:871.

Key words: absolute cross section; beam profile; electron scattering; scattering angle; solid angle; spectrometer.

A comprehensive calibration of the geometry of the NBS electron scattering apparatus is described. A complete set of measured parameters is tabulated in this report. Combining these parameters with observed values of certain variables as described herein permits the accurate determination of the solid angle, scattering angle, and target angle for each cross section measurement made with the apparatus. The uncertainty in a cross section measurement due to the imprecision of the geometry calibrations is less than one part in 10^3.

TN872. **Computer program package for metric conversion: Reference manual,** R. K. Anderson and J. O. Harrison, Jr., Nat. Bur. Stand. (U.S.), Tech. Note 872, 145 pages (July 1975) SD Catalog No. C13.46:872.

Key words: Caterpillar Tractor Co.; computer program; documentation; engineering drawing; General Motors Corporation; metric conversion; rounding; test problem; tolerance.

The programs in this package are designed to convert dimensions and other quantities appearing on engineering drawings from metric to U.S. customary units and vice versa. They were developed by Caterpillar Tractor Co. and General Motors Corporation. In addition to the programs themselves, the package contains documentation explaining how to get the programs running on different computers and how to use them, and test problems to permit users to verify that the programs run correctly on their own computers. The Caterpillar program converts 31 different metric units to their U.S. customary equivalents. In contrast, the General Motors programs convert in both directions but work with millimetres and inches only. The General Motors programs also use rounding conventions differing somewhat from those employed in the Caterpillar program. Both the Caterpillar and the General Motors programs are written in American National Standard FORTRAN and are suitable for use on a wide range of computers with little or no modification. The Caterpillar program is operated in batch mode while the General Motors programs are interactive.

TN873. **Electro-optical deflection measuring device,** R. A. Crist, R. D. Marshall, and H. I. Laursen, Nat. Bur. Stand. (U.S.), Tech. Note 873, 24 pages (Dec. 1975) SD Catalog No. C13.46:873.

Key words: buildings; deflections; instrumentation; structural response; wind loads.

The development and testing of an electro-optical device for the direct measurement of lateral deflections of tall structures are described. The device utilizes a tracking telescope mounted on a fixed reference and a light source attached to the structure of the level for which lateral deflections are to be measured. Operating characteristics of the system are based on the results of tests carried out over a period of several months in one of the elevator shafts of a 12-story building.

TN874. **Software testing for network services,** R. B. Stillman and B. Leong-Hong, Nat. Bur. Stand. (U.S.), Tech. Note 874, 40 pages (July 1975) SD Catalog No. C13.46:874.

Key words: dynamic analysis; NBS analyzer; NBS FORTRAN test routines; networking; systematic testing; testing tools.

This report is a first step toward indentifying effective software test and measurement tools, and developing a guide for their usage network-wide. The utility of two tools, the NBS FORTRAN Test Routines and the NBS Analyzer, is studied experimentally, and indications of their role in systematic testing in a networking environment are given.

TN875. **Interlaboratory intercomparisons of radioactivity measurements using National Bureau of Standards mixed radionuclide test solutions,** B. M. Coursey, J. R. Noyce, and J. M. R. Hutchinson, Nat. Bur. Stand. (U.S.), Tech. Note 875, 20 pages (Aug. 1975) SD Catalog No. C13.46:875.

Key words: environment; intercalibration; intercomparison; radioactivity; radionuclide; radiostrontium.

In 1973 the National Bureau of Standards (NBS) distributed three calibrated test solutions to interested laboratories. Two of these solutions each contained nine gamma-ray-emitting radionuclides that the participants were asked to identify and quantify. The third solution contained ^{89}Sr and ^{90}Sr-^{90}Y, and participants were asked to perform a quantitative radioactivity analysis of the mixture. The results reported by all of the participating laboratories are given here. Most of the activity values reported for the mixed gamma-ray-emitting solutions were within ± 20 percent of the corresponding NBS values, but less than half of the laboratories reported ^{89}Sr and ^{90}Sr-^{90}Y activity values both of which were within ± 20 percent of the NBS values.

TN876. **Exploring privacy and data security costs—A summary of a workshop,** J. L. Berg, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 876, 35 pages (Aug. 1975) SD Catalog No. C13.46:876.

Key words: computer security; data security; privacy; privacy costs; security costs.

On February 20, 1975, the ICST hosted a one-day round-table discussion on the economic aspects of privacy and data security costs. The workshop was chaired by Gary Bearden, U.S. Civil Service Commission. The participants were Walter L. Anderson, General Accounting Office; Richard A. Eberhart, Office of the Secretary, Department of Commerce; Earl P. Bassett, Jr. Vice President, 3M Company; Robert Caravella, Federal Trade Commission; Theodore Clemence, Bureau of Census; Richard L. Nolan, Harvard Business School; Stan Halper, Coopers and Lybrand; and Larry Simonette, Peat, Marwick, Mitchell and Company. The group discussed the benefits EDP managers or data base administrators might gain from the privacy requirements, the processes for identifying direct or hidden costs, and processes for allocating costs.

TN877. **A basis for standardization of user-terminal protocols for computer network access,** A. J. Neumann, Nat. Bur. Stand. (U.S.), Tech. Note 877, 29 pages (July 1975) SD Catalog No. C13.46:877.

Key words: command languages; computers; man-machine systems; networks; system commands; user protocols.

A user-terminal protocol is defined which enables a user at a terminal to access computerized information systems. The basic functions such as identification, authorization, and validation are outlined and various signals and messages making up the protocol are identified. The purpose of the paper is to establish a basis for standardization and development of a unified user protocol.

TN878. **The M40 fingerprint matcher,** J. H. Wegstein, Nat. Bur. Stand. (U.S.), Tech. Note 878, 14 pages (July 1975) SD Catalog No. C13.46:878.

Key words: computerized fingerprint identification; fingerprint; pattern recognition.

A procedure is described for automatically determining whether two fingerprint impressions were made by the same finger. The procedure uses the x and y coordinates and the in

dividual directions of the minutiae (ridge endings and bifurcations). The identity of the two impressions is established by computing the density of clusters of points in Δx, Δy space where Δx and Δy are the differences in coordinates that are found in going from one of the fingerprint impressions to the other.

TN879. **Fire buildup in a room and the role of interior finish materials,** J. B. Fang, Nat. Bur. Stand. (U.S.), Tech. Note 879, 49 pages (June 1975) SD Catalog No. C13.46:879.

Key words: buildings; fire growth; flame spread; heat release; interior linings; material ignitability; performance criteria; room fires; smoke; wood crib.

A variety of wall and ceiling panels in a full-scale room corner have been exposed to a fire from a standardized wood crib, simulating the environment produced by the burning of a single item of furniture, to evaluate their contribution to room fire growth. A total of twenty room corner tests were performed using selected combinations of eight wood-base and gypsum board-base interior finish materials on the walls and ceiling. Gas temperatures and velocities, surface temperatures, heat fluxes, smoke densities, and concentrations of oxygen, carbon dioxide and carbon monoxide were measured. Ignition times of newsprint, cotton fabric and plywood in the lower part of the room were also recorded. The results of these full-scale tests were compared with laboratory tests of the ease of ignition, surface flame spread, heat release rate and smoke generation on the same materials. The maximum upper room gas temperature has been found to agree with the ignition of such indicators as newsprint and plywood, and to represent a measure of fire hazard in terms of potential involvement of all combustible contents or room flashover. A temperature range of 450 to 650 °C appears to be the boundary between limited and full involvement.

TN880. **The service concept applied to computer networks,** M. D. Abrams and I. W. Cotton, Nat. Bur. Stand. (U.S.), Tech. Note 880, 38 pages (Aug. 1975) SD Catalog No. C13.46:880.

Key words: computer networks; interactive computing; man-machine interaction; performance measurement; time-sharing.

The Network Measurement System (NMS) represents the implementation of a new approach to the performance measurement and evaluation of computer network systems and services. By focusing on the service delivered to network customers at their terminals, rather than on the internal mechanics of network operation, measurements can be obtained which are directly relevant to user needs and management concerns. Furthermore, the type of measurement necessary to implement this approach can be made directly, without perturbing the network system under test.

This technical note introduces the service concept and other background information necessary to understand the need for and use of the NMS. The fundamental distinction between service and internal efficiency is clarified, both in general and in the environment of computer networks. A number of different measures of service are then discussed, followed by the presentation of several models of interactive use of networks. Then, the practical aspects of gathering data and applying this information to service measurement are reviewed, leading to a presentation of the NMS as it is implemented. The note ends with a discussion of applications for the NMS.

TN881. **Critical evaluation of data in the physical sciences—A status report on the National Standard Reference Data System, April 1975,** S. A. Rossmassler, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 881, 53 pages (Sept. 1975) SD Catalog No. C13.46:881.

Key words: atomic and molecular data; chemical kinetics; colloid and surface properties; mechanical properties; nuclear data; solid state data; standard reference data; thermodynamic data, transport properties.

This is a report on the status of the National Standard Reference Data System as of April 1975. Current activities and functions of the Office of Standard Reference Data are summarized. A complete list of data evaluation projects supported by the Office of Standard Reference Data during Fiscal Year 1975 is included; this list also includes projects which received financial support during the previous fiscal year, and which are still actively involved in some aspect of data compilation and evaluation. The list of projects includes continuing data centers in the United States whose activities fall within the scope of the system, but which are not formally affiliated with it. A list of publications resulting from the Standard Reference Data program is provided.

TN882. **Criteria for the performance evaluation of data communications services for computer networks,** D. S. Grubb and I. W. Cotton, Nat. Bur. Stand. (U.S.), Tech. Note 882, 36 pages (Sept. 1975).

Key words: computer communications; computer networking; data communications; networks; performance requirements; telecommunications.

In general, when telecommunications services are used as a means of interchanging information between information processing systems, or between terminals and systems, a number of parameters determine how well that interchange is performed. This report examines the following characteristics of telecommunications services: 1. Transfer Rate; 2. Availability; 3. Reliability; 4. Accuracy; 5. Channel Establishment Time; 6. Network Delay; 7. Line Turnaround Delay; 8. Transparency; 9. Security.

These terms are all defined and their significance discussed. The effects of these factors on data communication networks are illustrated.

TN883. **Waterproofing materials for masonry,** E. J. Clark, P. G. Campbell, and G. Frohnsdorff, Nat. Bur. Stand. (U.S.), Tech. Note 883, 86 pages (Oct. 1975) SD Catalog No. C13.46:883.

Key words: accelerated weathering; durability of waterproofing materials; masonry; performance criteria; waterproofing materials; water repellent materials.

The initial effectiveness and durability characteristics of fifty-five clear masonry waterproofing materials were evaluated using laboratory tests. This report contains the results of initial performance tests including water absorption, water vapor transmission, resistance to efflorescence and change in appearance. Durability tests, including periodic measurement of water absorption after exposures to accelerated weathering and outdoor exposures, were also conducted. Based on test results, performance criteria for clear waterproofing materials were developed. In addition, recommendations for the application of waterproofing materials were formulated. Finally, the report contains a summary of a survey concerning field experiences with waterproofing and a brief theoretical discussion of water flow.

TN884. **Calibration of unrecorded low and medium density type magnetic disk pack surfaces,** N. P. Goumas, Nat. Bur. Stand. (U.S.), Tech. Note 884, 23 pages (Oct. 1975) SD Catalog No. C13.46:884.

Key words: calibration factor; computer amplitude reference; computer storage media; disk calibration; disk

pack; magnetic disk; Standard Reference Surface; unrecorded disk surface.

This publication describes the design requirements and the operation of the NBS test bed that is used for calibrating unrecorded magnetic disk pack surfaces for low and medium density use. The signal level calibration is made with respect to a reference level that is derived from the NBS Standard Amplitude and Data Reference Surfaces that are held in repository at NBS. The techniques for calibrating the measurement system with the NBS repository Reference Surfaces and the calibration of candidate reference disks are described in detail.

TN885. **A technical review of the Nicaraguan building regulatory system,** R. N. Wright and I. A. Lamana, Nat. Bur. Stand. (U.S.), Tech. Note 885, 85 pages (Oct. 1975) SD Catalog No. C13.46:885.

Key words: architecture; building; building codes; building design; disaster mitigation; earthquakes; engineering; environmental hazards; housing; inspection and testing; safety.

This report on the Nicaraguan Building Regulatory System has been prepared under the auspices of the Organization of American States and the United States Agency for International Development. It presents an overview of the building regulatory system in Nicaragua; its activities in review of designs, issuance of building permits, inspection of construction, control of quality of materials, and issuance of occupancy permits. The technical bases for these activities are the building code and standards, the laboratory facilities for control of the quality of building materials, and the processes for development and application of codes and standards. Recommendations address the status and development of this system and its technical bases.

The losses in the December 23, 1972, Managua Earthquake provided dramtic evidence of the need for effective implementation of good building standards. Repetitions of these tragic losses elsewhere in Nicaragua and in a reconstructed Managua are certain unless a good building code is developed and adopted, its use and design by architects and engineers enforced by careful review of designs, and the implementation of these designs by the builders assured by inspection of construction and testing of building materials. A summary and critical review of U.S. building regulatory practices for areas with severe natural hazards is presented in Appendix B for guidance in building regulatory system planning and development. A survey of housing performance in Managua is presented in Appendix C to illustrate that earthquake resistant construction is feasible and economical for Nicaragua and other nations with comparable resources.

TN886. **Modification of fluorescent luminaires for energy conservation,** R. W. Beausoliel, W. J. Meese, and G. Yonemura, Nat. Bur. Stand. (U.S.), Tech. Note 886, 15 pages (Oct. 1975) SD Catalog No. C13.46:886.

Key words: capacitors; energy conservation; fluorescent lamp; fluorescent luminaire; lighting efficiency; power factor.

Reducing energy consumption in existing buildings by reducing the number of lamps presents technical problems when more than one fluorescent lamp operates from a single ballast. A preliminary investigation was made whereby capacitors were substituted for one fluorescent lamp in a two-lamp luminaire which operated with a single ballast. Under optimum conditions, lighting efficiency (foot-candles per watt) was nearly as high at reduced power input as it was with two lamps operating normally. No failures in lighting equipment or capacitors occurred and no fire hazards, other safety hazards or other unsatisfactory occurrences were observed. A more thorough investigation involving a number of parameters is needed to ascertain the feasibility of this modification.

TN887. **Six data base management systems: Feature analysis and user experiences,** E. Fong, J. Collica, and B. Marron, Nat. Bur. Stand. (U.S.), Tech. Note 887, 84 pages (Nov. 1975) SD Catalog No. C13.46:887.

Key words: data base applications; data base management systems; selection criteria; software features; system evaluation; system features; user experiences.

This report presents an objective overview of features of six selected data base management systems (DBMS) and Federal user experiences with these systems. Application criteria were developed in order to aid in the evaluation and selection of DBMS.

The advantages of generalized DBMS over traditional methods of software system development are discussed. The criteria for choice of the six systems' features are presented. The data reported were gathered from two sources: vendors and users. Vendor information consisted of side-by-side presentation of features of the six DBMS. User experiences reported are summarized under appropriate headings. This information is used to derive application criteria for assessing the usability and operational suitability of DBMS to a variety of data processing requirements.

The six systems reviewed are: ADABAS, IMS/VS, INQUIRE, MODEL 204, SYSTEM 2000, and TOTAL.

TN888. **Nuclear Science Education Day,** F. J. Shorten, Ed., Nat. Bur. Stand. (U.S.), Tech. Note 888, 95 pages (Nov. 1975) SD Catalog No. C13.46:888.

Key words: biology; career; ecological; electricity; energy; environment; fusion; medicine; nuclear; power; radiation; reactor; research; utilities.

These proceedings are a collection of invited papers given at the Nuclear Science Education Day Conference held on November 29, 1973 at the National Bureau of Standards, Gaithersburg, Md. The program was sponsored jointly by the ANS (Washington Chapter) and the NBS for secondary school science teachers and outstanding science students in the Washington area. Four main topics are covered: research and development in nuclear energy applications; man, environment and nuclear energy; nuclear science frontiers; and career opportunities in nuclear science. *These proceedings include the following papers (indented):*

Nuclear power: Everyone's involved, J. L. Liverman, *TN888*, pp. 1-12 (Nov. 1975).

Energy research and the Electric Power Research Institute, R. L. Loftness, *TN888*, pp. 13-33 (Nov. 1975).

The role of the public in the evaluation process, G. Charnoff, *TN888*, pp. 34-37 (Nov. 1975).

Assessing environmental effects, the risk and benefit concept, B. E. Leonard, *TN888*, pp. 38-45 (Nov. 1975).

Ecological monitoring techniques, B. Jensen, *TN888*, pp. 46-49 (Nov. 1975).

Radiation utilization in medicine and biology, V. P. Bond, *TN888*, pp. 50-61 (Nov. 1975).

Advanced concepts in applied nuclear science, G. A. Graves, *TN888*, pp. 62-76 (Nov. 1975).

Projected national and regional manpower needs for environmental and nuclear scientists, R. L. Murray, *TN888*, pp. 77-80 (Nov. 1975).

Educational opportunities at institutions of higher learning, D. Duffy, *TN888*, pp. 81-84 (Nov. 1975).

TN889. **Trace hydrocarbon analysis: The National Bureau of Standards Prince William Sound/Northeastern Gulf of Alaska baseline study,** S. N. Chesler, B. H. Gump, H. S. Hertz, W. E. May, S. M. Dyszel, and D. P. Enagonio, *Nat. Bur. Stand. (U.S.), Tech. Note 889,* 73 pages (Jan. 1976) SD Catalog No. C13.46:889.

Key words: baseline studies; gas chromatography; gas chromatography-mass spectrometry; hydrocarbons; liquid chromatography; petroleum analysis; trace analysis.

The low concentration of hydrocarbons anticipated in pollution baseline studies necessitates the development of analytical techniques sensitive at the submicrogram per kilogram concentration level. The method of analysis developed in this laboratory involves dynamic headspace sampling for volatile hydrocarbon components of the sample followed by coupled-column liquid chromatography for the nonvolatile components. These techniques require minimal sample handling, reducing the risk of sample component loss and/or sample contamination. Volatile sample components are separated from the matrix in a closed system and concentrated on a TENAX-GC packed precolumn, free from large amounts of solvent and ready for GC/GC-MS analysis. Nonvolatile compounds, such as the benzpyrenes, may be extracted from large volumes of water and concentrated on a Bondapak C18 packed precolumn for coupled-column liquid chromatographic separation and analysis. Results of the application of these techniques are presented and discussed.

TN890. **Productivity measurement in R&D: Productivity measurement experiment (PROMEX) in selected research and development programs at the National Bureau of Standards,** J. T. Hall and R. A. Dixon, Nat. Bur. Stand. (U.S.), Tech. Note 890, 52 pages (Dec. 1975) SD Catalog No. C13.46:890.

Key words: impact; objectives, output; performance measurement; production indices; production measurement.

This report describes an experiment in productivity measurement conducted at the National Bureau of Standards. The experiment concludes that no matter how sophisticated the analysis and synthesis processes become, statistical counts of output media (e.g., publications, citations, invited talks) will not serve as reliable measures of R&D productivity.

The conduct of the experiment included a work sampling study, a communications study, an output analysis, a value analysis approach to developing criteria for selection and evaluation of programs, construct of a rating system for evaluation of programs, and construction of a model of the R&D process.

TN891. **Issues in fire vehicle replacement: Users' views and synthesis,** P. B. Saunders, R. H. F. Jackson, P. R. Meyers, and M. H. Pearl, *Nat. Bur. Stand. (U.S.), Tech. Note 891,* 19 pages (Jan. 1976) SD Catalog No. C13.46:891.

Key words: engine pumper; fire vehicle; ladder truck; maintenance; replacement; specifications; standards.

This report documents the findings and recommendations from a study of fire vehicle replacement procedures. Exploration of that subject proved to require consideration of related issues arising in : (1) writing apparatus specifications, (2) maintaining and repairing vehicles, and (3) obtaining spare parts. The topics and most of the recommendations described herein are synthesized directly from visits and/or telephone interviews with fire department officials across the country. The recommendations of the study call for greatly increased communication among departments, the development of standards for vehicle performance, maintenance staff size, etc., and national and/or regional centers for training personnel and establishing standard vehicle testing procedures.

TN892. **Retrofitting a residence for solar heating and cooling: The design and construction of the system,** J. E. Hill and T. E. Richtmyer, Nat. Bur. Stand. (U.S.), Tech. Note 892, 99 pages (Nov. 1975) SD Catalog No. C13.46:892.

Key words: retrofitted solar residence; solar collector; solar heating and cooling system; solar-powered absorption refrigeration.

During 1972 and 1973, the National Bureau of Standards conducted controlled laboratory tests on a factory-built four-bedroom house having a floor area of 110 m^2 (1200 ft^2) equipped with a conventional gas furnace and central electric air conditioner incorporated into a forced air distribution system. During 1974, the house was moved onto the NBS grounds and a solar heating and cooling system was designed to be added to the house. Calculations have been made to show that more than 75 percent of the yearly energy needs for heating, cooling, and supplying domestic hot water could be obtained from the sun.

This report deals with the design and construction of the retrofitted system. It consists of 45 m^2 (485 ft^2) of double-glazed, flat-plate solar collector, 5.7 m^3 (1500 gallons) of water storage, and a 10,000 W (3 ton) lithium bromide absorption air cooling unit.

TN893. **Computer programs for structural chemistry: MATCH1 and MATCH2, FORTRAN programs to predict and evaluate mutual orientation of polycrystals,** B. Dickens and L. W. Schroeder, *Nat. Bur. Stand. (U.S.), Tech. Note 893,* 71 pages (Jan. 1976) SD Catalog No. C13.46:893.

Key words: computer calculations; crystal structure; epitaxy; lattice misfit; pattern recognition; twinning.

Two computer programs to evaluate possible structural matches for use in epitaxy and twinning studies have been written in FORTRAN V for the UNIVAC 1108. They should be readily convertible to other comparable computers.

The first program, MATCH1, requires knowledge of the unit cell parameters. It obtains all matching networks in two unit cell lattices and sorts the matches into an order of probable epitaxy (or twinning if the two unit cells are the same) based solely on criteria of dimensional mismatch and network area.

The second program, MATCH2, requires knowledge of positional parameters of the atoms in the crystal structures. It calculates the degree of structural fit for slices supplied from visual inspection of the crystal structures or as matching networks determined by MATCH1.

The slice comparison is carried out in terms of the vector set of the environment of each atom in each slice. The procedure is not valid when the twin operation is a rotation about the normal of the compositional plane or a reflection in a mirror parallel to this plane. The atomic patterns comprising the slices are matched piece by piece in MATCH2. A third program, MATCH3, will match whole patterns once three fiducial atoms in each pattern have been picked from the output of MATCH2 and will handle all the twinning cases. MATCH3 will be described in a future National Bureau of Standards Technical Note.

TN894. **Apparatus for testing oceanographic resistance thermometers,** G. T. Furukawa and J. L. Riddle, *Nat. Bur. Stand. (U.S.), Tech. Note 894,* 59 pages (Jan. 1976) SD Catalog No C13.46:894.

Key words: bridge; deep-sea thermometer; high pressure; oceanographic thermometer; platinum resistance thermometer; pressure; pressure intensifier; pressure seal; pressure vessel; resistance; resistance thermometer; test; thermometer; thermometer leads; thermostated bath; vacuum; water tight.

The design and construction of an apparatus for testing resistance-type oceanographic thermometers to 6.89×10^4 kPa(10,000 psi) are described. Detailed operating procedures for the apparatus are given. The results of performance tests with the apparatus are discussed.

TN895. **An overview of floor slip-resistance research with annotated bibliography,** R. J. Brungraber, *Nat. Bur. Stand. (U.S.), Tech. Note 895,* 113 pages (Jan. 1976) SD Catalog No. C13.46:895.

Key words: building safety; floor surface friction; occupancy safety; slip-resistance; slip-resistance testers; walking friction.

Slips and falls in the home as well as in public buildings have reached serious proportions (8,000,000 accidents per year in the home, resulting in 9,600 deaths and 1,600,000 disabling injuries). This paper reviews the literature relating to this problem. Based on studies of kinesiology and anthropometry, the coefficient of friction between foot surfaces and floor surfaces is found to be a significant parameter controlling slips and falls. A review of the general study of friction and a critical appraisal of methods for determining the coefficient of friction on slip-resistance of floors leads to a guide for selection of slip-resistance criteria. The paper concludes with a discussion of the legal aspects of the problem and the present status of slip-resistance specifications.

TN896. **NBS Reactor: Summary of activities July 1974 to June 1975,** R. S. Carter, *Nat. Bur. Stand. (U.S.), Tech. Note 896,* 150 pages (Jan. 1976) SD Catalog No. C13.46:896.

Key words: activation analysis; crystal structure; diffraction; isotopes; molecular dynamics; neutron; nuclear reactor; radiation.

This report summarizes all those programs which depend on the NBS reactor. It covers the period from July 1974 through June 1975. The programs range from the use of neutron beams to study of the structure and dynamics of materials through nuclear physics and neutron standards to sample irradiations for activation analysis, isotope production and radiation effects studies.

TN897. **Interpretation of data in the network measurement system,** S. W. Watkins and M. D. Abrams, *Nat. Bur. Stand. (U.S.), Tech. Note 897,* 46 pages (Mar. 1976) SD Catalog No. C13.46:897.

Key words: computer networks; data analysis; interactive; network service; performance evaluation; performance measurement; service.

The Network Measurement System (NMS) represents an implementation of a new approach to the performance measurement and evaluation of computer network systems and services. In this report, the interpretation of data within the NMS is described. These data have been acquired by the Network Measurement Machine (NMM) component of the NMS and are then interpreted by a Data Analysis Package (DAP), which produces meaningful information concerning the quality of network service delivered to interactive terminal users as well as a characterization of user demands and network communication facility utilization.

This report traces the flow of data from the time of capture by the minicomputer-based NMM through the several phases of modeling and structuring in the DAP. Included in this description is the statistical treatment of the data which provides quantitative measures of various aspects of network performance.

TN898. **A prototype semi-automated system for measuring air infiltration in buildings using sulfur hexafluoride as a tracer,** C. M. Hunt and S. J. Treado, *Nat. Bur. Stand. (U.S.), Tech. Note 898,* 24 pages (Mar. 1976) SD Catalog No. C13.46:898.

Key words: air infiltration instrumentation; air infiltration measurement; building ventilation rates; sulfur hexafluoride tracer.

A system is described which automatically operates a small gas chromatograph and measures parts per billion concentrations of sulfur hexafluoride (SF_6) in air. It samples air on a 10 minute cycle and records the response on a strip chart recorder. When SF_6 is distributed in the air of a building, data is obtained from which air infiltration rates may be determined.

TN899. **Development of proposed standards for testing solar collectors and thermal storage devices,** J. E. Hill, E. R. Streed, G. E. Kelly, J. C. Geist, and T. Kusuda, *Nat. Bur. Stand. (U.S.), Tech. Note 899,* 265 pages (Feb. 1976) SD Catalog No. C13.46:899.

Key words: solar collector; solar energy; solar radiation; standard; standard test; thermal performance; thermal storage.

A study has been made at the National Bureau of Standards of the different techniques that are or could be used for testing solar collectors and thermal storage devices that are used in solar heating and cooling systems. This report reviews the various testing methods and outlines a recommended test procedure, including apparatus and instrumentation, for both components. The recommended procedures have been written in the format of a standard of the American Society of Heating, Refrigerating, and Air Conditioning Engineers and have been submitted to that organization for consideration.

TN900. **Deflection performance criteria for floors,** R. A. Crist and J. R. Shaver, *Nat. Bur. Stand. (U.S.), Tech. Note 900,* 29 pages (Apr. 1976) SD Catalog No. C13.46:900.

Key words: deflection; dynamic; floor systems; human responses; performance criteria; serviceability; static; vibration.

Serviceability performance criteria for floor systems are discussed in terms of their static and dynamic components. Development of traditional static stiffness criteria is given along with a review of their strengths and weaknesses. Criteria for serviceable floors are presented from a vibration viewpoint and the derivation of an improved criterion is given. A new approach for future vibration criteria is described.

TN901. **Comparison of theoretical and experimental photoeffect data 0.1 keV to 1.5 MeV,** J. H. Hubbell and W. J. Veigele, *Nat. Bur. Stand. (U.S.), Tech. Note 901,* 43 pages (Apr. 1976) SD Catalog No. C13.46:901.

Key words: attenuation coefficients; cross sections; gamma rays; photoelectric effect; photons; x rays.

Graphs of calculated and experimental atomic photoeffect cross sections as a function of photon energy 0.1 keV to 1.5 MeV are presented for all elements Z=1 to 94. The calculated results presented are (a) the nonrelativistic Hartree-Fock self-consistent-field (SCF) results of Veigele, Henry, et al., over the range 0.1 keV to between 1.0 and 8.0 keV for all elements Z=1 to 94 and (b) the relativistic Hartree-Slater SCF results of Scofield over the range 1.0 keV to 1.5 MeV for all elements Z=1 to 101. The "experimental" data-points are derived by subtract-

ng theoretical scattering cross sections from total attenuation oefficient measurements in the literature. Differences between heoretical and experimental photoeffect data are typically a fac- or of two from 0.1 to 1.0 keV, 5-10 percent from 1.0 to 5.0 keV nd 1-5 percent from 5.0 keV up to energies, ranging from 20 eV for carbon up to 500 keV for lead, above which the photoef- ect cross section becomes fractionally too small to be accurately etermined from the total attenuation coefficient.

TN902. **Evaluation, revision and application of the NBS stylus/computer system for the measurement of surface roughness,** E. C. Teague, *Nat. Bur. Stand. (U.S.), Tech. Note 902,* 151 pages (Apr. 1976) SD Catalog No. C13.46:902.

Key words: amplitude density function; arithmetic average; autocorrelation function; average wavelength; kurtosis; minicomputer software; random error; skewness; surface microtopography; surface roughness; surface texture; systematic error.

This report describes in detail the hardware and software used t NBS to implement on a stylus instrument/minicomputer ystem the process of calibrating the system with an intererometrically measured step and the calculation of important haracterizations of surface profiles. The characterizations of a rofile which may be calculated include the arithmetic average alue, the mean square value, the amplitude density function, the utocorrelative function and the average wavelength. The report lso includes a statistical evaluation, using empirical and analytial techniques, of the calibration procedures' long term stability.

TN903. **The NIRA computer program package (Photonuclear Data Center),** H. J. Vander Molen and H. M. Gerstenberg, *Nat. Bur. Stand. (U.S.), Tech. Note 903,* 30 pages (Feb. 1976) SD Catalog No. C13.46:903.

Key words: central computer; computer programs; data manipulation; digital data; mass storage; NIRA; Photonuclear Data Center.

The Photonuclear Data Center's NIRA library of programs, executable from mass storage on the National Bureau of Standard's central computer facility, is described. Detailed instructions are given (with examples), for the use of the library to analyze, evaluate, synthesize, and produce for publication, camera-ready tabular and graphical presentations of digital photonuclear reaction cross-section data. NIRA is the acronym for Nuclear Information Research Associate.

TN904. **Correlation of floor vibration to human response,** J. R. Shaver, *Nat. Bur. Stand. (U.S.), Tech. Note 904,* 29 pages (May 1976) SD Catalog No. C13.46:904.

Key words: analysis; experimental; floor systems; human response; random process; spectral analysis; vib tion.

A new approach to the problem of perceptible floor vibrations is presented predicated on the realization that human activity and human response to this activity are random variables. Techniques for data reduction are discussed and a detailed description of one approach is given along with the associated computer program. Data from floor vibrations is compared with current criteria for human response to vibration.

TN905. **A test method for determining the effect of thermal transients on pressure-transducer response,** J. S. Hilten, C. F. Vezzetti, J. F. Mayo-Wells, and P. S. Lederer, *Nat. Bur. Stand. (U.S.), Tech. Note 905,* 52 pages (Mar. 1976) SD Catalog No. C13.46:905.

Key words: calibration; dynamic; electronic flash; photographic flashbulb; pressure; pressure measurement; pressure transducer; thermal transient; transducer; zero shift.

A test method for evaluating the effects of short-duration, thermal radiant-energy transients on pressure-transducer response is described. The method consists of monitoring pressure-transducer output (zero shift with the transducer at atmospheric pressure) as the transducer is exposed to radiation resulting from the ignition of a photographic flashbulb or from the discharge of an electronic flash. The method is intended to serve as an initial screening test. Thermal energy pulses as great as 0.1 J/cm^2, with durations of about 6 ms, have been generated using an electronic flash; pulses of up to 2.2 J/cm^2, with durations of about 37 ms, have been generated using No. 22 flashbulbs. In tests with No. 22 bulbs, 25 commercial pressure transducers have shown zero shifts ranging from 0.4 to about 400 percent of the full-scale output.

TN906. **A methodology for evaluating alternative technical and information management approaches to privacy requirements,** R. C. Goldstein, H. H. Seward, and R. L. Nolan, *Nat. Bur. Stand. (U.S.), Tech. Note 906,* 72 pages (June 1976) SD Catalog No. C13.46:906.

Key words: computer security; confidentiality; cost model; data security costs; PL 93-597; privacy; Privacy Act of 1974; privacy compliance techniques; privacy costs; privacy model; security costs.

Cost becomes an early concern in applying privacy safeguards to any computerized record-keeping system. To determine privacy cost impact one requires a concrete and rigorous approach that permits repeated analysis of carefully documented assumptions. Such a methodology appears in the work reported in the book *The Cost of Privacy* by Dr. Robert C. Goldstein. This report represents the application of that methodology to the technical requirements flowing from the Privacy Act of 1974 (PL 93-579).

The methodology presented reduces the legislation to 17 compliance steps. Each compliance step then decomposes into one or more specific actions required of the record-keeper. The actions, in turn, translate into the expenditure of different resources. The resources, in dollars, are computed by a set of algorithms collectively called a privacy model and implemented as a computer program.

The privacy model contains algorithms reflecting resource expenditures for 56 distinct actions. Written as a FORTRAN program, the model produces several printouts that show the user the consequences of the input data. In addition to a total cost for conversion and an annual operating cost, the model provides sub-total costs for each compliance step. The model's potential uses include the comparison of costs associated with alternative safeguards, the selection of an optimal set of cost-effective safeguards, and the analysis of those factors having the greatest impact on costs.

TN908. **Measurement of computer communication networks,** M. D. Abrams, S. Treu, and R. P. Blanc, *Nat. Bur. Stand. (U.S.), Tech. Note 908,* 95 pages (July 1976) SD Catalog No. C13.46:908.

Key words: communications networks; computer networks; cost; interactive service; measurement; measures; performance; usability.

This report is concerned with aiding those responsible for the procurement of computer services from a Remote Access Network by providing a description of the measures, tools, and techniques applicable to the performance measurement of com-

puter communication networks. Cost considerations are discussed as a major component of evaluation. Measurement and evaluation methodology are surveyed, including various operational tools and techniques. Some exemplary data are also presented. Although the constituents are already present, a neatly packaged methodological product, perhaps in the form of a well-structured user's guide to network performance measurement, is not yet available.

TN909. **Investigation of wind damage in the Metropolitan Washington, D.C. area, April 3-4, 1975,** F. Y. Yokel, C. W. Yancey, L. E. Cattaneo, and R. D. Marshall, *Nat. Bur. Stand. (U.S.), Tech. Note 909,* 65 pages (May 1976) SD Catalog No. C13.46:909.

Key words: building codes; design standards; masonry construction; roofs; siding; structural engineering; wind; wind damage; wind engineering.

A limited investigation was conducted of wind damage that occurred on April 3 and 4, 1975 in the Metropolitan Washington, D.C. area. Meteorological data indicate that the winds were somewhat less severe than those that should be anticipated by designers. Thus, most of the observed damage reflects inadequacies in design or construction. Damage was observed in occupied buildings, as well as in buildings under construction. Damaged elements of occupied buildings included: masonry curtain walls; masonry gable walls; masonry veneer; roofs with overhangs; roofing; and cladding. Damaged elements of buildings under construction included roofs and masonry walls.

TN910-1. **Self-study manual on optical radiation measurements: Part I—Concepts, Chapters 1 to 3,** F. E. Nicodemus, Ed., *Nat. Bur. Stand. (U.S.), Tech. Note 910-1,* 93 pages (Mar. 1976) SD Catalog No. C13.46:910-1.

Key words: optical radiation measurement; photometry; radiometry; spectroradiometry.

This is the initial publication of a new series of Technical Notes (910) entitled "A Self-Study Manual on Optical Radiation Measurements." It contains the first three chapters of this Manual. Additional chapters will be published, similarly, as they are completed. The Manual is a definitive tutorial treatment of the measurement of incoherent optical radiation that is complete enough for self instruction. Detailed chapter summaries make it also a convenient authoritative reference source.

The first chapter is an introduction that includes a description of optical radiation and the ray approach to its treatment in this Manual (based on geometrical optics), a discussion of relevant parameters and their use in a measurement equation as a systematic technique for analyzing measurement problems, and a presentation of the system of units and nomenclature used.

The second chapter, on the distribution of optical radiation with respect to position and direction, introduces the basic radiometric quantity, radiance, and its important invariance properties. It is shown how to determine the total power in a beam from the radiance distribution and to determine the distribution of radiance at any surface, through which the beam passes, in terms of the distribution at any other surface that also intersects the entire beam.

TN912. **The network measurement machine—A data collection device for measuring the performance and utilization of computer networks,** R. Rosenthal, D. E. Rippy, and H. M. Wood, *Nat. Bur. Stand. (U.S.), Tech. Note 912,* 91 pages (Apr. 1976) SD Catalog No. C13.46:912.

Key words: computer networks; data acquisition; man-machine interaction; minicomputer; network measurement; performance measurement.

The Network Measurement Machine (NMM) is a device used to acquire data for the performance measurement of computer network systems and services. By focusing on the service delivered to network customers at their terminals, measurements can be made that are directly relevant to user needs and to management concerns.

This technical report presents the details of a data acquisition device. The device is a minicomputer-based system that employs regular (off-the-shelf) and special purpose hardware under the control of a specially written software acquisition system. The technical aspects of inserting the NMM into the data communications portion of a computer network are discussed. The detailed nature of both the hardware and the software data acquisition system is presented with a discussion of the important design decision trade-offs.

TN913. **Modification of an NBS reference spectrophotometer,** K. L. Eckerle, *Nat. Bur. Stand. (U.S.), Tech. Note 913,* 43 pages (July 1976) SD Catalog No. C13.46:913.

Key words: averaging spheres; high accuracy transmittance; light averaging devices; linearity; photometric precision; reference spectrophotometer; ultraviolet; wavelength calibration.

The description of a new reference spectrophotometer capable of making transmittance measurements accurate to 0.0001 transmittance units has already been reported. The purpose of this publication is to describe some modifications that have been made to this instrument and to report some further measurements performed with it. The extension of the range of the instrument down to 200 nm, providing a capability for making measurements over the spectral range 200 to 800 nm, is outlined, and extensive testing of the light averaging effectiveness of several types of devices and spheres is reported here.

TN914. **A new dynamic pressure source for the calibration of pressure transducers,** C. F. Vezzetti, J. S. Hilten, J. F. Mayo-Wells, and P. S. Lederer, *Nat. Bur. Stand. (U.S.), Tech. Note 914,* 35 pages (June 1976) SD Catalog No. C13.46:914.

Key words: calibration; dynamic; dynamic calibration; dynamic pressure; dynamic pressure source; liquid column; pressure; pressure source; pressure transducer; sinusoidal pressure; transducer.

A dynamic pressure source is described for producing sinusoidally varying pressures of up to 34 kPa zero-to-peak, over the frequency range of approximately 50 Hz to 2 kHz. The source is intended for the dynamic calibration of pressure transducers and consists of a liquid-filled cylindrical vessel, 11 cm in height, mounted upright on the armature of a vibration exciter which is driven by an amplified sinusoidally varying voltage. The transducer to be calibrated is mounted near the base of the thick-walled aluminum tube forming the vessel so that the pressure-sensitive element is in contact with the liquid in the tube. A section of the tube is filled with small steel balls to damp the motion of the 10-St dimethyl siloxane working fluid in order to extend the useful frequency range to higher frequencies than would be provided by an undamped system.

The dynamic response of six transducers provided by the sponsor was evaluated using the pressure sources; the results of these calibrations are given.

TN915. **Metrication problems in the construction codes and standards sector,** C. T. Mahaffey, *Nat. Bur. Stand. (U.S.), Tech*

Note 915, 25 pages (June 1976) SD Catalog No. C13.46:915.

Key words: building regulations; dimensional coordination; metric conversion; planning and scheduling.

This report is a response to a request for an outline of problems to be faced by the building standards development and building regulatory sectors of the American building industry. It includes a discussion of the SI metric units themselves, giving examples of the conventions regarding their use adopted in other countries to illustrate the nature of the decisions that must be made by the U.S. building industry. It discusses the relationship of dimensional coordination to the metric conversion effort, its impact on the U.S. building regulatory system and illustrates some of the decisions these sectors need to make. It also discusses some of the organizational problems required to involve all segments of the industry in this decision-making process, and for implementing these decisions in a coordinated way on a national scale.

TN916. **Software exchange directory for university research administration,** Z. G. Ruthberg and G. R. Bolotsky, *Nat. Bur. Stand. (U.S.), Tech. Note 916*, 215 pages (Apr. 1976) SD Catalog No. C13.46:916, $2.80.

Key words: directory; equipment management software; fiscal administration software; grant/contract software; personnel management software; proposal/award software; research administration; software exchange; software summary; software survey; space management software; university systems.

The Institute for Computer Sciences and Technology (ICST) at the National Bureau of Standards (NBS) has developed a Software Exchange Directory for the University Research Administration under a contract with the Research Management Improvement Program (RMIP) at the National Science Foundation (NSF). The one hundred Universities and Colleges receiving the largest Federal funding for research and development were sent an Office of Management and Budget (OMB) approved survey instrument developed for this purpose at ICST. Seventy-five institutions sent responses suitable for 83 Directory entries under Administrative Information and 315 Directory entries under Software Package Summaries. An administrative entry contains information on the reporting unit, the basic administrative structure and parameters, computer usage, automated functional areas, and comments. A package entry contains a functional description, software and hardware characteristics, history, availability and comments. The administrative entries have been indexed by funding size, size of research staff, number of Federal granting agencies, and number of contracts and grants awarded in Fiscal Year 1974. The software packages have been indexed by function, computer used and language used. The detailed entries and indexes should help open communication channels for this community of computer users and thus maximize transferability of these programs between institutions. They also draw a comprehensive state-of-the-art picture of this area of computer use.

TN917. **A review of network access techniques with a case study: The network access machine,** R. Rosenthal, *Nat. Bur. Stand. (U.S.), Tech. Note 917*, 36 pages (July 1976) SD Catalog No. C13.46:917.

Key words: access procedures; command language; computer networks; job control language; macros; minicomputers; protocols; teleprocessing.

The computer industry's ability to serve a diverse and expanding user community is evidenced by the rapid growth of computer network services. Computer service providers design and market their own offerings as they deem best, given their own market and their own set of resources. This has led to a proliferation of similar resources requiring different user access procedures. With emphasis on currently operating and planned systems that assist users in accessing available network services, this report identifies the techniques used in network access devices. By examining these devices, the trend toward improving the interface between the user and the computer is brought more clearly into focus and up to date.

One specific solution—A Network Access Machine (NAM)—is described in detail. The NAM is a minicomputer system that acts as a network access point for a user at his terminal and assists the user through the automatic execution of access procedures. This minicomputer facility allows the user to specify (or to have specified) his own network command sequences for execution on a specified network and host connected to that network. Computer responses are analyzed to assure agreement with those anticipated for specific commands. Conditional parameterized expansions allow the use of the same commands on different host computer and different networks.

TN918. **Survey of building code provisions for historic structures,** M. Green and P. W. Cooke, *Nat. Bur. Stand. (U.S.), Tech. Note 918*, 47 pages (Sept. 1976) SD Catalog No. C13.46:918.

Key words: building codes; cities; health and safety; historic preservation; states.

In order to resolve conflicts between health and safety objectives and historic preservation objectives, a number of states and cities have adopted special building code provisions. A survey was conducted to determine the extent of adoption of such special provisions. The survey included the states, territories and member cities of the Association of Major City Building Officials (AMCBO). The survey responses revealed that sixteen of the forty-seven responding states have special provisions or regulations as do fifteen of the twenty-four responding cities. The majority of states and cities have established a special preservation appeals board. Legislation and special provisions are reviewed in the report. Recommendations for additional research are included.

TN919. **Operating system structures to support security and reliable software,** T. A. Linden, *Nat. Bur. Stand. (U.S.), Tech. Note 919*, 51 pages (Aug. 1976) SD Catalog No. C13.46:919.

Key words: capability; capability-based addressing; computer security; extended-type objects; operating system structures; protection; reliable software; reliability; security; small protection domains; types.

Security has become an important and challenging goal in the design of computer systems. This survey focuses on two system structuring concepts that support security; namely, small protection domains and extended-type objects. These two concepts are especially promising because they also support reliable software by encouraging and enforcing highly modular software structures—in both systems software and in applications programs. Small protection domains allow each subunit or module of a program to be executed in a restricted environment that can prevent unanticipated or undesirable actions by that module. Extended-type objects provide a vehicle for data abstraction by allowing objects of new types to be manipulated in terms of operations that are natural for these objects. This provides a way to extend system protection features so that protection can be enforced in terms of applications-oriented operations on objects. This survey

also explains one approach toward implementing these concepts thoroughly and efficiently—an approach based on the concept of capabilities incorporated into the addressing structure of the computer. Capability-based addressing is seen as a practical way to support future requirements for security and reliable software without sacrificing requirements for performance, flexibility, and sharing.

TN920. **Use of synthetic benchmarks for estimating service bureau processing charges,** D. M. Conti, *Nat. Bur. Stand. (U.S.), Tech. Note 920,* 47 pages (July 1976) SD Catalog No. C13.46:920.

Key words: benchmarking; charging algorithms; service bureaus; synthetic benchmarking; workload characterization.

This report describes the development of a new synthetic benchmark technique for estimating batch processing charges at service bureau sites. This technique was used to estimate the cost of processing a large batch workload at a number of service bureaus within the same mainframe family. The method was found to be low-cost, yet reasonably accurate for a certain class of service bureau charging algorithms. Refinements of this method are suggested which will extend its applicability to other algorithms. The procedures used to create and run the benchmark, together with the projection of total workload cost are described.

TN921. **Survey manual for estimating the incidence of lead paint in housing,** W. G. Hall and L. T. Slovic, *Nat. Bur. Stand. (U.S.), Tech. Note 921,* 111 pages (Sept. 1976) SD Catalog No. C13.46:921.

Key words: lead paint; lead paint detection; lead paint programs; lead poisoning; portable x-ray fluorescence; random sampling; x-ray fluorescence.

This manual is intended as a guide for municipal managers in performing a survey to determine the prevalence of lead based paint in their community's dwelling units. There are four parts to the Manual, each is intended for a different audience.

Part I discusses the preliminary considerations for a survey. It is intended for the department head or executive who will initiate plans for the survey. It presents a managerial overview of the processes, the cost determinants, criteria for the establishment of objectives and the resources required.

Part II is intended for the survey manager and the inspector supervisors. It contains more detailed information on the planning, staffing, training, and execution of the data collection phase of the survey.

Part III is for the use of the person responsible for the control and management of the data collected and for the analysis of these data.

The Appendices contain quite detailed information about procedures we have used in previous surveys. These may be used as they are described or may be modified or adapted to meet specific objectives.

TN922. **Economic analysis of experimental lead paint abatement methods: Phase I,** R. E. Chapman, *Nat. Bur. Stand. (U.S.), Tech. Note 922,* 112 pages (Sept. 1976) SD Catalog No. C13.46:922.

Key words: abatement; building economics; building materials; economic analysis; housing; lead-based paint; lead poisoning.

Public and private concern about the potential for lead poisoning in children due to the ingestion of lead-based paint chips has resulted in a Federally sponsored program to develop technologies by which lead-based paint may be eliminated from the nation's housing. Through this program lead-based paint abatement techniques were tested in field deleading operations conducted in Washington, DC, and Atlanta, GA. The program also focused on the collection of data on the direct costs of labor, materials and special equipment associated with these abatement techniques.

This report provides a statistical analysis by abatement technique and building component (i.e., walls, doors, door frames, windows and frames, and miscellaneous trim) of this direct cost data. Abatement techniques are then ranked according to their relative costs. A cost model is developed for each category (ranking) which identifies the key factors which affect direct cost and provides a framework whereby direct costs may be estimated. Recommendations are made for further refinement of the model; a methodology through which the optimal combination of lead-based paint abatement techniques can be identified is also outlined.

TN923. **Applications of thermography for energy conservation in industry,** C. W. Hurley and K. G. Kreider, *Nat. Bur. Stand. (U.S.), Tech. Note 923,* 31 pages (Oct. 1976) SD Catalog No. C13.46:923.

Key words: energy conservation; energy surveys; infrared; nondestructive evaluation; thermographic surveys; thermography.

Infrared thermography has been developed as a tool to measure the temperature of various types of surfaces. Notable applications include thermal detection of diseases such as cancer and circulatory problems in human beings, aerial land mapping of hot surfaces to detect thermal pollution and geological formations, and remote scanning of buildings to detect heat losses. More recently, infrared scanning has been used to detect defects in high amperage electrical connections, transformers, and steel processing furnaces in industrial environments.

It was the intent of the NBS IR program to build on these technologies to assist energy conservation engineers to assess heat losses in industrial plants. IR teams from the NBS Center for Building Technology had previously used the equipment to survey heat losses in buildings where the IR camera was found to be particularly useful in detecting infiltration problems, missing insulation, and construction defects. Our intent in this project was to survey furnaces and heating systems in addition to electrical and mechanical systems to find areas suggesting energy conserving actions. This qualitative survey has been found to be an excellent method to detect heat losses in unit process equipment and auxiliary systems. This survey method described in this paper was carried out in fifteen industrial plants in order to develop a methodology and examine the feasibility of the approach.

In addition to the qualitative survey quantitative data was gathered by calibrating the temperature of the "hot spots" uncovered in the survey. This information was very useful in developing priorities and estimating the magnitude of the heat loss due to a given defect.

TN924. **Procedures for the calibration of ASTM E127-type ultrasonic reference blocks,** D. J. Chwirut, G. F. Sushinsky, and D. G. Eitzen, *Nat. Bur. Stand. (U.S.), Tech. Note 924,* 43 pages (Sept. 1976) SD Catalog No. C13.46:924.

Key words: aluminum ultrasonic reference standards; ASTM-type reference standards; calibration; interim reference standard; longitudinal beam; measurement system; nondestructive evaluation; pulse-echo; ultrasonics.

A service for the calibration of ASTM E127-Type ultrasonic ference blocks has been established at the National Bureau of andards. A single well-characterized reference block, carefully osen to be as close as possible to "typical" or "nominal," has en designated as an interim standard against which other ocks can be compared. As refinements are made and the stem becomes better understood, new standards may be veloped leading to the development of an absolute national andard. The facilities and procedures used in this calibration rvice are described herein.

N925. **Overviews and justifications for low gravity experiments on phase transition and critical phenomena in fluids,** M. R. Moldover, R. J. Hocken, R. W. Gammon, and J. V. Sengers, *Nat. Bur. Stand. (U.S.), Tech. Note 925,* 99 pages (Oct. 1976) SD Catalog No. C13.46:925.

Key words: critical point; gravity effects; phase transitions.

Important scientific questions concerning pure fluids and fluid ixtures near critical points are identified and are related to the rogress of several disciplines. Consideration is given to uestions about thermodynamic properties, transport properties, nd the complex nonlinear phenomena which occur when fluids ndergo phase transitions in the critical region. We discuss, uantitatively, the limitations to answering these questions by xperiments in the earth's gravitational field. The distinction is ade between practical limits which may be extended by adances in technology and intrinsic ones which arise from the odification of fluid properties by the earth's gravitational field. he kinds of experiments near critical points which could best xploit the low gravity environment of an orbiting laboratory are entified. These include studies of the index of refraction, conant volume specific heat, and phase separation.

N927. **Development of dynamic calibration methods for pogo pressure transducers,** J. S. Hilten, P. S. Lederer, C. F. Vezzetti, and J. F. Mayo-Wells, *Nat. Bur. Stand. (U.S.), Tech. Note 927,* 58 pages (Nov. 1976) SD Catalog No. C13.46:927.

Key words: bias pressure; calibration; dynamic calibration; dynamic pressure; high pressure; liquid medium; pogo pressure; pressure source; pressure transducer; sinusoidal; space shuttle; transducer.

Two dynamic pressure sources are described for the calibraon of pogo pressure transducers used to measure oscillatory ressures generated in the propulsion system of the space shute. Rotation of a mercury-filled tube in a vertical plane at equencies below 5 Hz generates sinusoidal pressures up to 48 Pa, peak-to-peak; vibrating the same mercury-filled tube inusoidally in the vertical plane extends the frequency response rom 5 Hz to 100 Hz at pressures up to 140 kPa, peak-to-peak. he sinusoidal pressure fluctuations can be generated by both ethods in the presence of high pressure (bias) up to 55 MPa.

Calibration procedures are given in detail for the use of both ources. The dynamic performance of selected transducers was valuated using these procedures; the results of these calibraions are presented. Calibrations made with the two sources near Hz agree to within 3 percent of each other.

TN928. **Computer programs for the evaluation of activity and osmotic coefficients,** B. R. Staples and R. L. Nuttall, *Nat. Bur. Stand. (U.S.), Tech. Note 928,* 56 pages (Dec. 1976) SD Catalog No. C13.46:928.

Key words: activity coefficients; aqueous; computer programs; data evaluation; electrolytes; electromotive force; isopiestic method; osmotic coefficients; nonlinear least squares; thermodynamic properties; vapor pressure.

A number of specialized computer programs have been developed for the purposes of calculating thermodynamic properties directly from experimental data and for subsequent data manipulation, including nonlinear least-squares fitting of the data to empirical or semiempirical equations that describe the function over a range of compositions, temperatures or other parameters. The details of the programs used in the critical evaluation of mean activity and osmotic coefficients and sample runs for each program are discussed. Osmotic coefficients can be calculated from direct vapor pressure measurements or from isopiestic molalities. Activity coefficients can be calculated from electromotive force measurements of galvanic cells, both without liquid-junction and with transference. A nonlinear least-squares program fits data from all sources as a function of ϕ and ln γ. Once the parameters of the fitting equation have been obtained, another program can be used to calculate a table of m, γ, ϕ, a_w, and ΔG^{ex} at rounded molalities.

TN929. **A survey of current literature on sampling, sample handling, and long term storage for environmental materials,** E. J. Maienthal and D. A. Becker, *Nat. Bur. Stand. (U.S.), Tech. Note 929,* 40 pages (Oct. 1976) SD Catalog No. C13.46:929.

Key words: chemical analysis; environmental samples; long-term storage; microbiologicals; organics; pesticides; radionuclides; sample handling; sampling; trace elements.

This article is the result of an extensive literature survey to establish optimum sampling, sample handling and long term storage techniques for a wide variety of environmental samples to retain sample integrity. The components of interest in these samples are trace elements, organics, pesticides, radionuclides or microbiologicals. This survey was done both manually and by use of various bibliographical retrieval services. Also the advice and opinions of workers in various aspects of the fields was obtained.

TN930. **A measurement assurance program for electric energy,** N. M. Oldham, *Nat. Bur. Stand. (U.S.), Tech. Note 930,* 23 pages (Sept. 1976) SD Catalog No. C13.46:930.

Key words: electric energy; electricity; electric power; measurement assurance; transport standard; watthour meter.

A Measurement Assurance Program for Electric Energy is described which enables a meter laboratory to evaluate the accuracy of its calibration process relative to the legal units of energy maintained by the National Bureau of Standards. A laboratory participating in this program periodically determines its process offset by testing an NBS transport standard as part of its regular workload (using the same procedures used to test its working standards). Subsequent monitoring and tests for local control can improve the reliability and assure the adequacy of the participant's calibration process.

TN931. **Environmental effects on microphones and type II sound level meters,** E. B. Magrab, Ed., *Nat. Bur. Stand. (U.S.), Tech. Note 931,* 120 pages (Oct. 1976) SD Catalog No. C13.46:931.

Key words: acoustic calibrators; A-weighting; barometric pressure; crest factor; ground cover; humidity; instrumentation; microphones; sound level meters; statistical control processes; temperature.

For four different manufacturer's Type II sound level meters numerous experimentally determined data concerning the effects of frequency, temperature, angle of incidence of the sound, and types of ground cover and reflecting surfaces on sound level meter readings are presented. Data are also given for the effects of ambient barometric pressure on several manufacturers'

acoustic calibrators, the effect of frequency and crest factor on the sound level meters' detector circuit, the linearity of the sound level meters' range potentiometer and meter scale, and the precision of the A-weighted response in a randomly incident (diffuse) sound field. Additional data are given concerning the effects of temperature and humidity on the sensitivity of electret, condenser, and ceramic microphones. Finally, important statistical concepts and recommended data monitoring procedures are presented to insure that the precision of repeated sound level measurements is known.

TN932. **Concrete strength during construction,** H. S. Lew, T. W. Reichard, and J. R. Clifton, *Nat. Bur. Stand. (U.S.), Tech. Note 932,* 56 pages (Dec. 1976) SD Catalog No. C13.46:932.

Key words: compressive strength; concrete; maturity; mechanical properties; nondestructive evaluation; pull-out strength; splitting tensile strength.

The early strength gain characteristics of a concrete at various temperatures was investigated in this study. In addition, the applicability of two widely known nondestructive evaluation methods were examined for the purpose of determining the compressive strength of concrete at early ages.

For destructive evaluation, standard cylinder compresso tests, splitting tensile tests and pull-out tests were made o specimens cured at 73 °F (22.8 °C), 55 °F (12.8 °C) and 35 ° (1.7 °C). For nondestructive evaluation, both probe penetrati and rebound hammer tests were performed on slabs. Tests we carried out at the age of 1, 2, 3, 5, 7, 14, 28 and 42 days aft casting the concrete.

Statistical analyses were made to examine the possibility using maturity of concrete as a parameter to correlate test resul of concrete cured at different temperatures. Rate of gain of tl splitting tensile strength, pull-out bond strength and elast modulus were compared with that of compressive strength.

The results show that when related to maturity, the rate of i crease in the splitting tensile strength is about the same as that the compressive strength, whereas the rate of increase in tl pull-out strength and the modulus are slightly greater than that the compressive strength. The results of nondestructive evalu tions revealed that the compressive strength could not be es mated correctly by the probe method using the manufacture conversion charts. Because of lower rebound readings, tl rebound hammer could not be used to estimate the compressi strength at early ages.

3.18. CONSUMER INFORMATION SERIES

Practical information, based on NBS research and experience. vering areas of interest to the consumer. Easily understand- le language and illustrations provide useful background owledge for shopping in today's technological marketplace.

IS1. **Fibers and fabrics,** J. M. Blandord, Nat. Bur. Stand. (U.S.), Consumer Info. Series 1, 31 pages (Nov. 1970).

Key words: Apparel, textile; blends, fabric; care instructions, textiles; consumer goods, textile; fabrics, textile; fibers, textile; flammability, textile; glossary, textile; properties, textile fiber; textiles; wash-and-wear textiles.

Fibers and fabrics is especially designed for the consumer ho purchases and cares for fabrics, apparel, home furnishings, id household textile products. It characterizes the properties. ethods of care, and major uses of the consumer textile products the United States. Included in the booklet are sections on fabric ends, wash-and-wear textiles, and a glossary of commonly- sed textile terms.

IS2. **Tires, their selection and care,** A. Brenner, Nat. Bur. Stand. (U.S.), Consumer Info. Series 2. 32 pages (Nov. 1970).

Key words: Construction; maintenance; passenger car tires; safety; tires, passenger car; wear.

The booklet provides the information needed to obtain maxi- num safety, wear, and performance from tires. It discusses such actors as matching the tire to driving habits, types of roads ormally driven, and loads to be carried. Also covered are proper ire maintenance, and the relationship among driving habits, ire wear, and safetv.

CIS3. **Adhesives for everyday use,** K. F. Plitt, Nat. Bur. Stand. (U.S.), Consumer Info. Series 3. 17 pages (No . 1970).

Key words: Adhesion; adhesive properties; adhesive selection; adhesives, bonding; surface preparation.

This publication is intended to assist the consumer in selecting nd using adhesives for ordinary applications. It covers the type f adhesives generally available in retail stores and points out ne major features of each type.

IS4. **Facts about hearing and hearing aids,** E. L. R. Corliss, Nat. Bur. Stand. (U.S.), Consum. Inf. Ser. 4, 35 pages (Nov. 1971).

Key words: Audition; communications; hearing; hearing aids; selection of hearing aids; speech communication.

A consumers information publication containing information n hearing aids including selection, use, and maintenance.

CIS5. **Care of books, documents, prints and films,** W. K. Wilson and J. L. Gear, Nat. Bur. Stand. (U.S.), Consum. Inf. Ser. 5, 19 pages (Dec. 1971).

Key words: Films; negatives; paper; photographs; preservation of records; prints; records; repair of records; storage of records; slides.

This paper describes what the average person can do to care for the books, documents, films and prints that he hopes to preserve for a long time. It tells (1) what *can* be done with respect to storage and simple repair, (2) what *not* to do, such as storage in hot attics and damp basements, (3) when to seek professional help and (4) where to go to find more detailed information.

CIS6. **Color in our daily lives,** D. B. Judd, Nat. Bur. Stand. (U.S.), Consum. Inf. Ser. 6, 32 pages (Mar. 1975) SD Catalog No. C13.53:6.

Key words: color; environment; experimenting with; harmony; hues; illumination; light; personal uses; relationships; uses.

If you are like most consumers, color is at once a delight, a challenge, and a problem. Color is a delight because it can convert an otherwise drab costume, scene, or room into a thing of beauty. It is a challenge because it brings out our creative ability and enables us to brighten and enliven our surroundings at a comparatively cheap cost. It is a problem because, improperly used, it can fail in its purpose, and if we are unsure of the ways in which colors go together, the choice of a tie, a lipstick, a drapery fabric, or a wall paint to match furniture and carpet can become an unpleasant chore.

Because of the importance of color in our daily lives, and the widespread lack of knowledge about the relationship of colors, we are pleased to bring you this extraordinary booklet as a part of our Consumer Information Series. It has been written in simple language, but in its scientific accuracy, and in the precise

CIS7. **What About Metric?,** L. E. Barbrow, Nat. Bur. Stand. (U.S.), Consum. Inf. Ser. 7, 16 pages (Oct. 1973) 80 cents, SD Catalog No. C13.53:7.

Key words: Metric system; SI; weights and measures.

The metric system of measurement, how it compares with our customary system, and how it will affect everyday life are described in everyday terms. Examples of computations of the type frequently encountered by the average citizen are included to illustrate the relative simplicity of the metric system. Although extensive use of the metric system in the United States is envisioned to be several years in the future, the reasons for at least becoming acquainted with the system now are discussed. The necessary acquaintanceship for everyday life involves the learning of fewer than ten metric units of measurement.

CIS8. **Making the most of your energy dollars in home heating and cooling,** M. Jacobs and S. Petersen, Nat. Bur. Stand. (U.S.), Consum. Inf. Ser. 8, 20 pages (June 1975) SD Catalog No. C13.53:8. 2nd Printing, Oct. 1975. 17 pgs.

Key words: building economics; consumer information; energy conservation; home economics; home improvements; insulation.

This booklet is a consumer-oriented adoption of BSS64 (Retrofitting Existing Housing for Energy Conservation: An Economic Analysis) which provides basic energy conservation information of an economic nature to homeowners. It is concerned primarily with energy conservation improvements which will decrease heating and cooling costs in houses. Investment in insulation, storm windows and doors, and weatherstripping/ caulking is examined with regards to different climates and different energy prices in order to determine the combination of these improvements which will provide the greatest long-run economies in space heating and cooling to the homeowner. Information of a general nature on the proper use of such improvements is outlined and further references are listed.

3.19. NBS INTERAGENCY REPORTS

A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution by the National Technical Information Service (NTIS), Springfield, Va. 22151, in paper copy or microfiche form. This series MUST be ordered from NTIS by the "COM, PB, or AD" number listed at the end of each entry.

NBSIR 73-101. Penetration Resistance Tests of Reinforced Concrete Barriers, R. T. Moore, 83 pages (December 1972). Order from NTIS as COM 73-10867. [See 13384 for abstract.]

NBSIR 73-102. Energy Conservation Through Effective Utilization, C. A. Berg, 53 pages (February 1973). Order from NTIS as COM 73-10856. [See 13385 for abstract.]

NBSIR 73-105. Environmental Evaluation of Polyurethane Foam Core Sandwich Panel Construction, J. R. Shaver, L. W. Masters, T. W. Reichard, and J. H. Pielert, 47 pages (December 1972). Order from NTIS as PB 219-118. [See 13386 for abstract.]

NBSIR 73-108. **City games—City I operator's manual,** J. E. Moriarty, 24 pages (Oct. 1973). Order from NTIS as COM 74-10701-2.

Key words: city; computer; directors; economic; games; government; metropolitan; players; sectors; simulation; social; urban.

City 1 is an operational simulation game in which participants make economic, government, and social decisions affecting a hypothetical metropolitan area. The game is run on an IBM 1131 Central Processor with at least 8K and single disc storage.

This manual describes the methods of operating the Central Processor relative to the game along with the special coding required to change and/or update the computer program and core mapping.

It is assumed throughout this manual that the operator knows how to cold start the 1130, change carriage tapes, and load and clear the card reader.

NBSIR 73-109. **City games—City I director's manual,** J. E. Moriarty, 76 pages (Sept. 1973). Order from NTIS as COM 74-10701-1.

Key words: city; computer; director's; economic; games; government; metropolitan players; sectors; simulation; social urban.

City I is an operational simulation game in which participants make economic and government decisions affecting a hypothetical metropolitan area. Through the use of a computer, the simulated urban system responds to the participant's as any real city would. The City I Director instructs the players in procedure and coordinates the overall game play. This manual describes the details of administering the game from the Director's point of view and presents examples of decision codes, formats, and general information necessary to direct the game.

NBSIR 73-110. **City games—City I player's manual,** J. E. Moriarty, Ed., 150 pages (Mar. 1973). Order from NTIS as COM 73-11191.

Key words: city; computer; directors; economic; games; government; metropolitan; players; sectors; simulation; social; urban.

City I is an operational simulation game in which participants make economic, government, and social decisions affecting a hypothetical metropolitan area. Through the use of a computer, the simulated urban system responds to the participant's decisions as any real city would. Each player in City I is assigned to a team which shares an economic and governmental role. This manual describes the player details for the economic and government sectors along with general information required for game play. It is one of three manuals necessary for game play (Player's Manual, Director's Manual, Computer Operator's Manual). Each of these manuals are designed to be used for reference and by themselves will not describe enough details for a complete game play. The game is run on an IBM 1130 computer with 8K core and single disc.

NBSIR 73-112. **City games—City 4 computer operator's manual,** J. E. Moriarty, 56 pages (Sept. 1973). Order from NTIS as COM 74-10702-3.

Key words: City IV; computer; Fortran; gaming; IBM 360/70; JCL; simulation.

This manual is written for an IBM 360/70 computer. It describes the necessary Fortran & JCL commands required for computer operation of the CITY IV game. Test commands and sequences are presented along with complete computer operating instructions for the Game. It is expected that this manual along with a Game Director's manual will provide complete instructions for the operation of CITY IV.

NBSIR 73-113. **City games—City 4 director's manual,** J. E. Moriarty, Ed., 286 pages (Mar. 1974). Order from NTIS as COM 74-10702-1.

Key words: city; computer; director's; economic; games government; metropolitan players; sectors; simulation; social; urban.

City 4 is an operational simulation game in which participant make economic and government decisions affecting a hypothetical metropolitan area. Through the use of a computer, the simulated urban system responds to the participant's as any real city would. The City 4 Director instructs the players in procedure and coordinates the overall game play. This manual describes the details of administering the game from the Director's point of view and presents examples of decision codes, formats, and general information necessary to direct the game.

NBSIR 73-114. **City games—City 4 player's manual,** J. E. Moriarty, Ed., 276 pages (Feb. 1974). Order from NTIS as COM 74-10702-2.

Key words: city; computer; directors; economic; games government; metropolitan; players; sectors; simulation; social; urban.

City 4 is an operational simulation game in which participant make economic, government, and social decisions affecting a hypothetical metropolitan area. Through the use of a computer the simulated urban system responds to the participant's decisions as any real city would. Each player in City 4 is assigned to a team which shares an economic and governmental role. This manual describes the player details for the economic and government sectors along with general information required for game play. It is one of three manuals necessary for game play (Player's Manual, Director's Manual, Computer Operator's Manual). Each of these manuals are designed to be used for reference and by themselves will not describe enough details for a complete game play. The game is run on an IBM O.S./360 computer.

NBSIR 73-116. Study of the Local Resistance of Conventional Plywood Subflooring to Concentrated Load, F. Y. Yokel, 64 pages (March 26, 1973). Order from NTIS as PB 220-432. [See 13388 for abstract.]

BSIR 73–119. Laser Damage in Materials, A. Feldman, D. Horowitz, and R. M. Waxler, 52 pages (February 1973). Order from NTIS as AD 75–789. [See 13529 for abstract.]

BSIR 73–121. Structural Tests of a Wood Framed Housing Module, C. W. Yancey and N. F. Somes, 111 pages (March 26, 1973). Order from NTIS as COM 73–10860. [See 13389 for abstract.]

BSIR 73–125. Interlaboratory Evaluation of the Tunnel Test (ASTM E 84) Applied to Floor Coverings, T. G. Lee and C. Huggett, 56 pages (March 1973). Order from NTIS as COM 73–11189. [See 13530 for abstract.]

BSIR 73–126. Structural Tests of Mechanical Connections for Concrete Panels, L. E. Cattaneo and F. Y. Yokel, 118 pages (November 1972). Order from NTIS as PB 219–124. [See 13390 for abstract.]

BSIR 73–127. Evaluation of Lead Paint Hazard Elimination Methods Part II, D. Waksman, L. F. Skoda, E. J. Clark, M. Godettee, 77 pages (March 1973). Order from NTIS as PB 213–352. [See 13391 for abstract.]

BSIR 73–128. Resistivity and Carrier Lifetime in Gold-Doped Silicon, W. R. Thurber, D. C. Lewis, and W. M. Bullis, 56 pages (January 31, 1973). Order from NTIS as AD 760–150. [See 13419 for abstract.]

BSIR 73–129. Evaluation of GRP Rod and Rope Materials and Associated End Fittings, N. Halsey, R. A. Mitchell, and L. Mordfin, 87 pages (December 1972). Order from NTIS as AD 759–913. [See 13392 for abstract.]

BSIR 73–131. Human Factors Evaluation of a Voice Encoding System, V. J. Pezoldt and J. J. Persensky, 51 pages (March 1973). Order from NTIS as COM 73–10863. [See 13393 for abstract.]

BSIR 73–132. State of the Art on Durability Testing of Building Components and Materials, L. W. Masters, W. C. Wolfe, W. J. Rossiter, Jr., and J. R. Shaver, 128 pages (March 1973). Order from NTIS as PB 222–300. [See 13637 for abstract.]

BSIR 73–135. Fire Endurance Tests of Steel Sandwich Panel Exterior Wall and Roof/Ceiling Constructions, B. C. Son, 38 pages (December 1972). Order from NTIS as PB 221–310. [See 13394 for abstract.]

BSIR 73–138. Time Series Forecasting of Highway Accident Fatalities, A. R. Craw, 37 pages (March 1973). Order from NTIS as COM 73–10868. [See 13395 for abstract.]

BSIR 73–140. Fire Endurance Test of Plywood-Faced Exterior Walls for Single Family Housing, B. C. Son, 24 pages (March 1973). Order from NTIS as PB 220–226. [See 13396 for abstract.]

BSIR 73–141. Fire Endurance Tests of Plywood on Steel Joist Floor Assemblies, With and Without Ceiling, H. Shoub and B. C. Son, 35 pages (March 1973). Order from NTIS as PB 220–430. [See 13397 for abstract.]

BSIR 73–144. Climatological Data at the Proposed Prototype Sites in the United States for the Evaluation of HUD Operation BREAKTHROUGH Housing Systems, T. Kusuda, 136 pages (April 10, 1973). Order from NTIS as PB 220–849. [See 13398 for abstract.]

BSIR 73-145. **Study of relationships between activity, reaction, garment parameter patterns and injury severity for fire incidents involving apparel,** L. B. Buchbinder, 33 pages (Apr. 1973). Order from NTIS as COM 75-10541.

Key words: accident patterns; apparel; apparel fires; burn injury; FFACTS; fire; flammable fabrics; garment fires; garment parameters; injury severity; victim's activity; victim's reactions.

Fire accidents result from the interaction of a number of environmental, human, and physical factors, all of which may effect the severity of the burn injury. Using information gathered from case histories in the Flammable Fabrics Accident Case and Testing System, this study seeks to identify patterns in the apparel fire accident variables: (1) activity preceding the accident, (2) parameters of fabrics and garments involved, (3) reaction of victim, and (4) severity of the burn injury. It will also attempt to define the extent and nature of the relationships between these accident variables.

This interim report gives a detailed description of the methodology employed in the development and completion of the study, with emphasis on accident pattern identification and classification for apparel fire incidents. Preliminary results of the study are included which identify certain recurring patterns of activity leading to burn injuries.

NBSIR 73–146. Outdoor Performance of Plastics X. Final Update of Weathering Data, W. J. Rossiter, Jr., 113 pages (March 1973). Order from NTIS as COM 73–10989. [See 13399 for abstract.]

NBSIR 73–148. Evaluation of the Column Connections Used in a Precast Concrete Modular Housing System, F. Y. Yokel and T. W. Reichard, 90 pages (March 26, 1973). Order from NTIS as PB 220–366. [See 13401 for abstract].

NBSIR 73–151. On Uncertainty in Mass Measurement, J. R. Donaldson, 10 pages (March 1973). Order from NTIS as COM 73–10866. [See 13402 for abstract.]

NBSIR 73-152. **Measurement of transit time and related transistor characteristics,** D. E. Sawyer, G. J. Rogers, and L. E. Huntley, 131 pages (Oct. 1973). Order from NTIS as AD 914258.

Key words: delay time; electronics; high-frequency probes; Sandia bridge; scattering; S-parameters; transistors; vector voltmeter.

Two instruments for transistor delay-time measurements, the vector voltmeter and Sandia bridge, were analyzed and comparative measurements were made on several types of commercial and two special transistors. It was found that extraneous pickup at the measurement frequency can cause large errors in measured delay time. A technique for minimizing these errors was developed and verified for the Sandia bridge by removing the frequency dependence of delay force, probe tip protrusion and lateral motion (skating) with loading were recorded for special probe assemblies to be used in an automatic wafer prober for measurements on transistors in custom-designed integrated circuit wafers. The data is used to assist in adjusting the probers. A technique was developed for determining the effects of the probe assemblies on transistor measurements made from 0.1 to 2.0 GHz. Each probe assembly may be represented by an equivalent circuit consisting of three unknowns; these unknowns are determined by making impedance measurements at the input connectors with the probe tips contacted by combinations of open circuits, short circuits, and resistors of known value. Arrays of such terminations were successfully fabricated and characterized. An S-parameter interlaboratory testing program was developed. The plan calls for six of each of three types of transistors to be measured by participants at frequencies from 0.11 to 2.0 GHz. Additionally, a 10-dB attenuator and R-C networks on TO-72 headers are to be circulated to pinpoint measurement discrepancies.

NBSIR 73–154. A Summary of the Relationships Between Accident Indices and Rates Following a Redefinition of "Failure", A. R. Craw, 17 pages (March 1973). Order from NTIS as COM 73–10865. [See 13403 for abstract.]

NBSIR 73–156. A Study of the Strength Capabilities of Children Ages Two Through Six, W. C. Brown and C. J. Buchanan, 56 pages (August 7, 1973). Order from NTIS as COM 73–11286. [See 13595 for abstract.]

NBSIR 73–157. National Program of Metrology for Ecuador, T. M. Stabler, 33 pages (April 1973). Order from NTIS as COM 74–10394. [See 13777 for abstract.]

NBSIR 73–159. U.S. Membership in the International Organization of Legal Metrology, T. M. Stabler, 12 pages (April 1973). Order from NTIS as COM 73–11174. [See 13454 for abstract.]

NBSIR 73–161. Field Test of Hydraulic Performance of a Single-Stack Drainage System at the Operation BREAK-THROUGH Prototype Site in King County, Washington, R. S. Wyly and D. E. Rorrer, 66 pages (May 1973). Order from NTIS as PB 225–310. [See 13778 for abstract.]

NBSIR 73–162. Executive Summary of a Proficiency Test Assessment of Clinical Laboratory Capability in the United States, P. W. Finkel and T. R. Miller, 9 pages (May 1973). Superseded by NBSIR 73–162. Order from NTIS as COM 74–10542. [See 13404 for abstract.]

NBSIR 73–163. A Proficiency Test Assessment of Clinical Laboratory Capability in the United States, P. W. Finkel and T. R. Miller, 114 pages (May 1973). Supersedes NTIS Nos. COM 73–11190 and COM 73–11193. Order from NTIS as COM 74–10542. [See 13779 for abstract.]

NBSIR 73–164. Fire Endurance Test of a Steel Sandwich Panel Floor Construction, B. C. Son, 25 pages (April 1973). Order from NTIS as PB 221–642. [See 13405 for abstract.]

NBSIR 73–165. Fire Endurance Test on a Steel Tubular Column Protected with Gypsum Board, B. C. Son, 23 pages (April 1973). Order from NTIS as PB 221-474. [See 13406 for abstract.]

NBSIR 73–166. Fire Endurance Test of an Interdwelling Double Wall Construction of Paper Honeycomb and Gypsum Board, B. C. Son, 24 pages (April 1973). Order from NTIS as PB 222–297. [See 13407 for abstract.]

NBSIR 73–167. Fire Endurance Test of a Roof/Ceiling Construction of Paper Honeycomb and Gypsum Board, B. C. Son, 20 pages (January 1973). Order from NTIS as PB 222–298. [See 13408 for abstract.]

NBSIR 73–168. Fire Endurance Test of a Fiber Glass Reinforced Polyester Double Wall Assembly, B. C. Son, 26 pages (April 1973). Order from NTIS as PB 221–184. [See 13409 for abstract.]

NBSIR 73–169. Fire Endurance Test of a Wood Stud Interdwelling Double Wall Construction, B. C. Son, 21 pages (April 1973). Order from NTIS as PB 221–185. [See 13410 for abstract.]

NBSIR 73–170. Fire Endurance Test of an Interdwelling Double Wall Constructed of Polyurethane Foam-Filled Sandwich Panels, B. C. Son, 27 pages (April 1973). Order from NTIS as PB 221–193. [See 13411 for abstract.]

NBSIR 73–172. Standardization and Measurement Services in Turkey, H. S. Peiser, R. J. Corruccini, and S. B. Newman, 91 pages (October 14–28, 1972). Order from NTIS as COM 73–11175. [See 13476 for abstract.]

NBSIR 73–173. Fire Endurance Tests of Double Module Walls of Gypsum Board and Steel Studs, B. C. Son, and H. Shoub, 32 pages (April 1973). Order from NTIS as COM 73–10844. [See 13412 for abstract.]

NBSIR 73–175. Estimates of Vehicular Collisions with Multistory Residential Buildings, S. L. Fribush, D. Bowser, and R. Chapman, 72 pages (April 1973). Order from NTIS as COM 74–10395. [See 13781 for abstract.]

NBSIR 73-177. **Comparison of the fire performance of neopren and flame retardant polyurethane mattresses,** W. J. Parker, 4 pages (Apr. 1973). Order from NTIS as COM 75-10336.

Key words: fire retardant; fire test; heat release ignition mattress; smoke; toxic gases.

Full scale fire tests of a neoprene and two different types c flame-retardant polyurethane mattresses were performed in room-sized compartment at the National Bureau of Standard The mattresses were tested in two orientations, horizontal an vertical and with two types of coverings, a fire retardant treate cotton and a high temperature nylon ticking, in addition to th bare mattress insert. In addition to the visual observations, th burning rates, ceiling temperatures, optical density of the smok and the toxic gas concentrations were measured. This series c tests were repeated on small mattress sections to examine th relevance of small scale tests as a means of predicting full scal behavior. The flame spread index was measured with the radiat panel (ASTM E162); and the smoke and toxic gas concentra tions were measured in the NBS smoke density chamber. Mea surements were also performed in the heat release rate calorim ter and the ease of ignition test apparatus.

NBSIR 73-180. **Testing of the NBS clinical microcalorimeter,** E J. Prosen and R. N. Goldberg, 31 pages (Apr. 1973). Orde from NTIS as COM 74-10139.

Key words: clinical chemistry; clinical microcalorimetry microcalorimeter; NBS microcalorimetry; testing of micro calorimeter.

The NBS Clinical Microcalorimeter has been tested for sta bility, sensitivity, ease of operation, and accuracy. The accurac was tested by means of electrical calibration and the determina tion of the heat of neutralization of HCl(aq) with NaOH(aq). Th heat of this reaction agrees with the best literature value withi the precision of the calorimeter. The precision is about 0.6 pe cent when measuring about 50 mJ of heat of chemical reactio The accuracy is estimated as 1 percent. The precision of electr cal energy determination is about 0.4 percent for energies c from 1 to 1400 mJ.

NBSIR 73–182. Analyses for Decision in the Office of Flan mable Fabrics: The Level of the Standard, A. R. Crav 80 pages (April 1973). Order from NTIS as COM 73 11284. [See 13596 for abstract.]

NBSIR 73–183. USAC Transferability, D. F. Quigley, 7 pages (April 1973). Order from NTIS as COM 73–1117 [See 13413 for abstract.]

NBSIR 73–184. A Cell Model for Isoperibol Calorimeter K. L. Churney, E. D. West, and G. T. Armstrong, 1(pages (April 1973). Order from NTIS as COM 73–1111 [See 13474 for abstract.]

NBSIR 73–185. Standardization and Measurement Servic in Korea, H. S. Peiser, T. D. Coyle, and R. K. Eby, 4 pages (June 19–30, 1972). Order from NTIS as COM 7 11287. [See 13608 for abstract.]

NBSIR 73–187. The Effect of Impact Loadings on the Pe formance of Wood Joist Subflooring Systems, H. S. Lev 49 pages (May 1973). Order from NTIS as PB 221–18 [See 13472 for abstract.]

NBSIR 73–188. Structural Tests on Housing Components Glass Fiber Reinforced Polyester Laminate, T. W. Reicl ard, W. E. Greene, Jr., L. E. Cattaneo, and L. W. Ma ters, 98 pages (April 1973). Order from NTIS as PB 221 183. [See 13473 for abstract.]

NBSIR 73–189. A Comparison of Several Methods f Forecasting U.S. Traffic Fatalities, A. R. Craw, 45 pag (May 1973). Order from NTIS as COM 73–11173. [S 13510 for abstract.]

BSIR 73–190. Acoustical Evaluation of a Single Family Attached Steel Frame Modular Housing System Constructed on an Operation Breakthrough Prototype Site, T. L. Quindry, 21 pages (April 1973). Order from NTIS as PB 221–189. [See 13414 for abstract.]

BSIR 73–191. Acoustical Evaluation of a Single Family Attached Wood-Frame Modular Housing System Constructed on an Operation Breakthrough Prototype Site, T. L. Quindry, 21 pages (April 1973). Order from NTIS as PB 221–695. [See 13455 for abstract.]

BSIR 73–192. Acoustical Evaluation of a Single Family Detached Honeycomb Panel Housing System Constructed on an Operation Breakthrough Prototype Site, T. L. Quindry, 19 pages (April 1973). Order from NTIS as PB 222–231. [See 13415 for abstract.]

BSIR 73–197, (Revised). Clinical Laboratory Performance Analysis Using Proficiency Test Statistics, P. W. Finkel and J. W. Rowen, 63 pages (December 1973). Order from NTIS as COM 74–10468. [See 13564 for abstract.]

BSIR 73–198. General Purpose Scientific Document Code Operations Under Exec 8, R. McClenon, 21 pages (May 1973). Order from NTIS as COM 73–11289. [See 13598 for abstract.]

IBSIR 73-199. **Experimental and analytical studies of floor covering flammability with a model corridor,** W. Denyes and J. Quintiere, 115 pages (May 1973). Order from NTIS as COM 74-10129.

Key words: flame spread; floor covering materials; model corridor; scaling laws; test method.

An experimental model corridor facility was designed, constructed, and instrumented. The facility examines flame spread over floor covering materials in a small scale corridor under a forced air flow condition. A gas burner flame serves as the ignition source.

A study was made of the factors influencing flame spread in the model corridor. These factors included energy release rate of the ignition source, air velocity, and model corridor geometry. Twenty-six carpet materials and 5 other floor covering materials were studied in the model corridor, and 369 flame spread runs were conducted.

It was found that flame spread behavior in the model corridor generally involves either a rapidly accelerating flame front which propagates the full 8 foot length of the test section ("flameover"), or involves a decelerating flame front which results in extinction a short distance from the ignition source. Radiant heating of the floor material due to hot products of combustion heating the ceiling is a significant factor in causing flameover. Carpet assembly was found to affect flame spread more significantly than pile fiber type.

The data have been analyzed to determine quantitatively the effects of the factors influencing flame spread. Scaling relationships have been presented to attempt to extrapolate the model corridor results to full scale corridor fires.

Finally a procedure has been suggested for using the facility in a floor covering flammability test method. The procedure is based on determining the minimum energy input rate to cause flameover.

NBSIR 73-200. **A model corridor for the study of the flammability of floor coverings,** W. Denyes and J. W. Raines, 40 pages (May 1973). Order from NTIS as COM 74-10478.

Key words: air flow, energy input; flameover; flame spread; floor covering flammability; model corridor; test repeatability.

A program was carried out to develop a laboratory test method that would measure the flame propagation characteristics of floor covering materials. A facility was designed which included a floor mounted specimen in a rectangular cross-sectional duct having a forced supply of air and a gas burner ignition source. The effects of variations in duct size, ignition source, and air flow were studied. Factors influencing repeatable test results were explored. Flame spread was measured by an observer and temperature and heat flux measurements were recorded on an electronic digital data acquisition system.

NBSIR 73–201. Composite-Overlay Reinforcement of Cutouts and Cracks in Metal Sheet, R. A. Mitchell, R. M. Woolley, and D. J. Chwirut, 94 pages (February 1973). Order from NTIS as COM 73–11221. [See 13607 for abstract.]

NBSIR 73-202. **Conservation via effective use of energy at the point of consumption,** C. A. Berg, 37 pages (Apr. 1973). Order from NTIS as COM 74-10479.

Key words: buildings; energy conservation; industrial equipment.

The practices and equipment employed at the point of energy consumption in buildings and in industrial processes permit excessive consumption of energy. It is estimated that if full application of the economically justifiable technical improvements presently available were made to equipment and practices in buildings and industry, as much as 25 percent of the total primary fuel consumption in the U.S.A. could be conserved. The reasons why economically justifiable application of effective technology at the point of energy consumption has not been widely adopted in the past are considered. The needs to facilitate adoption of effective equipment and practices in the future are discussed.

NBSIR 73–203. Chemical Kinetics Data Survey IV. Preliminary Tables of Chemical Data for Modelling of the Stratosphere, D. Garvin, Editor, 97 pages (May 1973). Order from NTIS as COM 73–11288. [See 13597 for abstract.]

NBSIR 73–206. Chemical Kinetics Data Survey V. Sixty-six Contributed Rate and Photochemical Data Evaluations on Ninety-four Reactions, D. Garvin, Editor, 120 pages (May 1973). Order from NTIS as COM 73–11253. [See 13563 for abstract.]

NBSIR 73–207. Chemical Kinetics Data Survey VI: Photochemical and Rate Data for Twelve Gas Phase Reactions of Interest for Atmospheric Chemistry, R. F. Hampson, Editor, 127 pages (August 1973). Order from NTIS as AD 769266. [See 13770 for abstract.]

NBSIR 73–208. Residential Buildings and Gas-Related Explosions, E. F. P. Burnett, N. F. Somes, and E. V. Leyendecker, 32 pages (June 1973). Order from NTIS as COM 74–10127. [See 13782 for abstract.]

NBSIR 73–209. Survey of Various Approaches to the Chemical Analysis of Environmentally Important Materials, B. Greifer and J. K. Taylor, 237 pages (July 1973). Order from NTIS as COM 74–10469. [See 13783 for abstract.]

NBSIR 73-210. **LEAA police equipment survey of 1972. Volume I: The need for standards—priorities for police equipment,** R. Ku, E. Bunten, and P. Klaus, 212 pages (July 1973). Order from NTIS as COM 74-11767.

Key words: police; police equipment; standards.

The report describes the methodology of and summarizes a portion of the data from the LEAA Police Equipment Survey of 1972. One of a series of seven reports resulting from this nationwide mail survey of a stratified random sample of 1386 police departments, the present report summarizes the answers of 1100

police departments concerning the need for performance standards for items of law enforcement used in their departments. Each sample department was asked to rank one list of equipment categories and nine lists of equipment items within those categories in terms of the need for standards for those equipment within their own departments. The data are presented by all responding departments, by all city departments, by seven department types, and by ten LEAA geographical regions. Data describing the characteristics of the responding departments are also presented.

NBSIR 73-211. **LEAA police equipment survey of 1972. Volume II: Communications equipment and supplies,** S. Mumford, P. Klaus, E. Bunten, and R. Cunitz, 175 pages (Final July 1971-July 1973). Order from NTIS as COM 74-10950.

Key words: communications; mobile radio; police; police equipment; portable radio; standards.

The report outlines the methodology of and summarizes a portion of the data from the LEAA Police Equipment Survey of 1972. One of a series of seven reports resulting from this nationwide mail survey of a stratified random sample of police departments, the present report summarizes the answers of 428 police departments concerning their communications equipment and supplies: use of mobile radios and portable radios; power supplies for portable radios; scramblers; portable/mobile radios; helmets with built-in communications; needs for standards and problems associated with communications equipment and supplies. The data are presented by all responding departments and by seven department types.

NBSIR 73-212. **LEAA police equipment survey of 1972. Volume III: Sirens and emergency warning lights,** P. Klaus and E. Bunten, 141 pages (July 1971-Sept. 1973). Order from NTIS as COM 74-11009.

Key words: emergency warning lights; police equipment; sirens; standards.

The report outlines the methodology of and summarizes a portion of the data from the LEAA Police Equipment Survey of 1972. One of a series of seven reports resulting from this nationwide mail survey of a stratified random sample of police departments, the present report summarizes the answers of 437 police departments concerning their sirens and emergency warning lights: use of sirens and lights; experience with most commonly used electronic sirens, electromechanical sirens, and emergency warning lights; purchasing, repair and replacement of this equipment; and training of officers in use of this equipment. The data are presented by all responding departments and by seven department types.

NBSIR 73-213. **LEAA police equipment survey of 1972. Volume IV: Alarms, security equipment, surveillance equipment,** J. L. Eldreth, E. D. Bunten, and P. A. Klaus, 147 pages (July 1971-Oct. 1973). Order from NTIS as COM 74-11771.

Key words: alarm systems; cameras; police; police equipment; security equipment; surveillance equipment.

The report outlines the methodology of and summarizes a portion of the data from the LEAA Police Equipment Survey of 1972. One of a series of seven reports resulting from this nationwide mail survey of a stratified random sample of police departments, the present report summarizes the answers of 447 police departments concerning their use of alarm systems, cameras, security equipment, and surveillance equipment: purchasing practices, typical patterns of use, and needs for standards for such equipment. The data are presented by all responding departments and by seven department types.

NBSIR 73-214. **LEAA police equipment survey of 1972. Volume V: Handguns and handgun ammunition,** S. Bergsman, E. Bunten, and P. Klaus, 102 pages (July 1971-Aug. 1973). Orde from NTIS as COM 74-11239.

Key words: ammunition; handguns; police; police equip ment; standards.

The report outlines the methodology of and summarizes a po tion of the data from the LEAA Police Equipment Survey 1972. One of a series of seven reports resulting from this natio wide mail survey of a stratified random sample of police depar ments, the present report summarizes the answers of 445 polic departments concerning their officers' use of handguns an handgun ammunition: on-duty and off-duty use, types an calibers in use, and problems encountered. The data a presented by all responding departments and by seven depar ment types.

NBSIR 73-215. **LEAA police equipment survey of 1972. Volun VI: Body armor and confiscated weapons,** G. B. Hare, P. Klaus, and E. D. Bunten, 104 pages (Oct. 1973). Order fro NTIS as COM 74-11010.

Key words: ballistic protective equipment; body armo confiscated weapons; police; standards.

The report outlines the methodology of and summarizes a po tion of the data from the LEAA Police Equipment Survey 1972. One of a series of seven reports resulting from this natio wide mail survey of a stratified random sample of police depar ments, the present report summarizes the answers of 440 poli departments concerning body armor and confiscated weapon preference for hidden or visible body armor; use of other ballist protective equipment; routine operations where body arm would be most useful; current problems and failures with prese equipment; needs for standards for the testing and assessment penetration capabilities of body armor; disposition of confiscate weapons. The data are presented by all responding departmen and by seven department types.

NBSIR 73-216. **LEAA police equipment survey of 1972. Volun VII: Patrolcars,** E. D. Bunten and P. A. Klaus, 115 pages (Ju 1973). Order from NTIS as COM 74-11011.

Key words: patrolcar; police; police vehicles; standards.

The report outlines the methodology of and summarizes a pc tion of the data from the LEAA Police Equipment Survey 1972. One of a series of seven reports resulting from this natio wide mail survey of a stratified random sample of police depa ments, the present report summarizes the answers of 449 poli departments concerning their patrolcars: purchasing practice types of options and accessories usually selected; types of equi ment stored in the patrolcar; typical patterns of use; and nee for standards for systems or aspects of patrolcars. The data a presented by all responding departments and by seven depa ment types.

NBSIR 73–217. Use of Computer Networks in Support Interactive Graphics for Computer-Aided Design a Engineering, M. D. Abrams, J. A. Hudson, P. Meissn T. N. Pike, Jr., R. M. Rosenthal, and F. H. Ulmer, pages (June 30, 1972). Order from NTIS as COM 7 10470. [See 13784 for abstract.]

NBSIR 73–218. NEPA and the Environmental Moveme A Brief History, L. G. Llewellyn and C. Peiser, 40 pa (July 1973). Order from NTIS. [See 13785 for abstrac

NBSIR 73–220. Test of a Polyester Composite Wall Pa for Moisture Accumulation and Potential Removal Moisture Through Venting, C. I. Siu, W. M. Ellis, and Kusuda, 18 pages (May 1973). Order from NTIS as 222–437. [See 13610 for abstract.]

NBSIR 73–221. Abnormal Loading on Buildings and P gressive Collapse, N. F. Somes, 76 pages (May 197

Order from NTIS as PB 220-849. [See 13475 for abstract.]

BSIR 73–223. Penetration Tests on J-SIIDS Barriers, R. T. Moore, 86 pages (June 4, 1973). Order from NTIS as COM 73–11220. [See 13562 for abstract.]

BSIR 73-228. Summary of Flame Spread and Smoke Generation Tests Conducted for Operation Breakthrough, J. B. Ferguson, 27 pages (July 1973). Order from NTIS as PB 222–425. [See 13609 for abstract.]

BSIR 73–231. Response Characteristics of a Portable X-ray Fluorescence Lead Detector: Detection of Lead in Paint, J. C. Spurgeon, 37 pages (June 1973). Order from NTIS as PB 224–645. [See 13766 for abstract.]

BSIR 73-233. **Non-metallic antenna-support materials,** D. E. Marlowe, N. Halsey, R. A. Mitchell, and L. Mordfin, 53 pages (Apr. 1973). Order from NTIS as COM 74-11770.

Key words: Composite materials; end fittings for FRP rod; environmental resistance of GRP rod; fiber-reinforced-plastic rod; glass-reinforced-plastic rod; guys, antenna; mechanical properties of GRP rod; pultrusion; reinforced plastic rod; stress rupture of GRP rod.

A program was initiated to develop a non-conductive FRP rod aterial for use as guy lines and catenaries in large antenna stems. It is intended that the longterm structural properties of e new material, under adverse weathering conditions, be surior to those exhibited by the GRP rod and rope materials nich are available at the present time. Two new end fittings for RP rod were developed which out-perform commercially ailable fittings. These two fittings, which enable the tensile engths of the rod materials to be accurately determined, inude a shear-type fitting and a compression-type fitting. Defiencies in the physical characteristics of existing GRP rod aterials were identified, and modifications to the manufacturing ocesses were proposed to overcome these deficiencies. A subntract was let for the manufacture of experimental GRP rods ing the modified processes. A bank of six high-capacity creep sting machines was designed and is being assembled. These achines, which will accomodate long specimen lengths, are uipped with environmental chambers to permit stress-rupture sting under elevated temperature and saturated humidity conitions.

BSIR 73-234. **Drapery and curtain fires—data element summary of case histories,** A. K. Vickers, 28 pages (July 1973). Order from NTIS as COM 74-10128.

Key words: burns; case histories; curtains; death; draperies; FFACTS; fires; flammable fabrics; houses; standards; statistical data.

A preliminary examination of 1,567 computerized case histoes from the NBS Flammable Fabric Accident Case and Testing ystem has found 77 incidents in which curtains and draperies ere involved in fires. This report is a summary of information lating to these 77 incidents, and includes the location of inidents, ignition sources, personal injury, fabrics involved and rsonal characteristics of victims. Fifteen people died from ese fires and 32 others were injured. Curtains or draperies ere the first fabric item to ignite in 28 of 55 curtain and drapery cidents in which the ignition source is known.

BSIR 73–240. Effects of Electroless Nickel Process Variables on Quality Requirements, F. Ogburn and C. E. Johnson, 34 pages (June 1973). Order from NTIS as COM 74–10986. [See 13786 for abstract.]

BSIR 73–242. Pilot Demonstration of Lead Based Paint Hazard Elimination Methods, T. H. Boone, T. R. Ray, W. G. Street, 38 pages (June 1973). Order from NTIS as PB 224–654. [See 13767 for abstract.]

NBSIR 73–244. The Role of Passive Film Growth Kinetics and Properties in Stress Corrosion and Crevice Corrosion Susceptibility, J. Kruger and J. R. Ambrose, 75 pages (July 1973). Order from NTIS as AD 767–326. [See 13769 for abstract.]

NBSIR 73-246. **Fire research publications, 1969-1972,** N. H. Jason, R. G. Katz, and P. A. Powell, 14 pages (July 1973). Order from NTIS as COM 74-10989.

Key words: bibliographies; construction materials; fire departments; Fire Research and Safety Act; fire tests; flammability tests; flammable fabrics; Flammable Fabrics Act; protective clothing.

A list of publications is provided representing the papers and journal articles prepared by Fire Technology Division and by Building Fires and Safety Section of the Center for Building Technology personnel and by external laboratories under contract to the Fire Technology Division from 1969 through 1972.

NBSIR 73–248. A Survey of the Sanitary Conditions of Migrant Labor Camps, C. Fried, R. Ramsburg, and S. Butler, 83 pages (August 1973). Order from NTIS as COM 74–10474. [See 13787 for abstract.]

NBSIR 73–251. Analytical Methods for the Detection of Toxic Elements in Dry Paint Matrices—A Literature Survey, M. Paabo, 49 pages (July 1973). Order from NTIS as PB 224–688. [See 13768 for abstract.]

NBSIR 73–252. MFPG Detection, Diagnosis, and Prognosis, 268 pages (September 1973). Order from NTIS as AD–772082. [See 13789 for abstract.]

NBSIR 73-254. **A mercury vapor generation and dilution system,** E. P. Scheide, R. Alvarez, B. Greifer, E. E. Hughes, and J. K. Taylor, 12 pages (Oct. 1973). Order from NTIS as COM 74-10987.

Key words: atomic absorption; gas generation system; mercury; occupational safety.

This report describes a system capable of producing well-defined test atmospheres of mercury in air or other diluent gas at concentrations between 0.005 and 0.5 μg/l and an analytical system for the analysis of these gas mixtures. Various parameters that affect the generator and analytical system and their interactions are discussed. This system provides a means of calibration of the various analytical systems for mercury now in use. The analytical unit of the system can also be used for the determination of mercury in industrial atmospheres by collecting the mercury on a silver wool collector, and then desorbing it by heat into a flameless atomic absorption spectrometer.

NBSIR 73-256. **Development of reference materials for atmospheric analysis of the occupational environment: Filter samples containing toxic metals,** R. Mavrodineanu, J. R. Baldwin, and J. K. Taylor, 16 pages (Oct. 1973). Order from NTIS as COM 75-11443.

Key words: analysis of toxic materials; atmospheric analysis; industrial hygiene; reference materials.

Techniques are described that may be used to prepare filters on which are deposited prescribed amounts of heavy metals, for use as reference materials in industrial atmospheric analysis. Working solutions, prepared from pure metals and highly purified acids and water, are pipetted onto the filters held in jigs to facilitate their application. The techniques were used to prepare three sets of reference materials containing the following metals: Set 1—Pb, Cd, Zn, Sn; Set 2—Pb, Zn, Mn; Set 3—Be. The amounts of each metal deposited on the filters correspond to those expected when collecting personal samples, in atmospheres when the concentrations are both below and above the TLV levels.

NBSIR 73-257. **A system for producing test atmospheres containing hydrogen cyanide,** E. P. Scheide, E. E. Hughes, and J. K. Taylor, 12 pages (Oct. 1973). Order from NTIS as COM 75-11444.

Key words: gas blending system; hydrogen cyanide; ion selective electrode; occupational safety.

A system capable of producing well-defined test atmospheres of HCN in air (or any other desired diluent) and an analytical system for the analysis of these gas mixtures is described. This system provides a means of calibration of the various analytical systems for HCN now in use. The analytical unit of the system can also be used for the determination of hydrogen cyanide in industrial atmospheres. By collecting the HCN in a sodium hydroxide solution, and measuring the cyanide content by the use of a cyanide-ion selective electrode, concentrations of HCN in air between 5 and 500 ppm were measured. This method is rapid and convenient and can easily be performed by a technician or adapted to automation.

NBSIR 73-258. **A gas dilution system for acrolein,** E. P. Scheide, E. E. Hughes, and J. K. Taylor, 11 pages (Oct. 1973). Order from NTIS as COM 75-11445.

Key words: acrolein; gas chromatography analysis; gas dilution system; occupational safety.

A system capable of producing well-defined test atmospheres of acrolein in air (or any other desired diluent) and an analytical system for the analysis of these gas mixtures is described. Using a bulk mixture of 9.0 ppm acrolein in nitrogen, and accurately blending this with a stream of clean, dry air, concentrations between 0.05 and 0.50 ppm can be produced. This system provides a means of calibration of the various analytical systems for acrolein now in use.

NBSIR 73-259. **A gas dilution system for methyl bromide,** E. P. Scheide, E. E. Hughes, and J. K. Taylor, 11 pages (Oct. 1973). Order from NTIS as COM 75-11446.

Key words: gas chromatography analysis; gas dilution system, methyl bromide; occupational safety.

A system capable of producing well-defined test atmospheres of methyl bromide in air (or any other desired diluent) and an analytical system for the analysis of these gas mixtures is described. Using a bulk mixture of 1000 ppm methyl bromide in nitrogen, and accurately blending this with a stream of clean, dry air, concentrations between 5 and 100 ppm can be produced. This system provides a means of calibration of the various analytical systems for methyl bromide now in use.

NBSIR 73-260. **A gas dilution system for arsine-air mixtures,** P. A. Pella, E. E. Hughes, and J. K. Taylor, 14 pages (Oct. 1973). Order from NTIS as COM 75-11440.

Key words: arsine; gas-blending; Gutzeit method; spectrophotometry.

A gas-blending system originally designed for chlorine-air mixtures was modified for producing arsine-air mixtures in the concentration range from 0.02 to 0.25 ppm. This system has been tested in order to provide accurately known concentrations of arsine-in-air for calibration of analytical monitoring devices. An analytical method has been developed for checking the concentration of arsine in the working standard and consists of the spectrophotometric measurement of an arsine-diethyldithiocarbamate complex in solution.

NBSIR 73-261. **A gas dilution system for hydrogen fluoride-air-mixtures,** P. A. Pella, E. E. Hughes, and J. K. Taylor, 23 pages (Oct. 1973). Order from NTIS as COM 75-11441.

Key words: fluoride analysis; gas-blending; HF-air mixtures; ion-specific electrode.

A gas-blending system was constructed for producing hydrogen fluoride-air mixtures in the concentration range from 1 to 20 ppm for the purpose of calibrating analytical monitoring devices. The system has been tested by measuring these HF concentrations using a fluoride ion-specific electrode.

NBSIR 73-262. **Some cutting experiments on human skin and synthetic materials,** J. R. Sorrells and R. E. Berger, 70 pages (Oct. 1973). Order from NTIS as COM 75-10370.

Key words: cut; edges, hazardous; experimental studies; human tolerances; injury; injury thresholds; inspection of edges; laceration; safety; simulation; skin; skin, cutting; synthetic materials, cutting; toys.

Human skin specimens were cut in vitro with edges of varying geometry over a normal force range of 0 to 89 newtons. Generally, at a given force, the smaller the included angle and the radius of an edge, the deeper the resulting cut. For a given edge and skin specimen, empirical curves fitted to the data indicate that the depth of cut increases with force, and that this rate of increase diminishes exponentially. Based on the experimental data, a convention was proposed for labelling the edges as safe or hazardous.

Synthetic materials were sought which, when applied in a specific manner to the test edges, would be completely penetrated by only those edges labelled hazardous. Then such materials could be used in an inspection procedure for unknown edges. Tests were conducted on many synthetics, but only a few showed possibilities in this regard.

NBSIR 73-263. Fire Endurance Tests of Unprotected Wood Floor Constructions for Single-Family Residences, B. C. Son, 65 pages (July 1973). Order from NTIS as PB 22[illegible] 284. [See 13790 for abstract.]

NBSIR 73-264. **Examination of failed one inch black iron pipe natural gas service line, Iowa Public Service Company, Eagle Grove, Iowa,** T. R. Shives, 24 pages (Aug. 30, 1973). Order from NTIS as PB243541.

Key words: black iron pipe; dimpled rupture; ductile fracture; gas pipe.

A fractured one inch black iron pipe natural gas service line which connected to a building involved in an explosion and fire in Eagle Grove, Iowa, on February 2, 1973, was examined by the NBS Mechanical Properties Section. The fracture was ductile in nature. There was no evidence found to indicate the presence of a preexisting crack. The fracture appeared to have been due to bending stresses caused by loading from an external source.

NBSIR 73-265. The Shirley Highway Express-Bus-On-Freeway Demonstration Project-Users' Reactions to Innovative Bus Features, T. H. Saks, R. F. Yates, and K. M. Goodman, 53 pages (June 1973). Order from NTIS as COM 73-11453. [See 13644 for abstract.]

NBSIR 73-266. Fire Spread on Exterior Walls Due to Flames Emerging from a Window in Close Proximity to a Reentrant Wall Corner, B. C. Son and J. B. Fang, [illegible] pages (April 1973). Order from NTIS as PB 225-28[illegible] [See 13791 for abstract.]

NBSIR 73-267. Report of Fire Tests on Flexible Connectors in HVAC Systems, L. A. Issen, 67 pages (July 197[illegible] Order from NTIS as COM 73-11955. [See 13792 for abstract.]

NBSIR 73-268. Laser Damage in Materials, A. Feldman, D. Horowitz, and R. M. Waxler, 44 pages (August 197[illegible] Order from NTIS as AD 768-303. [See 13793 for abstract.]

BSIR 73–275. Report to AID on an NBS/AID Workshop on Standardization and Measurement Services in Industrializing Economics, M. B. McNeil, 64 pages (September 1973). Order from NTIS as COM 74–10126. [See 13794 for abstract.]

BSIR 73–277. Evaluation of a Pressurized Stairwell Smoke Control System for a 12 Story Apartment Building, F. C. W. Fung, 53 pages (June 1973). Order from NTIS as PB 225–278. [See 13795 for abstract.]

BSIR 73-280. **Thermodynamics of chemical species important to rocket technology,** T. B. Douglas and C. W. Beckett, 109 pages (Jan. 1, 1973). Order from NTIS as COM 74-10549.

Key words: associated vapors; graphite; heat capacity; molybdenum; molybdenum pentafluoride; niobium; radiance temperature; spectral emittance; surface roughness; thermodynamic properties.

The enthalpy of high-purity molybdenum was accurately measured 273-1173 K, and joined smoothly to lower-temperature (German) and higher-temperature (NBS) results to give thermodynamic functions 273-2100 K. The heat capacity of a grade of Poco graphite was measured by a subsecond-duration pulse-heating technique 1500-3000 K (estimated inaccuracy, 3% or less). Based largely on earlier NBS IR and Raman spectroscopy, ideal-gas thermodynamic functions for MoF_5 were generated and are tabulated for 0-6000 K. Three alternative classical-thermodynamic or quasi-chemical treatments are developed for deriving thermodynamic properties from vaporization data on partially associated vapors, with calculations to illustrate experimental-error propagation for one treatment. A subsecond-duration pulse-heating technique was applied to niobium metal to measure its change in normal spectral emittance and radiance temperature at and near its melting point (wavelength, 650 nm), studying dependence on solid-state roughness (0.1 to 0.95 μm).

NBSIR 73-281. **Thermodynamics of chemical species important to rocket technology,** T. B. Douglas and C. W. Beckett, 122 pages (July 1, 1973). Order from NTIS as COM 74-10550.

Key words: electrical resistivity; iron; molybdenum pentafluoride; partly associated vapors; solid-state transformations; solution calorimetry; specific heat; spectral emittance; transition alloys; vapor pressure.

Using a subsecond-duration transient technique, the specific heat, electrical resistivity, and hemispherical total emittance were simultaneously measured 1500-2800 K for iron and the alloy 80Nb-10Ta-10W (estimated uncertainties: 3%, 0.5-1%, and 3% for the respective properties). Comparisons are made with generalized approximations. At the gamma-to-delta transformation of iron (about 1680 K), the temperature, heat of transformation, specific heat, spectral emittance, and electrical resistivity were measured, thereby demonstrating the feasibility of the technique for solid-solid transformations. Two other alloys were likewise measured. Solution calorimetry involving several thermochemical steps (including oxidation by XeO_3 in aqueous HF) gave the standard heat of formation of MoF_5(c). A new static vapor-pressure method, after verification to 1 percent by I_2 and MoF_6, and after modifications to deal with the necessarily added MoF_6, gave the vapor pressure of MoF_5 at 393 K and indicated (using also earlier NBS transpiration data) 85-90 mole percent of monomer in the saturated vapor.

NBSIR 73-287. **Procedures for the calibration of volumetric test measures,** J. F. Houser, 24 pages (Aug. 1973). Order from NTIS as COM 73-11928/1GA.

Key words: air density; calibration; gravimetric; neck; volumetric.

The values for graduated neck type volumetric vessels may be obtained by either gravimetric or volumetric calibrations. This text describes the two methods of calibration and the data reduction associated with each method. Procedures for preparing these vessels for test are discussed. Also included are illustrations for data recording.

NBSIR 73–288. Swiss Building and Housing Research Activities, H. R. Trechsel, 63 pages (August 1973). Order from NTIS as COM 73–11861. [See 13796 for abstract.]

NBSIR 73–289. Characterization and Testing of Interactive Graphics for Computer-Aided Design and Engineering, S. Treu, 36 pages (June 30, 1973). Order from NTIS as COM 74–10475. [See 13797 for abstract.]

NBSIR 73-290. **Development of a dynamic pressure calibration technique. A progress report,** P. S. Lederer, 4 pages (Oct. 15, 1973). Order from NTIS as COM 74-10974.

Key words: dynamic calibration; pressure; transducer.

Plans are described for experimental investigation of a hydraulic sinusoidal pressure calibrator as a basis for development of dynamic pressure calibration techniques for frequencies up to 2000 Hz.

NBSIR 73-294. **Cost sharing as an incentive to attain the objectives of shoreline protection,** H. E. Marshall, 70 pages (Dec. 1973). Order from NTIS as COM 74-10541.

Key words: beach erosion control; cost sharing; economics; efficiency; equity; incentives; shoreline protection.

The nation's shorelines are being eroded by high winds and waves. Nonfederal interests have traditionally received Federal help in the form of cost sharing for protective structures. This study provides the Army Corps of Engineers with an evaluation of alternative cost-sharing rules for shoreline protection with respect to efficiency, equity, and administrative feasibility.

Existing cost-sharing rules are described for hurricane, beach erosion, and emergency protection. The present cost-sharing system appears to induce local interests to choose (1) costly techniques of protection, e.g., engineering rather than management techniques, and (2) overbuilt projects in terms of the efficient scale.

It is concluded that the Association Rule, which requires local beneficiaries of shoreline protection to share in all of the costs of a project purpose in the proportion that local benefits bear to national benefits at the margin, should be applied to all shoreline protection programs. All techniques of protection should be subject to the same percentage cost-sharing rule. It is also concluded that *all* categories of project costs should have the same percentage cost share apply to them. Finally, Federal cost sharing might be used as an incentive to encourage local interests to comply with minimum land use requirements that would prevent shoreline damages.

NBSIR 73–295. Interim Report No. 7. Chemical Resistance and Physical Durability Testing of Coating Materials, J. R. Clifton, H. F. Beeghley, and R. G. Mathey, 22 pages (August 1973). Orde rfrom NTIS as COM 74–10471. [See 13798 for abstract.]

NBSIR 73-297. **Fracture and deformation of alumina,** S. M. Wiederhorn, 14 pages (July 31, 1973). Order from NTIS as AD 772066.

Key words: electron microscopy; fracture; mechanical properties; plastic deformation; sapphire; sodium chloride.

This report summarizes work conducted during the past eight years on the fracture and deformation of ceramic materials. Accomplishments discussed in this report include: an elucidation of fracture process of aluminum oxide and sodium chloride; the development of techniques to study the deformation of alu-

minum oxide during abrasion; and the development of techniques for measuring fracture mechanics parameters on ceramic materials.

NBSIR 73-299. **Examination of failed eight inch welded steel pipe natural gas main, UGI Corp., Coopersburg, Pennsylvania,** M. L. Picklesimer and T. R. Shives, 35 pages (Nov. 1973). Order from NTIS as PB243543.

Key words: brittle fracture; gas main pipe; welded steel pipe.

The Office of Pipeline Safety, Department of Transportation, submitted a four foot length of eight inch diameter welded steel pipe natural gas main containing a crack in the weld to the NBS Mechanical Properties Section for examination. The apparent crack origin was located at about the 4:30 o'clock position, assuming the top of the pipe to be at twelve o'clock and the outside of the bend of the pipe as installed was at three o'clock. The crack had propagated about two-thirds of the way around the pipe circumference. Optical and scanning electron microscopy revealed the fracture to have been predominantly brittle in nature. There was lack of weld penetration around a large part of the weld circumference and the weld metal exhibited some porosity. These features are normal for steel pipe welded by the oxyacetylene practice used at the time the weld was made. While these features of the weld helped to define the path of the fracture, they probably did not contribute to it. Examination of the fracture and comparison of its features with those of fractures produced in the laboratory indicated that failure was probably brought about as a result of a single event, impact loading from an external source.

NBSIR 73–301. Development of Insulation Transfer-Standards Using a Flat Plate Calorimeter, P. R. Ludtke, 43 pages (March 1973). Order from NTIS as COM 73–10762. [See 13416 for abstract.]

NBSIR 73–302. RF Null Detector NBS/SND, R. E. Stoltenberg, 88 pages (June 1973). Order from NTIS as COM 73–10869. [See 13420 for abstract.]

NBSIR 73–303. Fast Fourier Transform Implementation for the Calculation of Network Frequency Domain Transfer Functions from Time Domain Waveforms, W. L. Gans and N. S. Nahman, 53 pages (December 1972). Order from NTIS as AD 759–374. [See 13417 for abstract.]

NBSIR 73-304. **Reference-waveform generation using Debye dielectric dispersion,** N. S. Nahman, R. M. Jickling, and D. R. Holt, 98 pages (Dec. 1972). Order from NTIS as COM 74-10281.

Key words: pulse distortion in transmission lines; pulse techniques; reference waveform generation; time domain measurements; transient response Debye dielectric.

This report discusses the theory, construction, and operation of Reference-Waveform Generators using a tunnel diode transition-waveform generator driving 4.65 meter (15 foot), 3.10 meter (10 foot), and 1.55 meter (5 foot) liquid-dielectric uniform lossy coaxial lines to produce known 0.2 volt transition waveforms across 50 ohms with (10-90%) transition times from 205 to 560 picosecond. Each resultant Available-Waveform is characterized in terms of its departure from the step response of the uniform lossy coaxial line operating into a 50 ohm load. The liquid dielectric solutions are dispersive with relaxation times of the order of 4 picoseconds in which heptane is the solvent and the ketones, butanone, heptanone and octanone are the solutes in concentrations ranging from 0.25- to 2-molal.

NBSIR 73–308. Insulation of Liquid Oxygen Dewars, C. F. Sindt, 44 pages (April 1973). Order from NTIS as AD 763–325. [See 13418 for abstract.]

NBSIR 73–309. Random Sampling Oscilloscope Time Ba J. R. Andrews, 87 pages (June 1973). Order from NTIS COM 73–11981. [See 13799 for abstract.]

NBSIR 73–312. Notes on Infrared Absorption Experime in a Methane Molecular Beam, P. Kartaschoff, S. Jarv Jr., 32 pages (May 1973). Order from NTIS as CO 73–11893. [See 13800 for abstract.]

NBSIR 73-316. **Liquid helium pumps,** P. M. McConnell, pages (June 1973). Order from NTIS as AD 769542.

Key words: cavitation; helium; pump performance; pum superfluid.

This report summarizes studies of pump characteristics a performance in supercritical, normally boiling, and superfl helium, and also presents results on a survey of commercia available pumps for helium service. Experimental measureme were made on a centrifugal pump which produced a maxim head of about 15 meters and a maximum flow of about 2.5×1 m^3/s. Performance agreed approximately with classical affin laws, but cavitation appeared to provide less of a performa equipped with environmental chambers to permit stress-rupt testing under elevated temperature and saturated humidity c ditions.

NBSIR 73–318. Mass Quantity Gauging by RF Mode A alysis, R. S. Collier, D. Ellerbruch, J. E. Cruz, R. Stokes, P. E. Luft, R. G. Peterson, A. E. Hiester, pages (June 1973). Order from NTIS as N 73–273 [See 13664 for abstract.]

NBSIR 73–320. Bibliography of the Electromagnetics D sion June 30, 1972 to June 30, 1973, M. L. Woolley, pages (June 1973). Order from NTIS as COM 73–119 [See 13801 for abstract.]

NBSIR 73–322. Forced Convection Heat Transfer to S critical Helium I, P. J. Giarrantano, R. C. Hess, M. Jones, 45 pages (May 1973). Order from NTIS as 766–221. [See 13666 for abstract.]

NBSIR 73–326. Wavelength of a Slotted Rectangular L Containing Two Dielectrics, H. E. Bussey, 17 pages (J 1973). Order from NTIS as COM 73–11465. [See 13 for abstract.]

NBSIR 73-329. **Theory of adjoint reciprocity for electroacou transducers,** A. D. Yaghjian, 78 pages (Feb. 1974). Order fr NTIS as COM 74-10608.

Key words: adjoint operators; electroacoustic transduce reciprocity; scattering matrices.

Analytical techniques for the measurement of the exter characteristics of electroacoustic transducers have b developed by D. M. Kerns using a plane-wave scattering-mat (PWSM) formulation. Foldy and Primakoff, in their clas papers on linear electroacoustic transducers, utilize a spatial pedance-matrix (SIM) formulation. Both formulations involv continuous, linear "matrix" transformation in which reciproc is defined as a relationship between elements of the matrix.

The first portion of the present report demonstrates tha transducer satisfying the "SIM relations" also satisfies "PWSM equations" (but that the converse theorem does hold), and that the alternate expressions of reciprocity equivalent for transducers that obey both formulations.

The second portion of the report examines the equati which characterize the internal behavior of a large class of el troacoustic transducers. A linear operator approach is emplo to develop a generalized reciprocity lemma which is used establish adjoint reciprocity relations between the fields o given transducer and its adjoint transducers. The linear opera approach facilitates the identification of self-adjoint (reciprc or catireciprocal) transducers, and the adjoint reciprocity r

ons have utility in the extrapolation techniques of the PWSM ormulation. An adjoint "reciprocity theorem" and "principle of eciprocity" are derived from the generalized reciprocity relaons. Finally it is shown that the total power inputs for the adoint transducers belong to the same "value class" as the original ransducer.

BSIR 73-330. **Frequency domain measurement of baseband instrumentation,** N. S. Nahman and R. M. Jickling, 68 pages (July 1973). Order from NTIS as COM 74-10609.

Key words: bandwidth; diode; impedance; sampling; slotted line.

Microwave measurement techniques were developed for haracterizing the wideband feed-through sampling heads asociated with time domain sampling oscilloscopes and frequency omain network analyzers. Such characterization or modeling is ecessary for the removal of the oscilloscope distortion from the bserved waveform to yield the input waveform; also, it is useful or extrapolation in estimating oscilloscope performance at igher frequencies.

The techniques were developed through measurements on a ampling oscilloscope having a 28 picosecond transition time (10 o 90%) and a 12.4 GHz baseband bandwidth. The major results f the work are the development of voltage and impedance meaurement techniques which provide the means for determining he sampling-head equivalent circuit parameters. The techniques re based upon slotted-line measurements and are not inherently mited to any particular frequency range. Experimental results ere obtained for the sampling-head input impedance over the 7-2 GHz frequency range, and for the 10 GHz sampling loop imedance (vs. sampling-diode bias current).

BSIR 73-331. **Refrigeration of superconducting rotating machinery,** V. D. Arp, 75 pages (June 1973). Order from NTIS as COM 74-10238.

Key words: equation of state; helium; hydrodynamics; near-critical flow; refrigeration; superconductors; thermodynamics.

Recent work at the NBS Cryogenics Division in three areas elated to helium refrigeration is summarized: (1) Analysis is iven of a possible high pressure refrigeration cycle which offers n principle a reduced component size, but which turns out to be mpractical because of expansion engine inefficiencies. (2) Exact quations for flow of a real fluid are derived and applied to roblems of fluid flow near the critical point, as may occur with ome helium-cooled superconducting systems, and (3) Three ew equations of state for helium are given, each using different tate variables, to eliminate the need for iterative techniques in elium refrigeration cycle and fluid flow analysis.

NBSIR 73-335. **Calibration of radio receivers to measure broadband interference,** E. B. Larsen, 75 pages (Sept. 1973). Order from NTIS as COM 74-11051.

Key words: broadband interference; field strength meter; impulse standards; receiver bandwidth calibration; spectral intensity.

This report covers one phase of a project to improve the accuracy for calibrating field-strength to measure broadband signals, especially impulse interference. The amplitude of a narrowband signal is commonly expressed in μV, and a broadband signal is expressed in μV/MHz bandwidth. A future report (2nd phase) will deal with standards and techniques for producing a known impulse field to calibrate an antenna-receiver system in μV/(m · MHz). The technique used for initial calibration of a receiver as an RF voltmeter is new, employing a special L-pad with 48 Ω input resistor and 2 Ω output resistor across the receiver. The input power across 50 Ω is leveled, producing a low-impedance, constant-voltage source at the receiver input terminal.

Broadband interference is generally divided into two types: (a) random noise is best characterized by its power spectral density, and (b) impulse interference (uniform periodic pulses) is best quantified by its impulse strength. Several possible approaches were evaluated for defining and measuring various bandwidths of a receiver. The response of a receiver to impulses, as measured with a peak-reading detector, is proportional to the product of receiver impulse bandwidth and signal impulse strength. Of the two types of impulse sources evaluated here (pulsed DC and pulsed RF), the latter appears to be the most accurate and repeatable. We were able to produce a clean RF pulse, choosing an effective duration of 0.1 μs in our experiments, which covered a frequency range of 100 to 1000 MHz. The worst-case uncertainty of this standard source for calibrating receiver impulse bandwidth is $\pm$0.7 dB.

NBSIR 73–338. Calculated Liquid Phase Thermodynamic Properties and Liquid-Vapor Equilibria for Fluorine-Oxygen (FLOX) Mixtures, W. R. Parrish and M. J. Hiza, 28 pages (September 1973). Order from NTIS as COM 73–11660. [See 13803 for abstract.]

NBSIR 73-339. **Preliminary hydrogen freezing studies,** D. E. Daney, W. G. Steward, and R. O. Voth, 281 pages (Oct. 1973). Order from NTIS as COM 73-11985/1GA.

Key words: freezing rates; solid hydrogen; thawing; thermal conductivity.

The study summarized in this report is aimed at developing the technology required to fill space vehicle propellant tanks with solid hydrogen by in-place freezing. Planned continuation of this work was terminated with the loss of NERVA funding by the NASA. Therefore, progress to-date is summarized but substantial experimental results have not yet been obtained.

The program was to have been carried out in two phases: a mathematical analysis and experimental verification of the analysis. Freezing times and heat flux have been calculated for four geometrical shapes, and a range of sizes, refrigerant temperatures, ortho-para concentrations, and heat transfer coefficients. The results of these calculations are presented in generalized graphical form, in a total of 240 graphs.

The freezing experimental apparatus has been built and a preliminary test performed which generally demonstrates the validity of the analytical and experimental approaches. With only minor modifications the apparatus is ready for a full test program of hydrogen freezing and melting techniques.

NBSIR 73-341. **Test results for the Mooring Line Data Line,** D. A. Ellerbruch, 46 pages (Oct. 1973). Order from NTIS as COM 74-10885.

Key words: characteristic impedance; coupler; current; impedance, input impedance; Mooring Line Data Line; propagation characteristics; transmission line.

Results obtained from the Mooring-Line-Data-Line (MLDL) measurements program are presented. Frequency and time domain measurements are made to determine characteristics impedance, input impedance, current, and propagation parameters. Most of the measurements were made with an MLDL deployed specifically for this program; however, some were made on an MLDL deployed buoy.

NBSIR 73-342. **The thermophysical properties of methane, from 90 to 500 K at pressures to 700 bar,** R. D. Goodwin, 279 pages (Oct. 1973). Order from NTIS as COM 73-11978/1AS.

Key words: densities; enthalpies; entropies; equation of state; internal energies; isobars; isochores; isotherms;

Joule-Thomson inversion; latent heats of vaporization; melting line; orthobaric densities; PVT data; specific heats; speeds of sound; vapor pressures.

Thermophysical properties of methane are tabulated at uniform temperatures from 90.68 to 500 K along isobars to 700 bar. A novel equation of state is employed for the first time, having origin on the vapor-liquid coexistence boundary. Computations are based almost entirely on ideal gas specific heats and experimental P-ρ-T data via the equation of state, without weighting to data for derived properties. Good agreement with such data confirms validity of the equation and method. New P-ρ-T data are reported at 0.3 to 1.7 times the critical density.

NBSIR 73-343. **Calibration of impulse noise generators,** G. R. Reeve, 77 pages (Oct. 1973). Order from NTIS as COM 75-10282.

Key words: impulse; impulse generator calibration; impulse noise; impulse noise generator.

This report covers work performed by the Electromagnetics Division, Institute for Basic Standards, National Bureau of Standards, on a Signal Corps contract to develop a calibration system for impulse noise generators. Various technical approaches are discussed with their respective problems. A prototype system which was constructed is presented along with some measurements of its capability. Finally another approach is suggested utilizing newer techniques and instrumentation which should come closer to achieving the desired level of performance.

NBSIR 73-344. **Heat transfer and mixing of slush hydrogen,** C. F. Sindt and P. R. Ludtke, 40 pages (Nov. 1973). Order from NTIS as COM 74-10749.

Key words: heat transfer; liquid hydrogen; mixing; mixing power; paddle mixers; slush hydrogen; turbine mixers.

Heat transfer to slush hydrogen and mixing were investigated in a 1 m^3 cylindrical vessel. The effects of heat transfer rates on thermal stratification and on self-pressurization were measured. Temperature profiles in thermal stratification were found to be more dependent on slush level and slush settling rates than on liquid level. Solids in the slush appear to be involved in the heat transfer mechanism as slush level affected the amount of warm liquid reaching the top of the dewar and therefore affected the self-pressurization rates.

Mixing effectiveness and power requirements to mix slush hydrogen were determined for two configurations of turbine mixers and one paddle mixer. Mixing power requirements were found to be sensitive to the mixer location and configuration.

NBSIR 73-345. **Combustion of metals in oxygen phase II: Bulk burning experiments,** A. H. Tench, H. M. Roder, and A. F. Clark, 49 pages (Dec. 1973). Order from NTIS as COM 74-10239.

Key words: alloys; aluminum; combustion; ignition; oxygen; safety; stainless steel; steel, titanium.

This program was started to study combustion of the ordinary metals in oxygen, to provide information useful to designers of bulk oxygen handling equipment, particularly from the point of view of safety. We have studied the ignitability and combustability of carbon steels, stainless steels, aluminum alloys, titanium and copper metals, in oxygen atmospheres up to 60 psig. We encountered a violent reaction involving burning stainless steel and aluminum, a thermite reaction apparently, and have investigated this from a quantitative point of view. We have tried throughout to study the quantitative aspects of the combustion processes, and related quenching effects. Ordinary steel and stainless steel burn quite readily at these low oxygen pressures, and the stainless steel-aluminum reaction produces intense heat, with severe damage to neighboring structures. We are at the stage where further investigations could be carried out quite expeditiously and on a sound statistical basis.

NBSIR 73-346. **RF total mass gauging in large storage containers Empty tank modes,** R. S. Collier and D. Ellerbruch, 28 pages (Oct. 1973). Order from NTIS as COM 74-10240.

Key words: LOX storage container; radio frequency; total mass gauging.

This report describes experiments to determine the feasibility of radio frequency (RF) mass gauging for fluids stored in large containers. The experiments were done at the NASA Mississippi Test Facility using the 460,000 gallon LOX Storage Tank as an electromagnetic resonant cavity. The results show that the RF gauging technique is feasible for large containers.

NBSIR 73-347. **Active and passive mode locking of continuous operating rhodamine 6G dye lasers,** A. Scavennec and N. Nahman, 54 pages (Feb. 1974). Order from NTIS as COM 74-10674.

Key words: DODCI; dye laser; laser; mode-locked picosecond; rhodamine 6G.

Using confined and unconfined fluid flow dye cells with suitable mode locking methods continuously operating rhodamine 6G dye lasers have been built to produce narrow pulses (less than 4 ps) at about a 140 MHz pulse repetition rate. For active (acoustic) amplitude modulation mode locking methods optical pulses were obtained having about a 32 ps pulse width (FWHM). For passive mode locking methods optical pulses of ≤ 35 ps pulse width (FWHM) were obtained.

A three mirror cavity was used for the active mode locking studies while three and five mirror cavities were used in the passive studies. The three mirror passive mode locked laser employed a single dye cell containing both the rhodamine 6G (gain) and DODCI (loss) solutes in a single solution having glycol as the solvent. The active and passive mode locked carrier wavelengths were about 5900 Å and 5800 Å, respectively.

NBSIR 73-348. **An engineering feasibility study for one-way time transfer using the GOES satellite ranging system,** J. B. Milton and W. F. Hamilton, 38 pages (Dec. 1973). Order from NTIS as COM 74-10241.

Key words: clock synchronization; one-way time transfer; satellite timing; synchronous satellite.

The Time and Frequency Division of the National Bureau of Standards has conducted an engineering study to determine the feasibility of using the GOES satellite ranging system for precise (0.1 microsecond, one-sigma) time transfer to a receiving-only timing site. The GOES satellite ranging system, termed a trilateration system, will accurately locate this satellite within some coordinate structure. The sources of time transfer errors have been studied in some detail. These errors can be caused by satellite location errors, ground station location errors, unknown delays caused by the troposphere, the ionosphere, and the various equipments. Simplified designs for an automatic and a manually operated timing site are presented. Some technical problems found in the associated equipment are discussed. The study indicates that a secondary, or slave site, clock could be synchronized to within 0.1 microsecond; one-sigma, of some master clock utilizing a one-way, or receiving-only system.

NBSIR 73-349. **Characterization of a superconducting coil composite,** C. W. Fowlkes, P. E. Angerhofer, R. N. Newton, and A. F. Clark, 51 pages (Dec. 1973). Order from NTIS as COM 74-10241.

Key words: composite; low temperature; Poisson's ratio; superconductor; thermal expansion; Young's modulus.

The superconducting coil composite material being utilized by Annapolis Laboratory of the Naval Ship Research and velopment Center is characterized by its mechanical and ther- l properties. The Young's moduli, Poisson's ratios, and ther- l contractions are measured from room temperature to 4K and orted in this interim report. A micromechanical analysis ed upon volume fractions of constituents is used to predict m-temperature properties, and a comparison is made to the asured values.

SIR 73-351. **Thermal conductivity standard reference materials from 6 to 280 K: VI. NBS sintered tungsten,** J. G. Hust, 58 ages (Jan. 1974). Order from NTIS as AD 775367.

Key words: cryogenics; electrical resistivity; Lorenz ratio; Seebeck effect; standard reference material; thermal conductivity; transport properties; tungsten.

Thermal conductivity, electrical resistivity, Lorenz ratio, and rmopower data are reported for two specimens of NBS sin- ed tungsten for temperatures from 6 to 280 K. Variability of s tungsten was studied by means of electrical resistivity and idual resistivity measurements on 39 specimens. These data icate a material variability of about ± 10 percent in thermal nductivity at helium temperatures. Above 90 K variation in rmal conductivity is only about ± 1 percent. To reduce the un- tainty caused by specimen variation at low temperatures, aracterization by residual electrical resistivity data is scribed. By this procedure the low temperature uncertainty is duced to about ± 3 percent.

SIR 73-402. **NBS materials science and manufacturing in space research,** E. Passaglia and R. L. Parker, 127 pages (Nov. 1973). Order from NTIS as COM 74-10472.

Key words: materials processing; perfection; purity; space manufacturing; space processing; zero-g.

This report describes NBS work for NASA in support of ASA's Materials Science and Manufacturing in Space IS/MS) (now Space Processing) program, covering the period ovember 1, 1972 to October 31, 1973. The objectives of the BS program are to perform ground-based studies of those pects of space that could possibly provide a unique environ- nt for making materials more perfect or more pure. The ap- oach taken deals primarily with experimental and theoretical udies of the possible effects of the absence of gravitational rces on those materials preparation processes where the esence of gravity may be important in reducing perfection or rity. The materials preparation processes studied comprise 5 sks in the areas of crystal growth, purification and chemical ocessing, and the preparation of composites.

SIR 73-403. **Development and analysis of techniques for calibration of Kerr cell pulse-voltage measuring systems VII,** E. C. Cassidy, R. E. Hebner, R. J. Sojka, and M. Zahn, 129 pages (Nov. 1, 1973). Order from NTIS as COM 74-10016/5GA.

Key words: electric field measurement; electro-optic Kerr effect; high voltage measurement; impulse measurement; Kerr constant; liquid insulants; nitrobenzene; peak reading voltmeter; space charge.

To improve the accuracy of pulse voltage systems using the ectro-optic Kerr effect, it is necessary to improve the accuracy calibration of Kerr cells. In the past this has been attempted calibrating the cell under direct voltage and relying on the equency independence of the Kerr coefficient (below 10^8 Hz) insure that the calibration was valid under high voltage pulses. ace charge effects, however, modify the electric field distribu- n in the liquid under direct high voltage. The electric field and ace charge behavior in nitrobenzene have therefore been docu- ented as functions of the level and frequency of the applied oltage. In addition, to improve the efficiency of cell design and to facilitate the investigation of other liquids for use in Kerr cells, the electro-optic Kerr coefficient of nitrobenzene has been measured as a function of temperature and wavelength. Finally a new peak reading voltmeter based on the Kerr effect is described and the results of using the electro-optic Kerr effect to measure the voltage pulses in medical x-ray machines are presented.

NBSIR 73-404. **Mass transport and physical properties of large crystals of calcium apatites: Studies of $Ca(OH)_2$ crystals for use in electrolytic conversion of calcium fluorapatite crystals to calcium hydroxyapatite,** A. D. Franklin and K. F. Young, 37 pages (Sept. 1, 1972-Aug. 31, 1973). Order from NTIS as PB 203952.

Key words: ac impedance; calcium apatites; calcium hydroxide; crystal growth; electrolysis; interfacial polarization; ionic conduction; mass transport.

In order to convert single crystals of calcium fluorapatite to calcium hydroxyapatite, an electrolytic cell technique will be explored. To utilize such a technique, the cathode compartment must consist of a source of hydroxyl ions and a barrier to the flow of all others. Examination of the literature on metallic hydroxides suggests that a suitable cathode might be composed of an oriented $Me(OH)_2$ crystal, where Me is Mg, Ca, Sr, or Ba, backed up by a Pt electrode in an atmosphere containing H_2O and O_2. $Ca(OH)_2$ crystals have been grown from aqueous solution, and Pt electrodes evaporated onto them. An apparatus has been built to study their ac admittance as a function of temperature and atmosphere, and measurements begun. A computer program for handling the complex admittance data has been devised and tested.

NBSIR 73-405. **Use of organic coatings on the interior surfaces of equestrian statues at Memorial Bridge Plaza,** F. Ogburn, 9 pages (Nov. 1973). Order from NTIS as COM 74-10131.

Key words: bronze statuary; organic coatings; restoration; statues.

The equestrian statues at Memorial Bridge Plaza in the District of Columbia are bronze castings. The exterior finish is subject to corrosion processes associated with pores and cracks in the castings. The interior surfaces are subjected to high humidity and condensation. Detrimental corrosion is expected only at discontinuities in the plated coatings on the exterior surfaces. Painting of interior surfaces has been recommended, but the need for painting is not clear. The NCP is advised to keep the statues under close observation till the fall of 1974 and then reconsider their course of action.

NBSIR 73-406. **Reference materials for the determination of trace elements in biological fluids,** P. D. LaFleur, 22 pages (Dec. 1973). Order from NTIS as COM 74-11352.

Key words: arsenic; biological fluids; chromium; copper; fluorine; lead; nickel; reference materials; selenium; trace elements; urine.

The preparation of a number of reference materials for the analysis of trace elements in biological standards is described. The standards produced include mercury in urine at three concentration levels, five elements [Se, Cu, As, Ni, Cr] in freeze-dried urine at two levels, fluorine in freeze-dried urine at two levels, and lead in whole blood at two concentration levels. These reference materials have been analyzed for the element(s) of interest by one or more analytical techniques, and are supplied with known concentration levels.

NBSIR 73-407. **Report on a pre-test of a survey plan for estimating incidence of lead based paint,** L. S. Joel and H. W. Berger, 86 pages (Dec. 1973). Order from NTIS as COM 74-11078.

Key words: lead; lead paint poisoning; paints; poisoning; retail inventory; statistics; survey.

Lead in paint has been indicted as a major cause of lead poisoning of children. Federal regulations have been established to limit the amount of lead which may be added to paints that are intended for residential use. The intent of such a limitation is to curtail the incidence of present and future lead based paint poisoning of children.

This report presents the results of a "pre-test" for a nationwide survey plan that would be used to determine the availability, to the public, of paints that may contain lead compounds in hazardous quantities. Statistical summaries of the chemical analysis of 250 paints purchased by random selection at five retail outlets, are presented along with comments regarding the possible implications of those results. Recommendations are made about survey action beyond the pre-test described herein.

NBSIR 73-412. **The incidence of hazardous material accidents during transportation and storage,** W. A. Steele, D. Bowser, and R. E. Chapman, 40 pages (Nov. 1973). Order from NTIS as COM 74-10512.

Key words: accidents; hazardous material; storage of hazardous material; transportation of hazardous material.

This report is one of a series describing background research concerning the incidence of abnormal loading. The report is organized in terms of modes of hazardous material transportation and storage. These modes—pipeline, water, motor vehicle, and railroad transportation systems—are addressed in four sections with Storage Systems discussed in a fifth. The sections depend on the amount of available data, rather than the risk involved in an accident. A summary of the results is presented in the last section. On the whole, there is little empirical evidence to substantiate a threat to buildings from hazardous materials transport. However, trends in volumes shipped in proximity to structures of interest raises the prospect of future incidents.

NBSIR 73-413. **Measurement of depth-dose distributions in carbon, aluminum, polyethylene, and polystyrene for 10-MeV incident electrons,** J. C. Humphreys, S. E. Chappell, W. L. McLaughlin, and R. D. Jarrett, 54 pages (Nov. 1973). Order from NTIS as COM 74-10750.

Key words: aluminum; carbon; depth dose; depth-dose distributions; dye-film dosimeters; polyethylene; polystyrene; radiochromic dyes; 10-MeV electrons.

Depth-dose distributions of 10-MeV electrons incident on homogeneous media of carbon, aluminum, polyethylene, and polystyrene have been measured using thin radiochromic dye-film dosimeters. Two types of dye-film dosimeters were employed as "cavities" within the media in two different geometrical configurations. One configuration was a stack with the dosimeters interleaved between disks of the medium and placed perpendicular to the incident electron beam direction. The other configuration was a wedge assembly with a single piece of dye film placed between pieces of the medium at a small angle to the beam direction. The results show no significant difference between dosimeter type or experimental arrangement. In addition, good agreement is shown in comparisons of experimental and Monte Carlo calculated depth-dose distributions characterized by such parameters as extrapolated range, depth of peak dose, and ratio of peak to entrance dose.

NBSIR 73-414. **Building and evaluation of a polluted air delivery system,** G. P. Baumgarten and F. W. Ruegg, 36 pages (Apr. 1974). Order from NTIS as COM 74-10866.

Key words: air pollution; critical flow; laminar flow; nozzle; porous plug; sulfur dioxide concentration.

The building and evaluation of a prototype SO_2 polluted air delivery system (PADS) is discussed. The delivery system was built to deliver sulfur dioxide (SO_2) in air at a rate of 5 liters per minute with design concentrations by volume of 1.0, 0.1 and 0. parts per million. It consists of a diluent air delivery syst utilizing a critical flow sonic nozzle and three separate conc trated SO_2 in air flow systems utilizing laminar flow por plugs, one plug for each desired output concentration. T delivery system is contained in a dispatch case and the two ga are delivered to it from pressurized containers through detac ble supply lines. Prospective use by unskilled technicians c tated simplicity and durability and compactness.

By maintaining specific upstream pressures on the critical fl nozzle and the laminar flow porous plugs of 45 and 12 p respectively, the prototype PADS produced average output c centrations of 0.76, 0.100 and 0.003 parts per million of SO_2 air based on concentration measurements with an N calibrated analyzer. The expected output concentrations w 0.98, 0.105 and 0.010 respectively, based on flow calibration the individual components. The uncertainty of the output c centration is estimated to be about ± 10 percent.

NBSIR 73-415. **Noble metal constitution diagrams: Part II,** R. Waterstrat and R. C. Manuszewski, 170 pages (Aug. 197 Order from NTIS as COM 75-11448.

Key words: alloy phases; constitution diagrams; no metals; phase diagrams; phase equilibria; platinum gr metals.

Six binary constitution diagrams involving the noble me are presented. These diagrams include the V-Ru, V-Rh, Nb- Nb-Pd, Nb-Pt and Ta-Pd alloy systems.

Experimental alloys were prepared from starting materi having a nominal purity of at least 99.9 percent and precauti were taken to insure that no significant contamination was troduced during alloy preparation and heat-treatment. Tempe tures were measured to an accuracy within ± 20 °C.

NBSIR 73-416. **Report on meeting of ISO/TC 6/SC 5 test methods and quality specifications for pulp,** W. K. Wilson, J. Schulz, C. E. Brandon, and J. L. Borstelmann, 69 pages (N 16, 1973). Order from NTIS as COM 74-10511.

Key words: ISO recommendations; pulp; pulp, test methods; testing methods for pulp.

The ninth meeting of ISO/TC 6, Paper, SC 5, Test Methods for Pulp, was held in Madrid, Spain, November 2 1973. Over 30 delegates from 11 countries discussed meth for testing of pulp and, to some extent, paper. Methods w agreed upon for the determination of saleable mass of flash dri pulp, disintegration of pulp, laboratory beating of pulp, prepa tion of laboratory sheets, and measurement of ISO brightness pulp. It was agreed that ISO Recommendations for determi tion of saleable mass of pulp in lots, determination of dry mat content, and determination of trace metals in pulp should revised. Plans were made to continue studies of methods for determination of viscosity, aqueous extraction, dirt and shiv total sulphur content, saleable mass of unitized lots of pu statistical evaluation of number of sample bales, preparation laboratory sheets, and fiber classification and drainability.

NBSIR 73-417. **Evaluation of commercial integrating-type no exposure meters,** W. A. Leasure, Jr., R. L. Fisher, and M. Cadoff, 33 pages (Dec. 1973). Order from NTIS as COM 10477.

Key words: acoustics (sound); dosimeter; environmer acoustics; instrumentation; noise exposure; noise expos meters.

As a result of the promulgation of occupational noise expos regulations by the Federal government, there are a number commercial noise exposure meters on the market today that p vide a measure of noise integrated (with appropriate weighti

over a time interval. This report presents the results of an evaluation of such instruments by the National Bureau of Standards (under the sponsorship of the U.S. Environmental Protection Agency) as to their usefulness in monitoring compliance with occupational noise regulations as well as their applicability as instruments for use in achieving the broader goals of the EPA. Tests were designed and conducted to evaluate microphone and system response to sound of random incidence, frequency response, crest factor capability, accuracy of the exchange rate circuitry, performance of the noise exposure meter as a function of temperature, and the dependence of the device on battery voltage. The rationale of the test procedures utilized to evaluate overall system as well as specific performance attributes, details of the measurement techniques, and results obtained are discussed.

NBSIR 73-418. **Test methods for determining coaxial cable response to bending strain, bulk compression (hydrostatic pressure), axial strain, and torsional strain,** J. F. Mayo-Wells, S. Edelman, and J. Jacobs, 119 pages (July 1973). Order from NTIS as COM 74-11783.

Key words: cable; coaxial; mechanical; response; strain.

Test methods have been developed for measuring the response of specimen one-meter lengths of coaxial cables, considered as sensing elements, to four separate types of strain: bending strain, bulk compression, axial tension, and torsional strain. Measurements were made on commercially available coaxial cables made in the laboratory from insulated wire and wire braid. Cable dielectric materials investigated include tetrafluoroethylene (TFE), fluorinated ethylene propylene (FEP), cellular FEP, polyethylene, cellular polyethylene, and polyvinyl chloride. Data from the measurements are included in appendixes.

NBSIR 73-420. **Survey on metallic implant materials,** J. R. Parsons and A. W. Ruff, 55 pages (Dec. 1973). Order from NTIS as COM 74-11092.

Key words: biomaterials; corrosion; implant materials; mechanical properties; metals.

The application of metallic materials as orthopedic implants in the human body is reviewed, concentrating on materials presently in clinical use and undergoing laboratory evaluation for possible future use. The criteria considered explicitly are tissue compatibility, mechanical properties, corrosion resistance, and toxicity. The three principal metallic implant materials, stainless steel, cobalt alloys, and titanium, are discussed in detail. Wherever possible, comparisons are made between the materials in terms of the intended application.

NBSIR 73-421. **An overview of the factors impacting metrication of the U.S. housing industry,** R. G. Hendrickson and D. W. Corrigan, 35 pages (Dec. 1973). Order from NTIS as COM 74-11224.

Key words: codes; construction conference; domestic housing, U.S.; foreign metrication; levels of conversion; metrication; problems of metrication.

This report describes the work undertaken by the National Bureau of Standards for the Department of Housing and Urban Development to ascertain and delineate major problems associated with the metrication of the domestic housing industry of the United States. Source material for the study included, principally, the foreign experiences of Great Britain and Australia; information obtained from interviews with businesses and associations; depositions provided to the 1970 Construction Conference, held for the purposes of the U.S. Metric Study; and documents, both foreign and domestic, pertaining to aspects of metrication.

The results of the study indicate the critical impact of metrication will be the redefinition or accommodation of the 15,000 codes at the local level, and the coordination of the 127 standard-setting organizations in the United States to define, develop and implement standards consonant with requirements and desired industry goals.

NBSIR 73-422. **A study of air traffic data requirements and sources for FAA analyses,** W. F. Druckenbrod, J. F. Gilsinn, R. H. F. Jackson, L. S. Joel, and T. K. Ming, 51 pages (May 1974). Order from NTIS as COM 74-11240.

Key words: air traffic analyses; air traffic data; standard reference air traffic data; users of air traffic data.

This report describes activities undertaken to assess the practicability of establishing a single file or a set of files of standard reference air traffic data samples. These files would serve as a common data base for ongoing and anticipated future forecast and analytical investigations relevant to the accommodation of air traffic in the National Airspace System.

The study entailed surveys of past and present air traffic data collection activities, of existing data files, and of all identifiable users of air traffic data within the FAA, as well as FAA contractors whose work requires air traffic data.

The information resulting from these surveys has been evaluated and aggregated to identify data which will satisfy most of the requirements expressed by the data users. Two data sets are specified for terminal area requirements, two sets for enroute requirements, and one set for oceanic requirements. These data sets will satisfy most input requirements for all anticipated analysis efforts. However, depending on the type of study, supplemental information, which is identified in various parts of this report, will be required in some cases.

NBSIR 73-423. **Guidelines for the use of computer technology in the developing countries,** R. A. Simmons, 172 pages (Dec. 1973). Order from NTIS as COM 74-11722.

Key words: computer education and training; computer technology; less-developed countries; technology transfer; U.S. foreign assistance.

The objective of this report is to contribute to more effective use of computer technology by the developing countries. An intensive survey of computer use and development in nine selected countries and an analysis of other supporting data have resulted in the formulation of specific conclusions. Recommendations for guidance of responsible officials in the developing countries and in the Agency for International Development have been developed in response to the conclusions and are presented in summary form. Later sections of the report include the facts and discussions in support of the conclusions, with emphasis on the responsibilities of the national governments, the problems of education and training, present computer applications, and the role of ADP standards. The results of the individual country surveys are included in the appendix. The report is a part of joint efforts on the part of the Department of Commerce and the Agency for International Development to bring U.S. high technology more effectively to bear on the problems of economic and social development in the less-developed countries of the world.

NBSIR 73-424. **A study of young children's pull-apart strength (an addendum to NBSIR 73-156—a study of the strength capabilities of children ages two through six),** W. C. Brown, C. J. Buchanan, and J. Mandel, 17 pages (Apr. 1974). Order from NTIS as COM 74-10867.

Key words: children; children's strength; pull-apart; safety; strength; test methods; toys; toy safety.

The Child Pull-Apart Strength Study was conducted to provide information which can be used to develop reliable and realistic standards and test methods for children's toys. The study was conducted with over 500 children in the Washington Metropolitan area, and included both black and white children from varying economic and social backgrounds.

The pull-apart test device used is a prototype model designed and constructed at the National Bureau of Standards. This test device was designed to measure the force that children can exert when pulling an object apart.

The results of the pull-apart strength study are consistent with those obtained in the previous child strength study which dealt with twisting, pulling, pushing, and squeezing (NBSIR 73-156). The study provided quantitatively precise and useful information about the effects of age and sex on the pull-apart strength capability of children ages two through six. The results are exhibited in tables of averages, standard deviations, coefficients of variation, and 95th and 5th percentiles.

NBSIR 74-355. **Carbon thin film thermometry,** R. S. Collier, L. L. Sparks, and T. R. Strobridge, 65 pages (Oct. 1973). Order from NTIS as N74-30195.

Key words: calibration; carbon films; low temperature; thermometry; vacuum deposition.

This is a summary of work done on NASA(Marshall Space Flight Center) purchase order H-92167A concerning Carbon Thin Film Thermometry. Optimum film deposition parameters were sought on an empirical basis for maximum stability of the films. One hundred films were fabricated for use at the Marshall Space Flight Center; 10 of these films were given a precise quasi-continuous calibration of temperature vs. resistance with 22 intervals between 5 and 80 K using primary platinum and germanium thermometers. Sensitivity curves were established and the remaining 90 films were given a three point calibration and fitted to the established sensitivity curves. Hydrogen gas-liquid discrimination set points are given for each film.

NBSIR 74-357. **A modified Benedict-Webb-Rubin equation of state for parahydrogen,** R. D. McCarty, 74 pages (Feb. 1974). Order from NTIS as COM 74-10551.

Key words: critical point; equation of state; hydrogen; index of refraction; PVT; saturation properties; scaling laws.

A 32 term modified Benedict-Webb-Rubin equation of state has been applied to data for parahydrogen. The adjustable parameters in the equation of state were determined using data from the triple point to 2500 K, with pressures to 680 atmospheres. Extensive modifications have been made to the previously accepted PVT surface for the saturated liquid and vapor phases in the near critical region. These modifications have been made on the basis of subsequent refractive index data and the application of scaling law equations. Comparisons between experimental and calculated data are given.

NBSIR 74-359. **Semi-annual report on materials research in support of superconducting machinery,** L. L. Sparks, F. R. Fickett, J. G. Hust, P. J. Giarratano, H. M. Ledbetter, E. R. Naimon, W. F. Weston, M. B. Kasen, R. L. Tobler, R. P. Mikesell, R. L. Durcholz, C. W. Fowlkes, and R. P. Reed, 313 pages (Mar. 1974). Order from NTIS as AD 780596.

Key words: composites; fracture; liquid helium; mechanical properties; structural materials; superconducting machinery; thermal conductivity.

Results of six months research are reported to the sponsor, the Advanced Research Projects Agency of the Department of Defense. Subjects include magneto-thermal conductivity, thermal conductivity, composites, elastic properties, fracture toughness, fatigue, and tensile. All measurements include the temperature range 4 to 300 K. Materials examined are those either presently being used in superconducting machinery or considered for use in future prototypes. Material classes include stainless steels, inconels, titanium alloys, and composites.

Special results include: the thermal conductivity in a magnetic field is considerably lower than would be predicted; a comprehensive review of glass-reinforced composite behavior at low temperatures is included; the elastic moduli of 12 engineering alloys from 4 to 300 K are reported; and fracture toughness and fatigue crack growth rate data on AISI 304, AISI 316, A286, Ti-5Al-4V and Ti-6Al-2.5 Sn at 4, 76 and 300 K have been measured.

NBSIR 74-361. **Electromagnetic interference measurements at ASA, Fort Huachuca, Arizona,** H. E. Taggart and J. W. Adams, 72 pages (Dec. 1973). Order from NTIS as COM 74-11222.

Key words: APD; field strength; interference; power lines.

This report describes the work performed for the U.S. Army Security Agency Test and Evaluation Center (USASATEC), Fort Huachuca, Ariz. during the period from April 1973 to November 1973. The purpose of the project was to measure, analyze, and evaluate the electromagnetic environment at selected sites and to recommend methods of reducing the present levels of electromagnetic interference (EMI). The chief sources of EMI were the power lines in the area and sferics from thunderstorms. Both broadband EMI measurements and amplitude probability distribution measurements were made. Both electric and magnetic fields were measured. The frequency range covered was 15 kHz to 10 GHz. Measurements were made at three locations: 1) at Fort Huachuca USASATEC; 2) Willcox Dry Lake; and 3) Boulder, Colo. The report contains the test results, conclusions, and recommendations.

NBSIR 74-363. **Heat transfer in pulsed superconducting magnets,** V. Arp, P. J. Giarratano, R. C. Hess, and M. C. Jones, 137 pages (Jan. 1974). Order from NTIS as COM 74-11053.

Key words: forced convection heat transfer; pulsed power systems; pulsed superconducting magnets; superconductor losses; supercritical helium; transient heat transfer.

The first section of this report summarizes design problems for the development of advanced superconducting pulse magnets leading to recommendations for future work, primarily in (1) evaluation of eddy-current, hysteresis, and frictional losses, and (2) transient heat transfer between the superconductor and the helium. Two subsequent sections report measurements of forced convection heat transfer respectively to subcooled liquid helium and to supercritical helium just above the critical pressure.

NBSIR 74-364. **Detection of human intruders by low frequency sonic interferometric techniques,** R. E. Stoltenberg, 94 pages (May 1974). Order from NTIS as COM 74-11208.

Key words: human detector; interferometric technique; low frequency acoustics.

This report examines the theory and evaluates the results of over 200 tests of the use of low frequency sonic interference techniques for the detection of a human intruder in a confined area. The conclusions are that this technique is potentially a significant improvement over conventional methods with regard to area coverage and minimum velocity detection.

This work examined the intruder signature and background noise with respect to sonification frequency, source levels, intruder size, intruder velocity, source types, area coverage (to 692 sq. meters), and geometric position of the source and receiver in four radically different areas.

Interference effects of the intruder signature and noise were nalyzed with respect to bandwidth, spectral content, and magitude by both computer drawn spectral displays, and specific requency correlators.

NBSIR 74-365. **Impulse spectral intensity—what is it?,** M. G. Arthur, 25 pages (May 1974). Order from NTIS as COM 74-11375.

Key words: electromagnetic interference; Fourier transform; impulse spectral intensity; spectral intensity; spectrum amplitude; spectrum amplitude density.

The term, impulse spectral intensity, is often used in discus ions concerning electromagnetic interference and broadband ignal processing. In these discussions, the term is not used in a onsistent manner, resulting in confusion, equivocation, and ometimes, errors. As a step towards improving this situation, he mathematical basis for spectral intensity is reviewed and cerain of its features are clarified. Also, misuses of spectral intensiy are discussed, along with its limitations and proper use.

NBSIR 74-366. **Study of cryogenic propellant systems for loading the space shuttle,** R. O. Voth, W. G. Steward, and W. J. Hall, 95 pages (Apr. 1974). Order from NTIS as COM 74-11076.

Key words: computer modeling; cooldown; cryogenic flow; stresses; surges; transient flow; water hammer.

Computer programs have been written to model the liquid oxgen loading system for the space shuttle. The programs allow election of input data through graphic displays which schematially depict the part of the system being modeled. The computed utput is also displayed in the form of graphs and printed nessages. Any one of six computation options may be selected. The first four of these pertain to thermal stresses, pressure urges, cooldown times, flow rates and pressures during cooldown. Options five and six deal with possible water hammer effects due to closing of valves, steady flow and transient response o changes in operating conditions after cooldown.

Procedures are given for operation of the graphic unit and ninicomputer.

NBSIR 74-369. **Surface magnetic field noise measurements at Geneva Mine,** J. W. Adams, W. D. Bensema, and N. C. Tomoeda, 40 pages (June 1974). Order from NTIS as COM 74-11688.

Key words: earth-ionosphere waveguide; electromagnetic noise; EMI measurement technique; sferic interference.

Measurements of surface magnetic field noise were made at arious locations over the Geneva Coal Mine near Price, Utah, n June 12, 1973. The locations selected were on the surface ver emergency locator beacons underground at depths between 50 meters (1150 ft.) and 488 meters (1600 ft.). The surface terain where these measurements were made was mountainous, nd access was difficult. There were no power lines within everal miles, and the weather was clear; therefore, the magnetic oise levels were about as low as will normally occur.

Results of measurements of distant sferics indicate rather harp cutoff frequencies below which broadband, impulsive oise is attenuated. The mechanism of propagation for this noise bove the daytime cutoff frequency of 3500 Hz and the ighttime cutoff frequency of 1700 Hz is deduced to be a vaveguide formed by the D or E layers of ionosphere as an pper plane and the earth as a lower plane.

The measurement systems used are similar to those used earlir. The technique is to record broadband, analog signals, digitize he data, and use a fast-Fourier transform to obtain spectral lots. This technique is novel in that it can measure simultaneusly all magnetic field energy within a limited portion of the spectrum for a limited time, and, after processing, reproduce the events occurring in that time interval in great detail.

NBSIR 74-371. **Broadband pulsed/CW calibration signal standard for field intensity meter (FIM) receivers,** P. A. Simpson, 53 pages (June 1974). Order from NTIS as COM 74-11567.

Key words: broadband signal generator; impulse bandwidth; receiver bandwidth calibration; rf burst generator; spectral intensity.

This report describes the constructional details and the operation of a system for calibrating microwave field intensity meter (FIM) receivers in the frequency range 1 to 12.4 GHz. The system uses known levels of CW power to calibrate the receiver, and short duration (~20 ns) rf bursts to measure the bandwidth. An error analysis of the system is given. Schematic drawings of various circuits in the system are provided along with charts and tables for facilitating computations encountered when performing calibrations.

NBSIR 74-372. **Cryogenic refrigerators for shipboard forward looking infrared applications,** R. O. Voth, 75 pages (June 1974). Order from NTIS as AD-A006037.

Key words: cryogenics; infrared detector; low capacity; reliability; shipboard; 77 K refrigerator.

The Naval Ordnance Laboratory (NOL) has asked the Cryogenics Division of the National Bureau of Standards to investigate and evaluate 1) commercially available refrigerators, 2) refrigerators under development, and 3) new or novel ideas applicable to a refrigerator to cool infrared detectors in a shipboard Forward Looking Infrared (FLIR) system. Although a refrigerator has been selected for two prototype FLIR units, the study was initiated to select the most appropriate refrigerator for additional purchases of FLIR units. The FLIR requires a refrigerator capacity of approximately 2 watts at 77 K and a physical configuration allowing for an interface to the FLIR unit. Information was collected by interviewing FLIR manufacturers, surveying refrigerator manufacturers and by contacting users of similar systems. Correlation of this information with the NOL requirements is presented herein. The primary difference between airborne spaceborne refrigerators and a shipborne refrigerator is the accessibility for minor repairs on-board ship although major repairs may be deferred for extended periods of time. It is anticipated that the shipboard units will operate away from major maintenance facilities, for periods as long as 6 months, with the refrigerator operating at least half of this time. Thus, reliability and ease of maintenance are emphasized when evaluating the various systems.

NBSIR 74-375. **Refrigeration for an 8 K to 14 K superconducting transmission line,** D. E. Daney, 60 pages (Oct. 1974). Order from NTIS as COM 74-11657.

Key words: Brayton cycle; refrigeration; superconducting transmission lines; superconductors.

The performance of three supercritical refrigeration cycles for cooling superconducting transmission lines has been investigated for the temperature range of 8 K to 14 K. This temperature range is applicable to the Stanford superconducting (Nb_3Sn) line. These cycles, which were selected as being the most practical, are the Brayton cycle with the expander before the load, the Brayton cycle with the expander after the load, and the Brayton cycle with a separate supercritical helium loop and circulating pump.

The results are presented as curves of Wc/Q (ratio of the work of compression to the refrigeration load) vs the transmission line exit pressure for various transmission line pressure and tempera-

ture drops. Contrary to popular belief, all three cycles are competitive. Maximum efficiencies (percent of Carnot) are about 25 percent.

Estimated capital and operating costs are presented as a function of transmission line temperature for several values of thermal load per length of line.

NBSIR 74-377. **Picosecond pulse generators using microminiature mercury switches,** J. R. Andrews, 44 pages (Mar. 1974). Order from NTIS as COM 74-11449.

Key words: mercury switch; picosecond; pulse generator; pulse measurement; superconductivity.

Pulse generators have been built using microminiature mercury switches. A commercial RF coaxial switch was also evaluated as a pulse generator. A superconducting delay line ($t_r = 18$ ps, $t_d = 70$ ns) and a sampling oscilloscope ($t_r = 22$ ps) were used to measure the generated pulse 10-90 percent transition time. The best result obtained was a transition time of 39 ps. Pulse amplitudes were independently adjustable up to 50 volts. The microminiature mercury switches in general were found to give very unreliable operation.

NBSIR 74-378. **Time and amplitude statistics for electromagnetic noise in mines,** M. Kanda, 59 pages. Order from NTIS as COM 74-11450.

Key words: Allan variance analysis; amplitude probability distribution; amplitude statistics; average crossing rate; electromagnetic interference; electromagnetic noise; impulsive noise; interpulse spacing distribution; magnetic field strength; man-made noise; pulse duration distribution; time statistics.

The time and amplitude statistics necessary to adequately describe electromagnetic (EM) noise in mines are illustrated through computer software techniques. They are 1) Allan Variance Analyses (AVA), 2) Interpulse Spacing Distributions (ISD), 3) Pulse Duration Distributions (PDD), 4) Average Crossing Rates (ACR), and 5) Amplitude Probability Distributions (APD). These statistics are illustrated using data taken from a rather large store of raw analog data recorded in operational mines.

The curves generated for the illustrations characterize the noise environment in the mines from which the corresponding data were taken, and should aid in the design of reliable communication systems for such mines.

NBSIR 74-379. **Completion of the program to evaluate/improve instrumentation and test methods for electroexplosive device safety qualification,** P. A. Hudson, D. G. Melquist, A. R. Ondrejka, and P. E. Werner, 37 pages (June 1974). Order from NTIS as PB247658.

Key words: electroexplosive device safety; electromagnetic compatibility; electromagnetic interference; stray energy sensor.

Qualification of weapon and missile systems for electroexplosive device (EED) safety has been a continuing problem in the military services. Quantitative measurement of stray energy in EED's has been hampered by limitations of existing sensors. This report describes a new video diode detector instrumented EED (VIDEED) which responds to both the normal pin-to-pin energy (which would heat an EED bridgewire) and to the pin-to-case voltage (which might cause EED ignition due to arcing).

Also described in this report are the amplifiers, cables, adapters and recorders which make up the rest of the measuring system. Mention is also made of the test procedures used in testing the VIDEED system.

NBSIR 74-380. **Planar near-field measurements on high performance array antennas,** A. C. Newell and M. L. Crawford, 100 pages (July 1974). Order from NTIS as COM 74-11686.

Key words: antennas; near-field measurements; phased arrays.

The results of measurements which apply the planar near-field measurement technique to phased array antennas are described. Fast and efficient tests are used to determine the required scan area and data point spacing. The use of these tests can reduce the amount of data required for some antennas without significantly increasing the errors in computed results.

Measurements were made at different distances from the antennas, with the probe transmitting and receiving, and for both sum and monopulse difference patterns. Comparisons between the far-field patterns computed from the near-field data and those measured on far-field ranges are presented.

NBSIR 74-381. **Electromagnetic attenuation properties of clay and gravel soils,** D. A. Ellerbruch, 24 pages (Aug. 1974). Order from NTIS as COM 75-10522.

Key words: attenuation; clay; gravel; measurements; microwave; skin depth.

The objective of this work was to establish the feasibility of using active microwave techniques to differentiate between the different subsurface layers in a pavement system. The electromagnetic attenuation properties of clay and gravel soils were measured as a function of moisture content and frequency. Measurements were done at frequencies in the 0.5-4.5 GHz range. Soil samples were compounded in the laboratory at approximately 10, 50 and 90 percent saturation. Sample thickness was in the range 2.5-20.3 cm. Each homogeneous sample was sealed in a polyethylene container to retain the total moisture and to maintain a constant moisture content with depth.

NBSIR 74-382. **A study of the measurement of G/T using Cassiopeia A,** D. F. Wait, W. C. Daywitt, M. Kanda, and C. K. S. Miller, 199 pages (June 1974). Order from NTIS as AD 783433.

Key words: accuracy; antenna; calibration; Cassiopeia A; G/T; star flux.

This report describes a study intended to estimate the best possible accuracy of measuring the ratio G/T (system gain to system noise temperature) of a satellite communication ground station using the radio star Cassiopeia A (Cas A). The concept of G/T and its measurement using a radio star is briefly discussed. Results of an extensive literature search are presented, summarizing the properties of Cas A and its vicinity described by radio astronomers in order to utilize this information to assess the accuracy of a G/T measurement. Consideration is given to atmospheric effects upon a G/T measurement using Cas A based on information available in the literature. A detailed analysis of errors for gain measurements of large ground antennas, which includes the calibration of a standard gain antenna and the transfer of the calibration of this standard to a large antenna, is provided to validate radio star flux data since this analysis is not available in the literature. The results of these efforts are utilized to show that the best possible accuracy of a G/T measurement for a ground station having a 60 ft. diameter antenna and both practical and reasonable specifications is in the neighborhood of ± 0.25 dB.

NBSIR 74-387. **Microwave measurement of coal layer thickness,** D. A. Ellerbruch and J. W. Adams, 33 pages (Sept. 1974). Order from NTIS as COM 74-11643.

Key words: automation; coal; coal mine safety; dielectric constant; energy; microwave measurement; nondestructive testing; thickness of coal layer.

The possibility of using a microwave system to measure coal layer thickness in a mine was investigated. Measurements were made in two different mines near Pittsburgh, Pa., and near Fairview, West Virginia. Frequencies in the range 0.5 GHz-4.0 GHz were used to measure samples between 10-40 cm thick. All samples were backed with a naturally-occurring draw slate.

The results indicated a definite possibility of determining layer thickness in most cases, although anomalies may introduce enough error to give misleading results in some cases. Anomaly detection may be very useful in some cases. More experimental data and theoretical study are needed for complete verification.

Data from a model and measured data show considerable agreement. The real value of this model is to point out causes and effects, and what additional information is needed in order to obtain a measurement system that is optimum under most conditions.

The dielectric constant of coal is apparently a function of moisture content. Draw slate seems to have a significantly higher dielectric constant than coal. Also, a layer of coal having different electrical characteristics within the layer was detected with the microwave system.

This technique has great potential if fully developed. It would have significant impact in areas of energy, safety, and productivity.

NBSIR 74-388. **Electromagnetic noise in Grace Mine,** J. W. Adams, W. D. Bensema, and M. Kanda, 138 pages (June 1974). Order from NTIS as COM 74-11687.

Key words: amplitude probability distribution; coal mine noise; digital data; electromagnetic interference; electromagnetic noise; electromagnetic pulse (chemical); emergency communications; Fast Fourier Transform; Gaussian distribution; impulsive noise; magnetic field strength; measurement instrumentation; spectral density; time-dependent spectral density.

Two different techniques were used to make measurements of the absolute value of electromagnetic noise in an operating hard-rock mine, Grace Mine, located near Morgantown, Pennsylvania. Diesel-powered haulage equipment is used in this mine, and the electromagnetic noise environment it creates was measured to see how it differs from the environment created by electric-powered haulage equipment. One technique measures noise over the entire electromagnetic spectrum of interest for brief time periods. It is recorded using broadband analog magnetic tape and the noise data is later transformed to give spectral plots. The other technique records noise amplitudes at several discrete frequencies for a sufficient amount of time to provide amplitude probability distributions.

The specific measured results are given in a number of spectral plots and amplitude probability distribution plots.

NBSIR 74-389. **Electromagnetic noise in McElroy Mine,** M. Kanda, J. W. Adams, and W. D. Bensema, 170 pages (June 1974). Order from NTIS as COM 74-11717.

Key words: amplitude probability distribution; coal mine noise; digital data; electromagnetic communications; electromagnetic interference; electromagnetic noise; Fast Fourier Transform; Gaussian distribution; impulsive noise; magnetic field strength; measurement instrumentation; spectral density; time-dependent spectral density.

Two different techniques were used to make measurements of the absolute value of electromagnetic noise in and above an operating coal mine, McElroy Mine, located near Moundsville, West Virginia. 300-volt-dc and 480-volt-ac machinery was measured to see the electromagnetic environment it created. One technique measures noise over the entire electromagnetic spectrum of interest for brief time periods. It is recorded using broadband analog magnetic tape and the noise data is later transformed to give spectral plots. The other technique records noise amplitudes at several discrete frequencies for a sufficient amount of time to provide amplitude probability distributions.

NBSIR 74-390. **Electromagnetic noise in Itmann Mine,** W. D. Bensema, M. Kanda, and J. W. Adams, 113 pages (June 1974). Order from NTIS as COM 74-11718.

Key words: amplitude probability distribution; coal mine noise, digital electromagnetic communications; electromagnetic interference; electromagnetic noise; Fast Fourier Transform; Gaussian distribution; impulsive noise; magnetic field strength; measurement instrumentation; spectral density; time-dependent spectral density.

Two different techniques were used to make measurements of the absolute value of electromagnetic noise in an operating coal mine, Itmann No. 3 Mine, located near Mullens, West Virginia. The electromagentic environment created by 250-volt-dc and 550- and 950-volt-ac machinery in two longwall panels was measured and is reported. One technique measures noise over the entire electromagnetic spectrum of interest for brief time periods. It is recorded using broadband analog magnetic tape, and the noise data is later transformed to give spectral plots. The other technique records noise amplitudes at several discrete frequencies for a sufficient amount of time to provide amplitude probability distributions.

The specific, measured results are given in a number of spectral plots and amplitude probability distribution plots.

NBSIR 74-391. **Electromagnetic noise in Lucky Friday Mine,** W. W. Scott, J. W. Adams, W. D. Bensema, and H. Dobroski, 139 pages (Oct. 1974). Order from NTIS as COM 74-10258.

Key words: amplitude probability distribution; digital data; electromagnetic interference; electromagnetic noise; emergency communications; Fast Fourier transform; Gaussian distribution; impulsive noise; magnetic field strength; measurement instrumentation; mine noise; spectral density; time-dependent spectral density.

Measurements of the absolute value of electromagnetic noise and attenuation along a hoist rope were made in an operating hard-rock mine, Lucky Friday Mine, located near Wallace, Idaho. Spectra of electromagnetic noise generated by various pieces of equipment, spectra of specific noise signals at various depths, and noise and attenuation on the 4250 foot (1295 meter) hoist, were measured. Three techniques were used to make the measurements. First, noise was measured over the entire electromagnetic spectrum of interest for brief time periods. Data were recorded using broadband analog magnetic tape for later transformation to spectral plots. Second, noise amplitudes were recorded at several discrete frequencies for a sufficient amount of time to provide data for amplitude probability distributions. A third technique gave attenuation data through the direct measurement of field strength at various depths.

The specific measured results are given in a number of spectral plots, amplitude probability distribution plots and amplitude curves as a function of depth

NBSIR 74-393. **Semi-annual report on materials research in support of superconducting machinery,** R. P. Reed, R. L. Durcholz, F. R. Fickett, P. J. Giarratano, J. G. Hust, M. B. Kasen, H. M. Ledbetter, R. P. Mikesell, E. R. Naimon, R. E. Schramm, L. L. Sparks, R. L. Tobler, and W. F. Weston, 283 pages (Oct. 1974). Order from NTIS as COM 75-10768.

Key words: composites; elastic properties; fracture; liquid helium; mechanical properties; structural materials; superconducting machinery; thermal conductivity.

Results of six months of study on Materials Research in Support of Superconducting Machinery (April through September, 1974) are reported to the sponsor, the Advanced Research Projects Agency of the U.S. Department of Defense. The report is divided into five sections: thermal conductivity, magnetothermal conductivity, fatigue and fracture-toughness properties, properties of advanced composites, and elastic properties. The temperature range 4 to 300 K is covered by the study. Materials studied are either being used or are candidates for use in superconducting machinery and include: aluminum alloys, composites, inconels, OFHC copper, stainless steels, and titanium alloys.

Special results of the study include: fracture-toughness and fatigue-crack growth-rate data for AISI 310, Ti-5 Al-2.5 Sn, A286 stainless steel, and Inconel 750 at 4, 76, and 300 K; initial reports of tensile testing of composites at 4 K; a second review paper on advanced-composite low-temperature behavior; magnetothermal conductivity measurements on OFHC copper and Inconel 718 indicate that, in a magnetic field, the thermal conductivity may change by 100 percent; anomalous low-temperature elastic behavior of AISI 300 series stainless-steel alloys; and thermal conductivity data for OFHC copper, Inconel 750, and Inco Low-Expansion-Alloy. These data provide considerable insight into material characteristics at extremely low temperatures, assisting in material selection and efficient design.

NBSIR 74-394. **A rack-mounted precision waveguide-below-cutoff attenuator with an absolute electronic readout,** C. C. Cook, 45 pages (Nov. 1974). Order from NTIS as COM 75-10126.

Key words: absolute (unambiguous) readout; piston; precision attenuator; sensor; waveguide-below-cutoff.

A coaxial precision waveguide-below-cutoff attenuator is described which utilizes an absolute (unambiguous) electronic digital readout of displacement in inches in addition to the usual gear-driven mechanical counter/dial readout in decibels. The attenuator is rack-mountable and has the input and output rf connectors in a fixed position. The attenuation rate for 55, 50, and 30 MHz operation is given along with a discussion of sources of errors. In addition, information is included to aid the user in making adjustments on the attenuator should it be damaged or disassembled for any reason.

NBSIR 74-395. **Bibliography of the Electromagnetics Division, June 30, 1973 to June 30, 1974,** M. L. Woolley, 26 pages (Nov. 1974). Order from NTIS as COM 75-10161.

Key words: antenna parameters; attenuation; automated measurements; EM Metrology; field strength; impedance; noise; phase; power; pulsed quantities; squids; transmission lines; waveform analysis; waveguides.

This bibliography lists the publications of the NBS Electromagnetics Division between June 30, 1973 and June 30, 1974.

NBSIR 74-396. **Specification and measurement of frequency stability,** J. H. Shoaf, 44 pages (Nov. 1974). Order from NTIS as COM 74-11766.

Key words: Allan variance; frequency stability measurements; measurement system description; phase noise; spectral density; terminology standards.

This report gives concise definitions for specifying frequency stability for measurements in the frequency domain and time domain. Standards of terminology and of measurement techniques are recommended. Measurement systems are described in adequate detail so that the apparatus may be duplicated. Proposed extension of the measurement systems through 12.4 GHz is discussed.

NBSIR 74-398. **Provisional values for the thermodynamic functions of ethane,** R. D. Goodwin, 342 pages (June 1, 1974). Order from NTIS as COM 75-10130.

Key words: densities; enthalpies, entropies; equation of state; internal energies; isobars; isochores; isotherms; Joule-Thomson inversion; latent heats of vaporization; melting line; orthobaric densities; specific heats; speeds of sound; vapor pressures.

Thermophysical properties are tabulated at uniform temperatures over the entire range of fluid states from 90 to 600 K along isobars to 700 bar. A new, rational equation of state is employed for the first time. Thermodynamic functions in the compressed liquid at $T < T_c$ are obtained by use of specific heats $C_p(T)$ along a high pressure isobar.

NBSIR 74-426. **Survey plans and data collection and analysis methodologies: Results of a pre-survey for the magnitude and extent of the lead based paint hazard in housing,** W. Hall, T. Ayers, and D. Doxey, 110 pages (Jan. 1974). Order from NTIS as COM 74-11074.

Key words: housing; housing survey; lead; lead hazard; lead paint; lead poisoning; survey; urban health problems.

A pilot survey of housing in Washington, D.C. was carried out in order to develop and test methodologies, data collection procedures and formats that will be used in subsequent full scale surveys of cities to determine the magnitude and extent of the lead-based paint hazard in housing.

On site measurements of lead contents of interior and exterior surfaces were made (with portable x-ray fluorescence lead detectors, hereafter referred to as XRF's) on 115 dwelling units which were randomly selected from a Washington, D.C. city directory.

This report describes the procedures for identifying the survey sample, drawing the sample, and carrying out the survey. Computer programs for data handling and analysis are included and a brief summary of the data obtained from the pilot survey is presented.

NBSIR 74-430. **Chemical kinetics data survey VII. Tables of rate and photochemical data for modelling of the stratosphere (revised),** D. Garvin and R. F. Hampson, 104 pages (Jan. 1974). Supersedes NBSIR 73-203. Order from NTIS as COM 74-10724.

Key words: atmospheric chemistry; chemical kinetics; data evaluation; energy transfer; gas phase; high temperature air chemistry; ion-molecule reactions: optical absorption cross sections; photochemistry; quantum yield; rate constants.

Chemical kinetic and photochemical data for gas phase reactions pertinent to the chemistry of the stratosphere are presented in four tables. These tables give recommended values and also cite recent experimental work. They give data in the following subject areas: chemical reactions and photochemistry of neutral species, energy transfer reactions, high temperature air reactions, and ion-molecule reactions.

NBSIR 74-432. **1972 International Activities Center for Building Technology,** C. C. Raley, 68 pages (Aug. 1973). Order from NTIS as COM 74-10751.

Key words: cooperative programs; foreign visitors; information exchange; international building technology; international organization memberships; professional interaction

This report summarizes the Center for Building Technology's 1972 international activities including formal cooperative programs, exchange programs, special projects, international organization memberships, foreign guests at CBT, and CBT foreign travel.

NBSIR 74-434. **Test and evaluation of baby walkers and walker jumpers,** D. J. Chwirut, 19 pages (May 1974). Order from NTIS as COM 74-11079.

Key words: accident reports; baby walkers; infants; safety standards; test methods; walker-jumpers.

Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving baby walkers and walker-jumpers. Test methods were developed to simulate service conditions to determine if the characteristics leading to accidents are present in all or only a few of the items in the market. These test methods include tests for dynamic and static stability, step roll-over stability, plastic bead strength, durability, and location of scissor joints. The test methods and performance criteria are intended to supply information leading to federal safety standards.

NBSIR 74-438. **Pilot demonstration of lead based paint hazard elimination methods,** T. H. Boone, T. R. Ray, and W. G. Street, 26 pages (Dec. 1973). Order from NTIS as COM 74-10980.

Key words: cost analysis; housing; lead based paint; lead poisoning; surface preparation; surface refinishing; water wash paint removal.

This report describes the removal of lead base paint from exterior surfaces of a single family attached house using alkaline/solvent thixotropic liquid paint removers followed by a high-pressure/low-volume water spray.

The extent of the reduction of the lead based paint hazard, the cost of the process and the observed problems and merits of this water wash paint removal system are presented.

NBSIR 74-439. **Preparation of reference materials for stationary source emission analysis: Beryllium,** T. C. Rains, C. D. Olson, R. A. Velapoldi, S. A. Wicks, O. Menis, and J. K. Taylor, 12 pages (Mar. 1974). Order from NTIS as COM 74-10985.

Key words: air pollution; atomic absorption spectrometry; beryllium; chemical analysis; fluorimetric analysis.

Techniques are described for the preparation of reference materials useful for evaluating the accuracy and precision of analytical methods for measurement of beryllium emissions from stationary sources. These reference materials consist of membrane filters upon which are deposited microgram quantities of high-fired beryllium oxide and ampoules containing soluble beryllium and suspended beryllium oxide. Methods for measurement of the beryllium content of such materials by atomic absorption spectrometry and by spectrofluorimetry are described.

NBSIR 74-442. **High temperature slow crack growth in ceramic materials,** A. G. Evans, 48 pages (Feb. 1974). Order from NTIS as COM 74-10476.

Key words: ceramics; crack healing; crack propagation; cyclic fatigue; failure prediction; high temperature; static fatigue.

High temperature slow crack growth processes in several ceramic materials are examined under static and cyclic loading conditions. Data obtained at temperatures up to 1400 °C are used for purposes of failure prediction and for analysis of the slow crack growth phenomena. It is shown that purity plays a major role in slow crack growth resistance, particularly in the hot pressed materials, and that cycling in the low frequency regime does not significantly increase the rate of slow crack growth. The slow crack growth mechanisms appear to be primarily plasticity related. Two semi-quantitative mechanisms are presented, one due to dislocation motion and the other due to grain boundary sliding.

NBSIR 74-443. **Weight cleaning procedures,** H. E. Almer, 9 pages (Nov. 1973). Order from NTIS as COM 74-11003.

Key words: cleaning; standards; steam generator; storage; temperature equilibrium; weights.

Accurate and meaningful results in the calibration of weights depend on clean weights. This paper describes a method of cleaning weights.

NBSIR 74-444. **A review of natural stone preservation,** G. A. Sleater, 40 pages (Dec. 1973). Order from NTIS as COM 74-10548.

Key words: air pollution; historic structures; laboratory evaluation; natural weathering; stone decay; stone preservation.

With increased interest in stone preservation, it is desirable to know what causes stone to decay, and what materials can be used to preserve stone. This review covers the following topics: causes of stone decay, including faults in the stone, salts, natural weathering factors, air pollution, living organisms, and most importantly, water action; various materials that have been used to preserve stone, including paints, waxes, oils, inorganic chemical surface treatments and impregnants, silicones, siliconates, and synthetic organic polymers; methods of evaluating stone preservatives. Field and laboratory procedures for testing stone preservatives, the cleaning of stone, a glossary, and a bibliography are given in appendices.

NBSIR 74-449. **Fire endurance tests on walls and plumbing chases containing either metallic or nonmetallic drain waste and vent systems,** W. J. Parker, 83 pages (Nov. 1973). Order from NTIS as COM 75-10049.

Key words: ABS; cast iron; copper; drain; fire endurance; fire spread; fire test; Operation BREAKTHROUGH; plastic pipe; PVC; smoke; toxic gases; vent; waste.

Two full scale non-load bearing ASTM E-119 fire endurance tests were performed on plumbing chase and wall assemblies containing polyvinyl chloride (PVC) drain, waste, and vent (DWV) systems typical of installations serving two or more stories. For the systems tested which were typical of kitchen sink drain systems constructed and installed according to typical plans, the PVC piping did not contribute to the spread of fire through the plumbing chase to the adjoining dwelling during the test which lasted 50 minutes. A test failure not associated with the plastic piping aborted the test but there was no indication that there would have been a failure due to the piping if the test had continued for one hour.

Three full scale non-load bearing ASTM E-119 fire endurance tests were also run on walls with enclosed DWV systems of acrylonitrile butadiene styrene (ABS), PVC, copper, and iron.

Neither PVC nor ABS piping contributed to fire spread in a plumbing system consisting of 2-inch stacks and 1½-inch back-to-back laterals in a 2×3 fir-stud-and-gypsum-board wall. In one test in which the stacks and laterals were 4 inches in diameter and in another test in which the distance between wall surfaces was decreased by using 2×4 studs, the effective fire endurance rating of the wall assembly was reduced by the installation of the plastic plumbing.

This progress report on the fire endurance evaluation of five plumbing chase and wall assemblies is limited to construction assemblies in which the openings around the laterals were carefully sealed with plaster spackling. Additional tests are in progress to examine the effect of leaving the openings unsealed.

NBSIR 74-451. **Field comparisons of steel surveyors' tapes,** C. L. Carroll, Jr., 16 pages (Nov. 1973). Order from NTIS as COM 74-11385.

Key words: graduation; length; scale; tape; temperature; tension.

Report describes a field procedure to compare a steel surveyor's tape to a standard tape that has been calibrated by the National Bureau of Standards. The procedure requires only a hand-held magnifier, two short scales, and two spring balances. Temperature reading device is not required since both tapes are

made of steel and have the same temperature during the comparison.

NBSIR 74-452. **Design and evaluation criteria for energy conservation in new buildings,** Staff of the Center for Building Technology, NBS, 107 pages (Feb. 27, 1974). Order from NTIS as PB204586.

Key words: air leakage; building design; energy conservation; fenestration; HVAC systems; illumination; insulation; lighting; performance standard; thermal performance; ventilation; water heating.

This document contains design and evaluation criteria for energy conservation in most new buildings. It was prepared in response to a request by the National Conference of States on Buildings Codes and Standards to the National Bureau of Standards. It is intended to be the forerunner of a consensus standard to be promulgated by a national standards organization.

The requirements and criteria are performance-oriented to the extent permitted by present building design technology. The performance concept is applied at the subelement or subsystem level to synthesize an energy-efficient total system. The detailed criteria are directed toward the design of building envelopes with good thermal resistance and low air leakage, and toward practices in the design of mechanical and electrical systems which conserve energy. Design flexibility is achieved by providing for the acceptance of alternative design solutions that can be shown to save equivalent amounts of energy without following every detailed requirement.

NBSIR 74-454. **The equivalence of gravimetric and volumetric test measure calibration,** R. M. Schoonover, 16 pages (Feb. 1974). Order from NTIS as COM 47-10988.

Key words: check standard; closure; gravimetric calibration; standard deviation; test measure; volumetric transfer calibration.

This report discusses the statistical importance of observed differences between gravimetric and volume transfer calibrations of volumetric test measures. The data presented are results from the present NBS calibration program and conclusively show there are negligible differences between the two methods of calibration.

NBSIR 74-455. **Abstracts of papers on testing and analysis of flammable fabrics October 1972 to October 1973,** J. F. Krasny, 27 pages (Mar. 1974). Order from NTIS as COM 74-10865.

Key words: burn injuries; carpets; clothing; fabrics; fire retardants; flammability testing.

This collection of abstracts covers papers on textile flammability testing and analysis of flame retardant fibers and finishes, for the period October 1972 to October 1973. It is hoped that this collection will facilitate research in this area in which there has been great interest in connection with the introduction of fabric and garment flammability standards by the Federal and several state governments. Similar collections appear in the Proceedings of the Annual Meetings of the Information Council on Fabric Flammability, available from the Council, Room 510, 1457 Broadway, New York, N.Y. 10036.

NBSIR 74-456. **Evaluation of the fire performance of a dibromotetrafluoroethane—blown rigid polyurethane foam,** T. G. Lee, W. J. Parker, and M. Tryon, 17 pages (Apr. 1974). Order from NTIS as COM 74-11793.

Key words: dibromotetrafluoroethane; fire tests; flame spread index; heat release rate; ignition temperature; rigid urethane foam; smoke.

The fire performance characteristics of a dibromotetrafluoroethane—blown rigid polyurethane foam were measured by several laboratory test methods. Measurements included: surface flammability, smoke and gases generated at elevated temperature and during combustion, ignition temperature, rate of heat release, and fire growth. The maximum concentration of the blowing agent in the specimen was approximately 13 Wt%. Specimen density was 0.046 g/cm^3. As a function of temperature, release of blowing agent from collapsed cells began at about 60 °C and became considerable at 135 °C. The material had a flame spread index (ASTM E-162) of 11 with smoke levels of 170 and 480 (maximum specific optical density) under nonflaming and flaming exposures, respectively. The measured rate of heat release was 8.8 W/cm^2, about 5 times that of a fibrous glass insulation. The measured flash ignition temperature was 530 °C for the material.

NBSIR 74-457. **Transmission of electrons through foils,** S. M. Seltzer, 84 pages (Apr. 1974). Order from NTIS as COM 74-11792.

Key words: angular distribution; electrons; energy spectra; reflection; transmission; transport calculation.

The transmission of electrons through foils has been studied by a Monte Carlo method. Cases involving electrons with energies from 50 keV to 1 MeV normally incident on beryllium, mylar, aluminum, and titanium foils are considered. Good agreement with experimental results has been found for quantities such as the number transmission, the energy and angular distribution of the emergent electrons, and the spatial distribution of energy deposited in the foil.

A comprehensive set of results has been generated for 100, 150, 200, 300 and 400-keV electrons incident on beryllium, mylar, aluminum, and titanium foils that are commonly used as vacuum windows in conjunction with low energy electron accelerators. Quantities given are the electron number and energy transmission and reflection, the energy absorbed, and the energy and angular distribution of the transmitted electrons. It is shown that much of the results can be presented in a scaled form which reduces the explicit dependence on, and facilitates the interpolation with respect to, the incident energy.

NBSIR 74-458. **Laser damage in materials,** A. Feldman, D. Horowitz, and R. M. Waxler, 16 pages (Mar. 1974). Order from NTIS as AD 776-337.

Key words: absorption coefficient; damage threshold; electrostriction; inclusion damage; intrinsic damage; Kerr effect; laser damage; laser glasses; laser rod materials; modulator crystals; nonlinear index of refraction; optical glasses; polarizer materials; self-focusing.

This report summarizes the study of damage and self-focusing in materials used in Q-switch solid-state laser systems. In borosilicate crown glass, fused silica, dense flint glass, and yttrium aluminum garnet, self-focusing appears to be the main cause of damage. An analysis of damage threshold measurements with linearly polarized radiation suggests that the Kerr effect is the dominant self-focusing mechanism with a significant contribution to self-focusing from the thermal effect. The electrostrictive effect is negligible. The damage threshold in Nd:doped laser glasses appears to be intrinsic. In all the above materials, the damage threshold for circular polarization is greater than the damage threshold for linear polarization. In lithium niobate, calcite, potassium dihydrogen phosphate, and deuterated dihydrogen phosphate, damage at the lowest levels is caused by inclusions. Bulk and surface damage thresholds in Nd:doped thoria:yttrium oxide ceramic are obtained relative to bulk damage thresholds in several optical materials. Relationships, under different geometric boundary conditions are also derived for solid materials between the stress-optic coefficients and the electrostrictive coefficients.

NBSIR 74-461. **The calibration of small volumetric laboratory glassware,** J. Lembeck, 34 pages (Dec. 1974). Order from NTIS as PB246623.

Key words: burets; capacity; flasks; meniscus; pipets; volumetric calibration.

This report describes a procedure for testing small volumetric apparatus. The procedure is based upon a determination of the volume of water either contained or delivered by the vessel. There are techniques described for cleaning, reading the meniscus, filling, draining and weighing the contained or delivered volume.

NBSIR 74-464. **The Shirley Highway Express-Bus-On-Freeway Demonstration Project—second year results,** J. T. McQueen, R. F. Yates, and G. K. Miller, 87 pages (Nov. 1973). Order from NTIS as COM 74-10785.

Key words: bus transit; busway operations; commuter travel behavior; express bus-on-freeway operations; project evaluation; transit operations.

This report contains: (a) A review of the performance of the Shirley Highway Express-Bus-On-Freeway Demonstration Project between 1969 and 1973; (b) A description of the methodology and data use to estimate project measures of effectiveness; (c) A discussion of factors considered in commuter mode choice decision making.

NBSIR 74-465. **Shear and tension-bending fatigue test methods for threaded airframe fasteners,** D. J. Chwirut, D. E. Marlowe, and J. S. Steel, 56 pages (Sept. 1974). Order from NTIS as COM 75-10417.

Key words: airframe fastener; double shear; fatigue; single shear; tension-bending; test methods.

Fatigue test methods for threaded airframe fasteners loaded in other than direct tension are described. The types of loading considered are single shear, double shear, and tension-bending. The test fixtures used in these tests are described. Results of tests on lots of fasteners from different manufacturers indicate that fasteners considered identical on the basis of direct tension procurement tests exhibit different fatigue life characteristics when loaded in shear and/or tension-bending. Thus the test methods described herein may be of future value as procurement tests for airframe fasteners.

NBSIR 74-466. **Management of data elements in information processing,** H. E. McEwen, Ed., (Proceedings of a Symposium Sponsored by the American National Standards Institute and by The National Bureau of Standards, held at NBS, Gaithersburg, Maryland, Jan. 24-25, 1974), 490 pages (Apr. 1974). Order from NTIS as COM 74-10700.

Key words: American National Standards; American National Standards Institute; data; data base systems; data elements; data management; data processing; Federal Information Processing Standards; information interchange; information processing; information systems.

Recent technological advances in computers and communications make possible the integration of data systems and the exchange of data among them on an expanding scale. However, the full effect of these advances cannot be realized unless the need for uniform understanding of the common information (data elements) and their expression in data systems is recognized and means provided to effectively manage this information. The increasing interrelationships among the data systems of Federal, State, and local governments, and with industry and the public add emphasis and dimension to the need for the improved management of data elements in information processing.

These Proceedings are for the first Symposium on the Management of Data Elements in Information Processing held at the National Bureau of Standards on 1974 January 24 and 25. Over 400 representatives of Federal and State governments, industry and universities from 30 states, from Canada, and Sweden were in attendance. Thirty-four speakers discussed data element management in the fields of health care, water resources, state government information systems, transportation, libraries, market research, manufacturing, banking, information retrieval systems, military systems, computer programming and software systems, and motor vehicle registration.

NBSIR 74-467. **Simulated solar heat tests on M.U.S.T. air-inflatable, double-wall hospital ward shelters,** L. W. Masters, J. W. Grimes, and R. A. Crist, 64 pages (May 1974). Order from NTIS as COM 74-11754.

Key words: adhesives; air-inflatable shelter sections; cloth webs; polyester and nylon fabrics; sewn seams; sewn seam strapping; solar heat load; test procedure.

At the request of the United States Army Natick Laboratories (USANLABS), the Center for Building Technology conducted solar heat load tests on five sections of M.U.S.T. air-inflatable, double-wall hospital ward shelters. The purpose of the tests was to evaluate the effect of solar heat load, as simulated by infrared heat lamps, on various materials and construction designs proposed for use in shelters.

NBSIR 74-470. **Interaction of plasma proteins with surfaces,** C. A. Fenstermaker, W. H. Grant, B. W. Morrissey, L. E. Smith, and R. R. Stromberg, 83 pages (Mar. 22, 1974). Order from NTIS as COM 74-10984.

Key words: adsorption; blood protein; bound fraction; ellipsometry; polymer adsorption; protein adsorption.

The interaction of blood proteins with surfaces has been investigated with principal attention focused on those proteins that are either major constituents of blood plasma or are implicated as being important in the clotting process. Emphasis has been placed on molecular conformational changes occurring upon the interaction of such proteins with surfaces. The extension of adsorbed molecules of fibrinogen, albumin, and prothrombin on a number of selected materials was studied by ellipsometry. The results indicate a dependence of conformation on surface energy. Measurements of the bound fraction (number of carbonyl surface attachments) of these adsorbed blood proteins on a silica surface showed that approximately ten percent of the carbonyl groups were attached to the surface for prothrombin and serum albumin at all values of surface population for the solution concentrations studied. Competitive interactions of prothrombin and fibrinogen during the process of adsorption, displacement, and desorption have been measured and rates of adsorption of albumin were measured on chrome and silica surfaces.

NBSIR 74-471. **Life cycle costing of police patrol cars: Summary report,** R. T. Ruegg, 23 pages (Mar. 1974). Order from NTIS as COM 74-10981.

Key words: fleet management; life cycle costing; patrol cars; police fleets; vehicle leasing; vehicle management.

There are many different choices to be made with respect to police vehicle acquisition, utilization, maintenance, and disposition. Cost comparisons among the different alternatives are an important element in the choices to be made. To make valid cost comparisons, it is necessary to employ the techniques of life-cycle costing. This means the inclusion of all relevant costs and the conversion of costs to an equivalent basis to take into account differences in the timing of expenditures.

This report briefly summarizes the results of a larger study which compares the life cycle costs of some of the alternatives associated with police fleet management. The full report from which this report is derived is entitled *Life Cycle Costing: Efficiency in Vehicle Acquisition, Operation, and Disposition.*

The focus of the study is on police patrol cars, but the methods are applicable to other types of vehicles. Specific topics addressed by the larger study and summarized here are the cost effects of purchasing different sizes of patrol cars and different optional equipment, the advantages and disadvantages of direct ownership of vehicles as compared with leasing, the costs of contracting out maintenance as compared with self-maintenance of vehicles, the cost effects of alternative utilization practices, the optimal timing of vehicle replacement, and the comparative efficiency of different methods of vehicle disposition.

NBSIR 74-473. **Natural disasters: Some empirical and economic considerations,** G. T. Sav, 72 pages (Feb. 1974). Order from NTIS as COM 74-11719.

Key words: benefit-cost analysis; disaster mitigation; earthquakes; economics; efficient; floods; hurricanes; natural disasters; optimal; tornadoes; total cost minimization.

This study examines the extent of some of the losses resulting from natural disasters. An estimate of these losses is necessary in order to determine the potential benefits that might be realized from mitigating the negative economic impacts from natural disasters. Absolute and relative losses resulting from hurricanes, floods, earthquakes, and tornadoes are examined. This data will help individuals, communities, and the Federal government make better decisions as to how and what extent protection against disasters should be provided. The application of benefit-cost analysis for choosing the optimal level of protection against disasters is also discussed. Recommendations are made for further research in determining the economic feasibility of various techniques designed to mitigate the losses from disasters.

NBSIR 74-474. **Metallurgical analysis of wear particles and wearing surfaces,** A. W. Ruff, 59 pages (Apr. 1974). Order from NTIS as AD 778340.

Key words: bearings; electron diffraction; electron microscopy; gears; lubrication; particles; wear.

Results are presented from a program involved in characterizing the wear particles and surface degradation produced by wear in bearing and gear tests in which the effects of several variables on failure of the wearing surfaces has been examined. The information obtained has been correlated with the results of allied studies conducted by others in an attempt to develop an understanding of the processes producing wear and degradation of metal surfaces in sliding, rubbing, rolling, and/or rotating contact and the effects of lubricants, lubricant additives, bearing materials, etc. on these processes. The characterization of the wear particles and wearing surfaces should aid in the establishment of the interrelationships between wear particle shape, size, size distribution, chemical compositions, metallurgical structure, and surface damage prior to failure.

NBSIR 74-477. **Performance characteristics of a "bulk effect" humidity sensor,** J. W. Little, S. Hasegawa, and L. Greenspan, 33 pages (May 1974). Order from NTIS as COM 74-11784.

Key words: "Brady Array" sensors; electric hygrometer; humidity; humidity sensor; moisture measurement; relative humidity; water vapor measurement.

A laboratory study was made of the performance of "Brady Array" humidity sensors over a range of ambient temperatures from − 40 °C to + 20 °C encompassing relative humidities from 0 to 90 percent. Information was obtained on such characteristics as sensitivity, hysteresis, temperature effect, short-term and long-term repeatability.

NBSIR 74-479. **Analysis of cost-sharing programs for pollution abatement of municipal wastewater,** H. E. Marshall and R. T. Ruegg, 145 pages (Sept. 1974) Order from NTIS as COM 74-11769.

Key words: cost sharing; efficiency; equity; financing; nor plant treatment; sewage treatment, user fees; water pollu tion.

This study evaluates existing cost-sharing programs for waste water pollution abatement as described in the Federal Water Po lution Control Act Amendments of 1972, describes alternativ cost-sharing programs that provide improvements in terms of na tional efficiency and equity criteria as defined herein, and sug gests related areas for further research. Emphasis is on ho Federal cost sharing biases communities in favor of certain kinc of techniques. The approach is to describe the current cost-sha ing programs for both plant and nonplant techniques; to examir cost-sharing, legal, and other institutional biases against certai techniques; to analyze efficiency and equity effects of alternativ cost-sharing programs; and to describe the incentive effects c cost-sharing on nonfederal interests with respect to their choice among abatement techniques. Findings of the study are th more efficient abatement will result if the *same* percentage co share applies to all plant and nonplant techniques of abatemen the *same* percentage also applies to all categories of cost (e.g capital, land, operation and maintenance) for a given techniqu the *same* percentage applies to large and small communities; i stitutional constraints on the selection of nonplant techniques a removed; and if the program provides for Federal cost sharing every abatement technique that is technically viable.

NBSIR 74-481. **Absolute calibration of vibration standards by th three-mass reciprocity method,** J. D. Ramboz, 50 pages (Ap 1974). Order from NTIS as COM 74-11794.

Key words: absolute calibration; accelerometers; calibra tion; reciprocity calibration; vibration exciters; vibratio pickups; vibration standards.

Reciprocity calibration of electrodynamic vibration exciters reviewed. A new method is proposed. The theory for the ne Three-Mass reciprocity calibration method is developed. Th process requires that the electrical impedance of the exciter drive coil be measured for three added masses separate mounted on the exciter's armature. The sensitivity of the a celerometer mounted in the armature is solved in terms of change of electrical impedance for a change of mass, voltag ratio, electrical resistance, and frequency. A set of 38 measur ments were made at 1000 Hz to experimentally verify th theory. The value of sensitivity was 2.070 pC/g ± 1.3 percer This agreed to within about ± 0.65 percent of a transfer calibr tion from Bouche-Levy calibrated standards and the manufa turer's estimated value. Measurements were made to verify th theory; improvement to an uncertainty of about ± 0.2 percent ultimately possible in the absolute calibration using this metho

NBSIR 74-482. **An automated system for precision calibrati of accelerometers,** B. F. Payne, 196 pages (Apr. 1974). Ord from NTIS as COM 75-10147.

Key words: acceleration; automation; calibration; measur ments; minicomputer; shakers; standards; transducer vibration; vibration exciters; vibration pickups.

The report describes an automated system for acceleromet calibration under realtime control by a small, dedicated digit computer. The hardware components of the system and th software programs are given. The software automatically reg lates the rate and amount of data collected based on analysis input data. Printout of the frequency response of test acceleror eters is on a teletypewriter and also can be stored on a magne tape. Manual operation of the system is also described.

NBSIR 74-485. **Strength of glass—a fracture mechanics a proach,** S. M. Wiederhorn, 24 pages (May 1974). Order fro NTIS as AD 780704.

Key words: crack growth; fracture; glass; static fatigue; strength.

After a brief review of those factors that determine the strength of glass (brittleness, surface flaws, susceptibility to stress corrosion cracking), a discussion will be given of how fracture mechanics techniques can be used to understand the physics and chemistry of glass strength. In this paper we assume that the strength of glass is limited by the growth of cracks that are always present in normal glass surfaces. Fracture mechanics techniques can be used to characterize the crack growth and to relate the growth to experimental parameters such as temperature, environment, and glass composition. Crack growth data obtained in this manner can be used to develop a deeper understanding of fracture mechanisms, and to develop charts that can be used for the design of glass structural components. Examples of both applications are given in the paper.

NBSIR 74-486. **Reliability, life prediction and proof testing of ceramics,** S. M. Wiederhorn, 62 pages (May 1974). Order from NTIS as AD 780705.

Key words: ceramics; crack propagation; delayed failure; fracture; proof testing; Weibull analysis.

A critical review is presented of the use of proof testing as a design method for assuring the reliability of structural components. The advantage of proof testing over the statistical approach used for design lies in the insensitivity of the proof testing method to the detailed history of handling or processing of structural components. Methods are presented for developing and using proof test diagrams to assure component lifetime after proof testing. Procedures of proof testing and precautions that must be followed during proof testing are discussed. Provided these precautions are followed, proof testing offers a general method for assuring the reliability of structural components under stress.

NBSIR 74-487. **Proposed revision of American National Standard COBOL,** R. E. Rountree, Jr., Ed., 544 pages (Jan. 1974). Order from NTIS as COM 74-10886.

Key words: COBOL; data processing; Federal Information Processing Standard; information interchange; information processing; programming language; software.

This document is for review purpose only in anticipation of its becoming an American National Standard and subsequent adoption as a Federal Information Processing Standard. The American National Standard COBOL defines the elements of the COBOL programming language and the rules for their use. The standard is used by implementors as the reference authority in developing compilers and by users for writing programs in COBOL. The primary purpose of the standard is to promote a high degree of interchangeability of programs for use on a variety of automatic data processing systems.

NBSIR 74-488. **Measurements of railroad noise-line operations, yard boundaries, and retarders,** J. M. Fath, D. S. Blomquist, J. M. Heinen, and M. Tarica, 108 pages (Dec. 1974). Order from NTIS as COM 75-10088.

Key words: acoustics; noise measurement; noise (sound); railroad yard; trains.

A field investigation of noise emission from railroad operations was conducted. The objectives of the study were the establishment of a data base on the noise levels associated with railroad operations, both line (trains in transit) and yard, and the development of measurement procedures that could be utilized in regulations applicable to the noise from rail carrier equipment and facilities. For trains in transit, measurements were made as a function of horizontal distance from the tracks [five locations at 25, 50, 100, 200 and 400 feet] and as a function of microphone height [three different heights at the 25 and 50 foot microphone locations]. Train passby data are presented as the maximum A-weighted sound level observed during the passby and as Single Event Noise Exposure Levels (both A-weighted and one-third octave band levels). A-weighted sound level measurements were made at the boundary of the railyard, at 0.1 second intervals, for periods of time ranging from 1 to 23 hours over several days. These data are presented as the energy equivalent sound level and the level exceeded ten percent of the time. The directionality of retarder noise was also investigated. Measurements were made of the noise emitted in various directions during retarder operation.

NBSIR 74-495. **Development of a radiant panel test for flooring materials,** L. G. Hartzell, 79 pages (May 1974). Order from NTIS as COM 74-11575.

Key words: carpet; fire test; flammability; flooring; heat flux; ignition; radiant panel.

This paper summarizes the work of a year long program to continue the development of a radiant panel type test for flooring materials, the original concept of which was developed at the Armstrong Cork Company's Research and Development Center in Lancaster, Pennsylvania. This program at the National Bureau of Standards had as its goal, the further development of the test for possible adoption as a standard ASTM test method.

The program work was divided into five phases. During the first phase, an attempt was made to duplicate the performance of the original apparatus in a similar one at the National Bureau of Standards Laboratory. The proof of this duplication was shown in replicate testing using a wide range of flooring on both apparati.

In the second phase of the program, a new set of test conditions were found in an attempt to eliminate some of the more serious equipment and procedural problems of the test. These new conditions provided the test with the ability to rate flooring materials according to their ability to resist the surface spread flames.

Under the third and fourth phases of the program, the effects of changes in some test parameters was investigated and other test characteristics were measured. Phase V, the data analysis and report, concluded the program.

NBSIR 74-496. **Standard measurements of the resistivity of silicon by the four-probe method,** W. M. Bullis, 75 pages (Aug. 1974). Order from NTIS as COM 74-11576.

Key words: ASTM Committee F-1; electronics; four-probe method; resistivity; semiconductors; silicon.

An improved standard procedure for measurement of circular silicon slices with four in-line point probes has been developed in cooperation with the Resistivity Task Force of ASTM Committee F-1. Detailed analysis of a series of round-robin experiments showed that the procedure can attain a precision of ± 2 percent (three standard deviations) for interlaboratory comparisons of slices with room temperature resistivity between 0.005 and 120 ohm-cm. Resistivity nonuniformity in the test slices was shown to be a significant factor in limiting the precision which could be achieved. The importance of including correction factors for temperature, finite thickness, finite diameter, and unequal probe separations was demonstrated. The results of the round-robin experiments also emphasized that the precision quoted can only be achieved if the measurements are carefully and correctly made on a well maintained, accurately calibrated test system which meets the requirements imposed by the test method. Determination of the precision to be expected from the method in nonreferee applications such as routine production and quality control will require additional study of such factors as surface conditions, probe force, current levels, etc. Neverthe-

less, use of the various procedures of the method, in particular the sections on probe and measuring circuit evaluations and on thermal sinking of the wafer, would be expected to yield significantly improved precision in such applications. Use of these procedures on a regular and widespread basis should be encouraged.

NBSIR 74-497. **US/UK joint complementary research program in building, (wind loads, water supply, fire detection), July 1972-June 1973,** C. C. Raley, I. A. Benjamin, R. D. Marshall, and J. E. Snell, 24 pages (Oct. 1973). Order from NTIS as COM 74-11269.

Key words: cooperative programs; fire safety; hydraulics; international building technology; wind loads.

This is a status report of the progress achieved under the "Joint Complementary Research Program" sponsored by the Building Research Establishment (UK) and the Center for Building Technology (US), during the period July 1972 through June 1973. The program includes three projects: Wind Loads on Buildings, Design of Water Supply and Drainage Installations in Buildings, and Fire Detection in Buildings, each of which is discussed in the report.

NBSIR 74-499. **An analysis of the aging of paper: Possible reactions and their effects on measurable properties,** W. K. Wilson and E. J. Parks, 37 pages (Apr. 26, 1974). Order from NTIS as COM 74-11378.

Key words: accelerated aging; aging; aging of cellulose; aging of paper; cellulose; cellulose aging; natural aging; paper; paper aging; tests for paper.

Various reactions that cellulose can undergo are reviewed in relation to their bearing on the aging of paper. The principal reactions of cellulose are hydrolysis, oxidation, crosslinking, change in lateral order in the bonding area, and, during accelerated aging, thermal decomposition. The effects these various reactions might have on tests that are available for evaluating changes that occur during the aging of paper are reviewed. Some special examples of these reactions that occur during natural aging, because of special composition characteristics of the paper, are discussed. Suggestions are made concerning most sensitive tests for use in detecting changes in paper and tests, regardless of sensitivity, available for determining *what* happens during aging. Some general guidelines regarding specifications for permanent record papers are discussed.

NBSIR 74-501. **Development of specifications for archival record materials,** W. K. Wilson, 17 pages (May 23, 1974). Order from NTIS as COM 75-10131.

Key words: aging of paper; archival materials; natural aging; old paper; paper, aging of; paper, stability of; paper testing; stability of paper.

Effort on a long range program on the Development of Specifications for Archival Record Materials has included: (1) Reappraisal of research needs; (2) a study of 18 papers made in 1937, tested before and after dry accelerated aging in 1937, and tested again in 1973; (3) evaluation of 19 commercial papers, evaluated before and after moist accelerated aging in 1963, and tested again in 1973; and (4) development of specifications for copies from office copying machines.

A review of the literature on stability of paper and data obtained in this laboratory over the past several years indicate that a fresh approach is needed to a study of the stability of paper. The following tasks are suggested: (1) Continue to use handsheets of known composition; (2) study old papers to determine changes that probably have occurred during natural aging; (3) confine testing to methods that give some clues concerning what happens during aging such as zero span tensile, wet strength, peroxide formation, functional group content, and molecular chain length distribution; and (4) study the effect of cycling of relative humidity on the properties of paper.

NBSIR 74-506. **Development of a national anthropometric data base: A preliminary study report,** H. L. Steinberg, 85 pages (June 1974). Order from NTIS as COM 74-11632.

Key words: anthropometric survey; biostereometric body-dimensions; National Data Base.

A study was made to determine the need for development of a Nationally Representative Anthropometric data base. Potential users and their needs are identified and the inability of existing anthropometric data to satisfactorily meet these needs is established. Three scenarios for developing a useful data base are considered. Two involve the use of biostereometrics while the third takes a relatively conventional approach to obtaining body dimensions. Conclusions relevant to each of these scenarios, as well as the potential advantages/disadvantages of each, are developed. Salient conclusions common to all three scenarios include: The need for a (R & D type) pilot study; the desirability of linking the actual anthropometric survey to a National Center for Health Statistics (NCHS) "Health and Nutrition Examination Survey" (HANES); and a data base development time of at least 7 years. Program costs, detailed in an appendix, ranged from $2.4M to $5.2M. Mechanisms for administering and funding this survey were considered briefly. An estimation of the optimal sampling dimensions for the proposed survey, based on clothing industry needs, is given.

NBSIR 74-507. **Mercurous chloride polarizer material,** R. Forman, W. S. Brower, and H. S. Parker, 31 pages (June 1, 1974). Order from NTIS as ADA000343.

Key words: infrared; mercurous chloride; polarizer material; visible.

This contract report covers a feasibility study on the potential use of mercurous chloride crystals for construction of prism polarizers, primarily for the infrared region of the spectrum. In particular, the research has consisted of crystal growth from the vapor phase and optical characterization of the absorption, dichroism, and birefringence.

Crystal growth has been performed in quartz or Vycor ampoules sealed off under a pressure of 10^{-5} torr or better. Crystals are grown in a vertical modified Bridgman furnace by vapor transport. Repeated regrowth has been found to produce a continuous improvement in clarity, the best samples being virtually colorless. The growth rates used of 2 mm/day in tubes of 17 mm inside diameter have been found to be satisfactory for producing the crystals used to date, but strain patterns and a tendency to polycrystallinity indicate that slower growth rates should be attempted. Conditions for growth have not yet been optimized, but reasonably good growing conditions have been delineated.

Single crystal samples have been oriented by Laue back reflection techniques and measurements made of optical absorption, dichroism, and birefringence. Proper sample handling procedures have been determined to minimize thermal shock and thermal etching. The index of refraction has been measured at selected wavelengths, and calorimetric absorption studies have been performed at AFML on some of the samples produced.

NBSIR 74-509. **Strength and stability testing of high chairs,** D. J. Chwirut, 17 pages (June 1974). Order from NTIS as COM 74-11377.

Key words: accident reports; high chairs; infants; safety standards; stability and strength; test methods.

Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving high chairs. Possible test methods for determining the characteristics of the high chairs leading to the accidents were investigated, including the test methods recommended in the Juvenile Products Manufacturers Association Voluntary Safety Standard for High Chairs. These tests included tests for tray strength, chair static strength, foot rest strength, restraining strap strength, and stability. These test methods and performance characteristics are intended to supply information leading to federal safety standards.

NBSIR 74-510. **Effect of phase separation on the physical and chemical properties of glasses-density and chemical durability,** J. H. Simmons, S. A. Mills, and B. F. Howell, 33 pages (July 1974). Order from NTIS as AD 782793.

Key words: borosilicate glass; chemical durability; density; immiscibility.

This report covers results from density and chemical durability measurements on a borosilicate glass widely used commercially for chemical glassware while the glass undergoes liquid-liquid immiscibility. A net decrease in density is observed during an isothermal heat-treatment below the transition temperature. This density or molar volume change is related to the effect of pressure on the phase transition temperature by means of equations derived herein. The chemical durability of the material is measured following the ASTM titration technique and shows a large degradation of chemical resistance to attack by water as a result of sub-immiscibility structure development. The effect is analyzed in terms of the change in composition of the phases associated with the immiscibility transition.

NBSIR 74-511. **Fire research publications, 1973,** N. H. Jason, 13 pages (June 1974). Order from NTIS as COM 74-11448.

Key words: bibliographies; building fires; construction materials; fire departments; fire tests; flame spread test; flammability tests; flammable fabrics; Operation BREAKTHROUGH; protective clothing.

A list of publications is provided representing the papers and journal articles prepared by members of the Programmatic Center for Fire Research (PCFR) and by NBS personnel under contract to PCFR and by external laboratories under contract to the PCFR during 1973.

NBSIR 74-514. **1973 international activities, Center for Building Technology,** C. C. Raley, 54 pages (July 1974). Order from NTIS as COM 75-10102.

Key words: cooperative programs; foreign visitors; information exchange; international building technology; international organization memberships; professional interaction.

This report summarizes the Center for Building Technology's 1973 international activities including formal cooperative programs, exchange programs, special projects, international organization memberships, foreign guests at CBT, and CBT foreign travel.

NBSIR 74-515. **Report of conference on making service industries more productive through computers and automation,** A. K. McAdams and M. M. Henderson, 176 pages (June 1974). Order from NTIS as COM 74-11498.

Key words: automation; computers; productivity; service industries.

The Engineering Foundation and the National Bureau of Standards, Institute for Computer Sciences and Technology, cosponsored this conference to bring together persons actively concerned with the subject to identify gaps in knowledge, needs and opportunities in the area, and to point up governmental goals and programs to respond to such needs. This report contains the principal presentations and the texts of Workshop Panel reports prepared during the conference.

NBSIR 74-516. **Chemical kinetics data survey VIII. Rate constants of ClO_x of atmospheric interest,** R. T. Watson, 51 pages (June 1974). Order from NTIS as COM 74-11384.

Key words: absorption cross sections; atmospheric chemistry; chemical kinetics; chlorine; chlorine dioxide; chlorine monoxide; data evaluation; gas phase; optical; rate constants; stratospheric chemistry.

The quantitative data on reactions of chlorine atoms and the chlorine oxides are compiled. Preferred values for rate constants are given where possible. Optical absorption cross sections are given for the species that may photolyze in the atmosphere. The experimental techniques used to obtain the rate data are discussed.

NBSIR 74-518. **Instrumental colorimetry of retroreflective sign materials,** I. Nimeroff and W. A. Hall, 89 pages (Aug. 1974). Order from NTIS as PB239633.

Key words: colorimetry; highway signs; photoelectric tristimus colorimeters; photometry of retroreflective materials; retroreflective sign materials.

Because color-coded applications of highway signs increase, specifications of colors and color tolerances are required. In order to assure that the requirements are met within specified regions, a measurement technique needs to be developed and described. To accomplish these goals the U.S. Department of Transportation contracted with the National Bureau of Standards to conduct the required studies and make the necessary recommendations. Having previously performed a study for daytime conditions, the National Bureau of Standards was competent to perform a study for nighttime conditions. The colorimetric properties of 126 samples of retroreflective materials of 7 different colors were measured with 3 telecolorimeters in simulated nighttime conditions. One spectrophotometer was used to measure color of 38 of the samples in simulated daytime conditions. The colors measured were: red, orange, brown, yellow, green, blue and silver (white). Differences of color measured by means of different telecolorimeters on the same samples were evaluated.

As a result of these studies procedures for making colorimetric and photometric measurements were developed and are included in this report. On the basis of the color measurements and their variability tentative recommendations for color boundaries were prepared and are also included in this report.

NBSIR 74-519. **Photometric tests of vehicle glazing materials,** W. A. Hall, E. L. Walters, I. Nimeroff, and C. A. Douglas, 33 pages (Nov. 1974). Order from NTIS as PB 238284.

Key words: automobile paint colors; automobile windshield color; photometric tests; spectral reflectance; spectral transmittance; transmittance variation; vehicle glazing materials.

Measurements were made on the spectral transmittance of representative vehicle glazing materials and spectral reflectance of representative automobile paints. Colorimetric data were derived from these spectral measurements.

By varying the instrumental parameters of the in-laboratory procedure described in NBS Report No. 10902 for measuring the transmittance of glazing materials, errors in transmittance were obtained and were evaluated. The standard deviation of the transmittance measurements was less than 0.01 except at incidence angles of 70° where it was about 0.02.

NBSIR 74-520. **Evaluation of structural properties of masonry in existing buildings,** S. G. Fattal and L. E. Cattaneo, 127 pages (July 1974). Order from NTIS as COM 74-11480.

Key words: analysis; compressive strength; deflection; design; flexural strength; masonry walls; racking strength; seismic loading; shear strength; shear wall; stiffness.

The current state of knowledge on the structural behavior of masonry is synthesized to develop a methodology for the evaluation of the load capacity of masonry walls in existing buildings. A procedure is described for direct sampling and testing of specimens removed from masonry walls of buildings to determine their strength in shear, flexure and compression, and to measure their load-deformation characteristics. A documentation of strength and stiffness properties obtained from available test data is included to provide an alternate source of information on masonry of comparable construction. Sample calculations of masonry building analysis for seismic forces are given in Appendices A and B.

NBSIR 74-521. **HATCH—A model for fish hatchery analysis,** F. C. Johnson, 73 pages (July 8, 1974). Order from NTIS as COM 75-10187.

Key words: benefit/cost; fish hatchery analysis; fish hatchery management; fish hatchery operation; mathematical model.

The HATCH model is an automated system for analyzing the physical, biological and economic factors of fish hatchery operation and for computing optimal hatchery management policies.

NBSIR 74-522. **First interim report on salmon fishery modelling,** F. C. Johnson, 21 pages (July 8, 1974). Order from NTIS as COM 75-10080.

Key words: analysis of biological processes; economic performance; fisheries management; fisheries regulation; mathematical models; salmon fisheries model.

The salmon fishery modelling project is a joint State-Federal program for the development of improved techniques for analyzing the economic and biological effects of changes in the Pacific Coast salmon fishery regulatory parameters. This interim report covers the initial program design phase of the project.

NBSIR 74-523. **Preparations for gage block comparison measurements,** C. D. Tucker, 14 pages (July 9, 1974). Order from NTIS as COM 75-11126.

Key words: deburring; gage blocks, gage block comparator; linear variable differential transformer.

The methods described here for the cleaning and deburring of gage blocks can be useful to those individuals who have not established formal laboratory procedures for these operations. Many individuals may employ valid methods that vary somewhat from those employed at the National Bureau of Standards.

Many of the gage block comparators that are in use have not been periodically evaluated by the user. It is the intent of this report to set forth guidelines and procedures that may be used conveniently by metrologists to aid in obtaining more meaningful comparisons of gage blocks by the use of probe-type transducers.

NBSIR 74-524. **Practicality of diversion path analysis,** W. M. Murphey and J. C. Schleter, 36 pages (July 1974). Order from NTIS as COM 74-11568.

Key words: analysis; diversion of nuclear materials; diversion path analysis; internal control system characterization; nuclear material safeguards; safeguards.

One can define the safeguards system for nuclear material as the set of all protective actions taken to prevent or to deter attempts to divert nuclear material to unauthorized use. Maintenance of effective safeguards requires a program for routine assessment of plant safeguards systems in terms of their capabilities to satisfy safeguards aims. Plant internal control systems provide capabilities for detection of unprevented diversion and can provide assurance that diversion has not occurred. A procedure called Diversion Path Analysis (DPA) enables routine assessment of the capabilities of internal control systems in this regard and identification of safeguards problem areas in a plant. A framework for safeguards system design is also provided which will allow flexibility to accommodate individual plant circumstances while maintaining acceptable diversion detection capability. The steps of the procedure are described and the practicality of the analytical method is shown by referring to a demonstration test for a high throughput process where plant personnel were major participants. The boundary conditions for the demonstration case are given, along with some conclusions about the general procedure.

NBSIR 74-525. **Optical materials characterization,** A. Feldman, D. Horowitz, R. M. Waxler, I. Malitson, and M. J. Dodge, 20 pages (July 1974). Order from NTIS as AD 782564.

Key words: As_2S_3; chalcogenide glass; coefficient of thermal expansion; elastic constants; infrared laser window materials; KCl; photoelasticity; polycrystalline ZnSe; refractive index; stress-optical constants; thermal coefficient of refractive index.

A program has been established for measuring refractive index, n, stress-optical constants, q_{ij}, change of index with temperature, dn/dT, thermal expansion coefficient, α, and elastic compliances, s_{ij}, of infrared laser window materials. These parameters are necessary for determining the optical distortion that occurs in windows due to heating by the absorption of high power laser radiation. n and dn/dT are measured over a spectral range 0.2 to 50 μm by the method of minimum deviation on precision spectrometers. Twyman-Green and Fizeau interferometers which operate at 0.6328 μm, 1.15 μm, and 10.6 μm, are used for measuring q_{ij}, α, dn/dT and s_{ij}. Materials currently under study are polycrystalline ZnSe, As_2S_3 glass, chalcogenide glass (Ge 33%, As 12%, Se 55%), and KCl. Results are given for n and dn/dT in KCl, and q_{ij} and s_{12} in ZnSe, As_2S_3 glass, and chalcogenide glass.

NBSIR 74-526. **Analysis of non-reinforced masonry buildin response to abnormal loading and resistance to progressive col lapse,** W. McGuire and E. V. Leyendecker, 67 pages (Nov 1974). Order from NTIS as COM 75-10087.

Key words: abnormal loading; building; gas explosion; load bearing masonry; load-bearing walls; masonry; masonr research; progressive collapse.

Five case studies of susceptibility to progressive collapse wer made of non-reinforced masonry bearing wall buildings. All wer assumed to comply with governing building codes. Based on th assumed failure mechanisms, analysis indicated that two of th structures had excellent resistance to progressive collapse, on was marginal, and two had little resistance to progressive co lapse. Analytical approaches used are illustrated and areas c needed research are identified.

NBSIR 74-527. **Development of solid state samplers for work a mospheres,** B. Greifer, B. C. Cadoff, J. Wing, and J. K. Taylo 54 pages (June 1974). Order from NTIS as COM 74-11720.

Key words: air analysis; air sampler; charcoal; chlorin fluorine; gas analysis; hydrogen cyanide; hydrogen fluorid industrial hygiene; phosphine; sodium acetate; sorber, soli work atmosphere.

A program is described for evaluating the efficiency of solid sorbers for collecting trace quantities of hydrogen fluoride, phosphine, hydrogen cyanide, chlorine, and fluorine in work atmospheres for subsequent laboratory analysis. The gas handling and sampling instrumentation is described, and experimental results to date are presented.

Sodium acetate is a very efficient sorber for hydrogen fluoride, and its solubility in water proves to be highly advantageous for subsequent HF determination by ion selective electrode. Potassium permanganate impregnated silica gel sorbs phosphine effectively, and Ascarite has been found to sorb hydrogen cyanide, but quantitative experiments on the latter two systems are still in progress.

Work on chlorine and fluorine systems will be initiated in the near future.

NBSIR 74-529. **Project plans fiscal year 1974,** J. J. Diamond, 72 pages (July 1973). Order from NTIS as COM 74-11495.

Key words: anthropometry; communications equipment; forensic science; Law Enforcement Standards Laboratory; LESL; performance standards; project plans; protective equipment; security equipment; standards; warning lights and sirens.

Plans are presented for nineteen projects approved and funded for FY-74. They include plans for the preparation of performance standards, user guidelines and reports on law enforcement equipment in the communications, security, protective equipment, investigative aid, emergency equipment and clothing areas.

NBSIR 74-530. **Preparation of charcoal sampling tubes containing known quantities of adsorbed solvents,** B. C. Cadoff, E. E. Hughes, R. Alvarez, and J. K. Taylor, 36 pages (July 1974). Order from NTIS as COM 75-10041.

Key words: activated carbon; air sampling; gas standards; industrial hygiene.

The method in widespread use for the determination of the concentration of organic solvents in the work atmosphere consists in collection of the solvent by adsorption on activated charcoal followed by desorption with carbon disulfide and measurement by gas chromatography. This report describes techniques developed to produce reference standards for this determination and modifications in the analytical procedure to improve its precision and accuracy.

NBSIR 74-533. **Influence of windshield tint on the temperature in automobile passenger compartments,** W. S. Hurst and M. G. Scroger, 113 pages (Sept. 1974). Order from NTIS as PB 238573.

Key words: automobile compartment temperatures; automobile windshields; glazing materials; transmittance of vehicle glazing materials.

The effect of tinting in the glass of windshields on the air temperature in automobile passenger compartments was investigated. Measurements were performed with two nearly identical vehicles, one equipped with tinted windshield glass and one equipped with clear windshield glass. All other glass in both vehicles was tinted. Tests were performed statically, with the cars parked facing south, and dynamically, with the cars driven at approximately 80 km/h. In the static tests, the interior air temperatures as determined by liquid-in-glass thermometers were typically 2 to 3 °C cooler in the vehicle with the tinted windshield. In the dynamic tests, the differences in the interior air temperatures were smaller, typically about 0.5 to 1.5 °C. The interior air temperature differences determined with thermocouples varied with the thermocouple position. The differences typically ranged from a negligible amount (less than 1 °C) to about 6 °C; temperature differences as large as 16 °C were observed on the car dash.

NBSIR 74-535. **A selected and annotated bibliography of compilations of data relevant to biochemical thermodynamics,** G. T. Armstrong, G. R. Janes, and R. N. Goldberg, 81 pages (July 1974). Order from NTIS as COM 74-11659.

Key words: bibliography; biochemistry; biology; data compilations; thermochemistry; thermodynamics.

This report is a selected and annotated bibliography of sources of data compilations relevant to biochemical thermodynamics. Included in the annotations are brief descriptions of the type of thermodynamic properties tabulated, the class of materials dealt with, and the degree of completeness of the compilations.

NBSIR 74-537. **CODATA guidelines on reporting data for chemical kinetics,** 18 pages (Aug. 1974). Order from NTIS as COM 74-11577.

Key words: chemical kinetics; guidelines; recommended procedures for reporting data; standardization; units.

This document is a copy of the report, June 1974, of the Task Group on Data for Chemical Kinetics of the Committee on Data for Science and Technology (CODATA). In this report recommendations are made about the reporting of experimental chemical kinetics data.

NBSIR 74-539. **Energy conservation at the NBS laboratories,** J. D. Hoffman, 81 pages (July 1974). Order from NTIS as COM 74-11574.

Key words: contingency plans; electricity; energy conservation; heating fuels; humidity control; transportation.

An Energy Task Force was established at NBS to effect energy conservation, to develop contingency plans to keep the Laboratories functioning in the event of reduced energy supply and to assist employees with transportation problems. The NBS Laboratories use a total of ~ 115 million kWh of electricity and ~ 780 billion BTU of heating fuel annually to power equipment and to provide a reliable environment. The Task Force conducted a systems analysis of energy use and found that 85 percent of the energy is used in climate control. A mathematical model for the climate control system was developed that affords an accurate comparison between observed and calculated energy use. As part of the analysis of energy use, conservation measures were identified and implemented. These measures include lighting reductions, building and zone shut-downs, thermostat adjustments, and changes in cooling coil control parameters. The conservation actions resulted in a reduction of ~ 12 percent in electricity and ~ 18 percent in heating fuel. The Task Force formulated contingency plans to reduce energy use on short notice in preparation to respond to area-wide energy problems. These plans provide for a set of priorities to produce a reduction of 2-5 megawatts in electrical demand and for an effective doubling in oil storage capacity. Task Force recommendations address all phases of energy use and implementation of them will increase electricity conservation to ~ 15 percent and heating fuel conservation to ~ 21 percent.

NBSIR 74-541. **An evaluation of potentially useful separator materials for nickel-cadmium (Ni-Cd) satellite batteries,** H. A. Baker, S. D. Toner, and W. F. Cuthrell, 37 pages (Oct. 1974). Order from NTIS as COM 75-10618.

Key words: battery separators; nickel-cadmium batteries; satellite batteries; separator materials.

An evaluation intended to determine the potential suitability and probable efficacy of a group of separator materials for use in nickel-cadmium (Ni-Cd) satellite batteries was carried out. These results were obtained using test procedures established in

an earlier evaluation of other separator materials, some of which had also been used in experimental battery cells subjected to simulated use conditions.

The properties that appear to be most important are: high electrolyte absorptivity, good electrolyte retention, low specific resistivity, rapid wettability and low resistance to air permeation. Wicking characteristics and wet-out time seem to be more important with respect to the initial filling of the battery with the electrolyte.

While the properties of some of these materials indicate that they would be satisfactory, no specific conclusions can be drawn as to their actual effectiveness without further testing after they have been subjected to simulated use conditions in experimental cells.

NBSIR 74-542. **Economics of protection against progressive collapse,** R. E. Chapman and P. F. Colwell, 34 pages (Sept. 1974). Order from NTIS as COM 75-10081.

Key words: benefit-cost analysis; building safety; economics; progressive collapse; standards.

Public and government concern about the progressive collapse of buildings caused by abnormal loading has resulted in the development of draft standards to provide protection against progressive collapse. From society's viewpoint, standards for protection against progressive collapse should result in a level of protection which is more efficient (i.e., the net social benefits from protection should be increased). An economic model utilizing the principles of benefit-cost analysis is developed which establishes a methodology for determining the efficiency of various levels of protection against progressive collapse. An application of the model to a partial evaluation of a specific standard demonstrates some of the capabilities of the model. Recommendations are made for a complete evaluation of this standard and for the further refinement of the model.

NBSIR 74-543. **High temperature MHD materials,** S. J. Schneider, W. Capps, H. P. R. Frederikse, W. R. Hosler, D. A. Kauffman, E. M. Levin, C. L. McDaniel, T. Negas, and E. R. Plante, 129 pages (Aug. 1974). Order from NTIS as COM 74-11772.

Key words: coal slag; electrical conductivity (MHD); electrodes; insulators; MHD; MHD materials; MHD materials testing; phase equilibria (MHD); vaporization (MHD); viscosity (MHD).

Under the auspices of the Office of Coal Research the National Bureau of Standards has underway a program of materials research appropriate to magnetohydrodynamics (MHD). The overall objective of the work is to provide materials property information necessary for the design, construction, and operation of an open cycle, coal fired MHD electric generation plant. The program consists of several interrelated investigations in the areas of phase equilibria, electrical properties, vaporization, viscosity and materials testing. Initial work has centered on the behavior of coal slag but also encompasses the physical and chemical characteristics of other MHD process contaminants (alkali seed) and important electrode and insulator materials. The report summarizes the important technical results obtained during the period July 1, 1972-June 30, 1974 under the combined NBS-OCR program.

NBSIR 74-544. **Kerr coefficients of nitrobenzene and water,** R. E. Hebner, Jr., R. J. Sojka, and E. C. Cassidy, 35 pages (Aug. 7, 1974). Order from NTIS as COM 74-11525.

Key words: dielectric fluids; electrical properties of fluids; high voltage measurements; Kerr coefficient; Kerr effect; nitrobenzene; pulse measurements; water.

The Kerr coefficients of both water and nitrobenzene were measured and the variation of these quantities with temperature and wavelength was investigated. At a temperature of 296 K and at a wavelength of 632.8 nm, the following values for the Kerr coefficients were obtained $B(C_6H_5NO_2) = 3.24 \times 10^{-12}$ m/V^2, and $B(H_2O) = 3.43 \times 10^{-14}$ m/V^2.

The estimated uncertainty in the measurement in nitrobenzene is ± 6 percent while in water the estimated uncertainty is ± 8 percent.

The primary conclusion drawn is that although nitrobenzene can be used for accurate measurement of a wide, and fairly well defined, variety of high voltage pulses, the situation in water is more poorly understood. The primary areas of difficulty using water are the existence of turbulence under pulses of duration of a few microseconds and the possibility of a voltage dependence of the Kerr coefficient due to a saturation of the alignment of the molecules with the applied field.

NBSIR 74-545. **Notes on the fundamentals of measurement and measurement as a production process,** P. E. Pontius, 65 pages (Sept. 1974). Order from NTIS as COM 74-11656.

Key words: calibration; comparator; interferometer; length; long gage blocks; measurement process; uncertainty.

The concept of a measurement process as a production process is relatively new, having evolved in the last ten years. There have been significant contributions from many sources which have served to refine the initial ideas. The generalized concept of a measurement process is discussed together with techniques and examples for verifying the validity of the result. While some of the techniques may not be appropriate for certain highly specialized measurement processes, it is felt that the concepts are applicable to practically all measurement processes. For certain types of general measurement processes, which must operate in a variety of environments, and which must accommodate a variety of materials and properties, the techniques have been invaluable in understanding the manner in which measurement processes operate in a "real" world.

NBSIR 74-550. **Report to AID on an NBS/AID workshop on standardization and measurement services in industrializing economies,** M. B. McNeil, 92 pages (May 11-24, 1974). Order from NTIS as COM 74-11755.

Key words: AID; assistance; economics; foreign relations; industrializing nations; LDC's; measurement services; standardization.

On May 11-24, 1974, a Workshop was held at the National Bureau of Standards (Gaithersburg), under the sponsorship of AID, whose object was to give standards officials of industrializing nations insight into the standards and measurement systems in the United States and the role of the National Bureau of Standards, so that these officials might consider what parts of the U.S. system might usefully be adapted to conditions in their home countries. The report contains copies of speeches and presentations by representatives of both the U.S. and the industrializing nations, in addition to a general agenda of talks, presentations, and tours of laboratories both of NBS and of other organizations.

NBSIR 74-551. **An appraisal of methods for estimating self-reaction hazards,** W. Tsang and E. S. Domalski, 100 pages (June 1974). Order from NTIS as COM 74-11658.

Key words: activation energy; bond dissociation energy; computer programs; explosive sensitivity tests; heat of decomposition; oxygen balance.

The ability to identify and specify the thermal instability of chemical substances has been appraised as a result of examining

ertain test methods used to measure explosive sensitivity, and ertain computer programs designed to estimate reaction azards from a thermochemical approach. The bond dissociation nergy emerges as the parameter giving the best correlation with aterial sensitivity. The computer programs overemphasize exosive power as opposed to explosive sensitivity and label many ompounds hazardous when they are not. At present, regulations ecifying the handling and transport of commodities should folw the concept of self-reactivity based upon functional groups.

BSIR 74-552. **Technical manual for phosphor standards calibrator,** M. L. Greenough and H. K. Hammond III, 84 pages (Aug. 12, 1974). Order from NTIS as COM 74-11644.

Key words: fluorescence measurement; instrumentation, luminescence measuring; luminescence measurement; phosphorescence measurement.

This project involved two activities, 1) the fabrication and alibration of phosphor standards for use in the Postal Service lodel 4A8 Phosphoremeter and 2) the construction of an instruent to perform the calibration function. Both of these relate to andardization of the phosphorescent and fluorescent activity the luminescent coating applied to postage stamps by the Buau of Engraving and Printing. The purpose of the luminescent atings is to facilitate detecting the orientation of envelopes in cer-canceler machines during mail processing.

Work on the project entailed the fabrication of approximately phosphor standards, which are hand-sized aluminum blocks to which stamp-sized wafers of luminescent materials are ounted. Fabrication was carried out following the specific rocedures supplied by the Postal Service, with however, uthority to verify or alter the process as necessary. On the other ajor project effort, an instrument was designed and constructed llowing in general the basic design of an earlier breadboard evice developed under a prior project. In the system, quantitave evaluations are ultimately referred to calibrations at NBS of e relative irradiance of a lamp in the ultraviolet and visible reons of the spectrum.

This report, one of two covering the project, is in the form of chnical manual for the calibration instrument, and includes eory of operation, mechanical construction and detailed perating procedures.

BSIR 74-553. **Preparation and calibration of phosphor standards,** M. L. Greenough and H. K. Hammond, III, 70 pages (Oct. 1974). Order from NTIS as COM 75-10058.

Key words: fluorescence measurement; instrumentation, luminescence measuring; luminescence measurement; phosphorescence measurement.

This project involved two activities, 1) the fabrication and alibration of phosphor standards for use in the Postal Service lodel 4A8 Phosphormeter and 2) the construction of an instruent to perform the calibration function. Both of these relate to e standardization of the phosphorescent and fluorescent activi- of the luminescent coatings applied to postage stamps by the ureau of Engraving and Printing. The purpose of the luinescent coatings is to facilitate detecting the orientation of enelopes in facer-canceler machines during mail processing.

Work on the project entailed the fabrication of approximately phosphor standards, which are hand-sized aluminum blocks to which stamp-sized wafers of luminescent materials are ounted. Fabrication was carried out following the specific rocedures supplied by the Postal Service, with however, uthority to verify or alter the process as necessary. On the other ajor project effort, an instrument was designed and constructed llowing in general the basic design of an earlier breadboard evice developed under a prior project. Quantitatively in the system, evaluations are ultimately referred to calibrations at NBS of the relative irradiance of a lamp in the ultraviolet and visible regions of the spectrum.

This report, one of two covering the project activities, describes the preparation of luminescent wafers, their assembly into phosphor standards and the test procedures on completed standards. It includes a tabulation of the calibrated values of the new standards.

NBSIR 74-554. **City games, disk and tape generation,** J. Moriarty, 12 pages (Sept. 1973). Order from NTIS as COM 74-10703-2.

Key words: city model; computer; computer disks; computer tapes; duplicate tapes and disks.

This document contains the instructions for initializing duplicate disks for the CITY I model and duplicate tapes for the CITY IV model.

NBSIR 74-555. **City games, an executive's overview,** J. E. Moriarty, 50 pages (May 1974). Order from NTIS as COM 74-10704.

Key words: city; computer; computer games; economic; government; metropolitan; simulation; social.

The City Games are realistic gaming simulations of the operation of contemporary cities. They have been in continuous development since the 1960s with their completion by the National Bureau of Standards in 1973-74. In the City Games, participants experience intensive transactions in collaborative planning and in competitive negotiations for the allocation of limited resources. They emulate elements of the government, economic and social sectors of the city system and make planning decisions involving land use, schools, transportation systems, water and sewer facilities, zoning, tax structure, etc., etc.. In a 3-hour round of game play, representing a telescoped fiscal year, the decision maker makes quantitative decisions, implements them, and (through the computer aided simulation) sees the consequences of his actions. In successive rounds of play, the participant gains experience in trade-off negotiations, learns systematic approaches to typical problems and acquires new insights into the interdependences of the numerous components of a city system. City Game demonstrations can be conducted over a 2-3 day period and can accommodate between 30 and 60 active participants.

NBSIR 74-556. **City games, mathematical foundations,** J. E. Moriarty, Ed., 92 pages (Nov. 1973). Order from NTIS as COM 74-10703-1.

Key words: computer programs; computers; computer simulation; equations; mathematical foundations; mathematics; simulation; simulation module.

The CITY models are operational simulation games in which the participants make economic, government and social decisions affecting a hypothetical metropolitan area. Through the use of a computer, the simulated urban system responds to the participant's decisions as any real city would. To simplify the description of the theory of the CITY GAMES modules, this manual is written for the four module game. The equations for the other games can easily be obtained by eliminating the descriptors that do not apply to the particular game of intetest. The theoretical structure of all models is consistent and relevant only within the range from a central city area to a regional configuration. The description of the module components and equations are meant to show the scope of decisions including those by the user and by the programs and algorithms of the computer model.

NBSIR 74-557. **Non-metallic antenna-support materials,** N. Halsey, D. E. Marlowe, and L. Mordfin, 45 pages (June 1974). Order from NTIS as COM 75-11439.

Key words: composite materials; fiber-reinforced-plastic rod; glass-reinforced-polyester rod; guys, antenna; processing parameters, pultrusion; pultrusion; reinforced plastic rod; stress rupture of FRP rod; test methods, FRP rod; weatherability, FRP rod.

Thirteen samples of pultruded, glass fiber-reinforced-polyester rod material were manufactured using a different combination of the manufacturing process parameters for each. These samples were tested to evaluate the effects of nine different process parameters on the properties and characteristics of the rods. Elevated-temperature stress-rupture tests under saturated humidity were used as an accelerated measure of long-term weatherability. The test results were somewhat inconsistent, but it appears that certain process parameters, such as collimation and ultrasonic agitation of the rovings during pultrusion, were beneficial to both tensile strength and weatherability. Other parameters, such as pretensioning of the rovings, were beneficial to weatherability but detrimental to tensile strength. Additives to the resin system were generally detrimental.

A high speed tension test method was developed and it was found that the strength of the rod is substantially greater under high loading rates.

An approximate relationship was observed between transverse tensile strength and electrical breakdown voltage. However, neither of these characteristics, nor surface hardness, correlated with axial tensile strength or weatherability.

NBSIR 74-561. **Analysis of methodology for measuring national highway traffic safety,** R. G. Hendrickson and A. R. Craw, 42 pages (Sept. 1974). Order from NTIS as COM 74-11576.

Key words: highway traffic safety; indicators; safety program impact; traffic data systems.

This report covers a critique of current measures used by NHTSA to report and evaluate National Traffic Safety, and presents the development of proposed measures for evaluating the impact of NHTSA priority programs on the vehicle-driver-highway mix. The proposed measures emphasize the use of injury-severity levels and an extended set of driver-vehicle-highway descriptors to depict critical factors in National traffic patterns and trends. The conclusions and recommendations address extensions of current indicators to describe accident phenomena by driver and vehicle attributes, to enlarge the number and detail of descriptors of accident data and accomodate these extensions by more comprehensive development. Surrogates for National statistics and concentration of certain programs were investigated.

NBSIR 74-564. **Development and analysis of techniques for calibration of Kerr cell pulse-voltage measuring systems VIII,** R. E. Hebner, Jr., E. C. Cassidy, and R. J. Sojka, 55 pages (Aug. 21, 1974). Order from NTIS as COM 74-11726.

Key words: calibration; electrical measurements; high voltage measurements; insulating fluids; Kerr coefficient; nitrobenzene; pulse voltage measurement; space charge; water.

This report documents recent progress in the refinement of techniques for accurate calibration of pulsed voltage measurement based on the electro-optic Kerr effect. The work includes a discussion of calibration techniques and a comparison of calibrations performed in various laboratories. In addition the Kerr coefficients of water, nitrobenzene and Halowax oil were determined. The measurements in Halowax oil were performed under direct, 60 Hz alternating, and pulsed high voltage. The measurements of the Kerr coefficient of nitrobenzene and water were performed under pulsed high voltage, but measurements of the space charge dynamics in nitrobenzene under low frequency alternating voltage are discussed.

NBSIR 74-567. **FY 74 progress report on design criteria an methodology for construction of low-rise buildings to resi typhoons and hurricanes,** N. J. Raufaste, Jr., and R. D Marshall, 276 pages (July 1, 1974). Order from NTIS as CON 74-11631.

Key words: buildings; construction; data acquisition equip ment; design criteria; extreme winds; information transfe instrumentation; wind loads; wind tunnel modeling.

This report gives the major accomplishments of the secon phase of a three year project to provide engineering and technica assistance to the Agency for International Development (AID Department of State in developing improved design criteria fo low-rise buildings to better resist extreme winds. During FY 74 the Center for Building Technology project staff members com menced several tasks. These tasks will serve as major inputs t the development of improved design criteria. The principal task include: 1) selecting a second and third field test site in th Philippines, 2) instrumenting four full scale houses, at the site 3) instrumenting the University of Philippines wind tunnel facil ty, 4) participating in an International Workshop at Manila du ing November 1973, and 5) developing, in conjunction wit short-term consultants in Bangladesh and Jamaica, a methodolo gy for the transfer of technology.

NBSIR 74-568. **FY 75 project plans Law Enforcement Standard Laboratory,** 62 pages (Sept. 1974). Order from NTIS as CON 74-11578.

Key words: communications equipment; forensic science Law Enforcement Standards Laboratory; LESL; per formance standards; project plans; protective equipmen security equipment; standards.

Plans are presented for seventeen projects approved an funded for FY-75. They include plans for the preparation of pe formance standards, user guidelines and reports on law enforce ment equipment in the communications, security, protectiv equipment, investigative aids, courtroom equipment and com pliance testing areas.

NBSIR 74-572. **Torsional buckling of composite cylindrical shells** D. E. Marlowe and G. F. Sushinsky, 60 pages (Sept. 1974) Order from NTIS as COM 74-11791.

Key words: aircraft structures; buckling; composite materi als; metal reinforcement; stability; stacking sequence; thi shells; torsion.

The elastic buckling strength has been determined for thin walled composite and composite-reinforced-metal cylindrica shells. Tests were performed on boron/epoxy and graphite/epox y-all-composite specimens, on boron/epoxy-reinforced-titaniur specimens and on boron/epoxy and graphite/epoxy-reinforce aluminum specimens. Cylinders were tested with severa unidirectional-ply and cross-ply layups.

The results of the tests were compared with the bucklin strengths predicted by the torsional buckling analysis of Cha For the cylinders which fail by buckling, the experimental buck ling torques were approximately 81 percent of the torques pre dicted by the analysis.

The experimental results of tests on 39 specimens ar presented. Torsional buckling strengths which differ by as muc as a factor of two may result from reversing the direction of twi of a thin-walled cross-ply composite cylinder. This has bee shown to be equivalent to reversing the stacking sequence of th laminate. This is of potential importance in applications wher reversals of loading may occur. An "optimum" stackin sequence which produced significant increases in the predicte and measured buckling loads was determined. Cylinder fabricated with this stacking sequence exhibit considerable in creases in the strength-to-weight ratio over other sequences ex amined.

NBSIR 74-577-1. **Remittance processing system, Volume I (Refer to Volume II)**, P. D. Shupe, Jr., P. Meissner, and J. R. Park, 194 pages (Sept. 1974). Order from NTIS as COM 74-11723.

Key words: audit trail; check endorsement; check handling; data entry; document labeling; labeling; listing; man machine interface; MICR printing; remittance processing; remittance register.

The Remittance Processing System is a prototype developed for the Internal Revenue Service to test a new concept in automating the processing of taxpayer remittances. Central to the new processing concept was the integration of the Direct Data Entry System. Initial Entry Station with equipment components that would eliminate a number of individual manual operations, permit operator interface with the central DDES computer, and provide for verification of initial entry, check endorsement, audit trail data, remittance documentation, and affixing information to taxpayer documentation accompanying the remittance. This report describes the equipment which was configured to implement these processes and to demonstrate the viability of the concept.

NBSIR 74-577-2. **Remittance processing system. Volume II (Reference Volume I)**, P. D. Shupe, Jr., P. Meissner, and J. R. Park, 317 pages (Sept. 1974). Order from NTIS as COM 74-11724.

Key words: audit trail; check endorsement; check handling; data entry; document labeling; labeling; listing; man machine interface; MICR printing; remittance processing; remittance register.

The Remittance Processing System is a prototype developed for the Internal Revenue Service to test a new concept in automating the processing of taxpayer remittances. Central to the new processing concept was the integration of the Direct Data Entry System. Initial Entry Station with equipment components that would eliminate a number of individual manual operations, permit operator interface with the central DDES computer, and provide for verification of initial entry, check endorsement, audit trail data, remittance documentation, and affixing information to taxpayer documentation accompanying the remittance. This report describes the equipment which was configured to implement these processes and to demonstrate the viability of the concept.

NBSIR 74-578. **Development of microwave hygrometer model III**, D. P. Stokesberry and S. Hasegawa, 14 pages (Sept. 1974). Order from NTIS as COM 74-11765.

Key words: dew-point; hygrometer; microwave hygrometer.

This is a progress report on the design and construction of NBS microwave hygrometer, Model III. The hygrometer is intended for field or laboratory operation with a dew point range of − 40 to 40° C.

NBSIR 74-580. **Spectral characteristics of additional Bar Code Readers. II**, J. Cohen, 12 pages (Sept. 1974). Order from NTIS as PB248465.

Key words: bar code reader; filters; optical wedge; photodetector; relative spectral output; wavelength.

The spectral characteristics of two bar code readers (submitted by the U.S. Postal Service under Task No. 1, Agreement No. 74-02934 [Mod. No. 1]) have been measured as a function of wavelength in the approximate interval of 450 to 1200 nm.

NBSIR 74-581. **Development of a solid sorption tube for sampling hydrogen fluoride in the work atmosphere**, J. Wing and J. K. Taylor, 45 pages (Oct. 1974). Order from NTIS as COM 75-10127.

Key words: air analysis; air sampling; gas analysis; hydrogen fluoride; industrial hygiene; sodium acetate; sorber; solid; work atmosphere.

The efficiencies of several solid substances in a sorption tube for collecting trace quantities of hydrogen fluoride gas in work atmosphere have been evaluated. Reagent-grade sodium acetate crystals proved to be a very efficient sorbent for hydrogen fluoride. Its solubility in water and pH buffer properties are highly advantageous for subsequent fluoride determination by the ion selective electrode. Experimental results are presented for collection efficiencies of hydrogen fluoride gas at several concentration levels, flow rates, and collection times, the effects of elevated temperatures and humidity, and also breakthrough, bleed-out, storage and shipment studies. Specifications for construction of the sorption tubes are also given.

NBSIR 74-582. **FY 1973 progress report on design criteria and methodology for construction of low-rise buildings to better resist typhoons and hurricanes**, N. J. Raufaste and R. D. Marshall, 31 pages (July 2, 1973). Order from NTIS as COM 74-11645.

Key words: construction; design criteria; extreme winds; full-scale test buildings; housing; instrumentation; wind tunnel.

This report highlights the major accomplishments of the initial phase of a three fiscal year project to provide engineering technical assistance to the Agency for International Development (AID) for the development of design criteria for low-cost/low-rise buildings to better withstand the effects of extreme winds. This phase represents approximately a 3 month level of effort. During this period CBT project staff members commenced six introductory tasks. These tasks will set the pace for the second fiscal year level of effort. The tasks included: initiate dialogue with local organizations and institutes in developing countries, establish a local Philippine advisory committee; conduct on-site visits to developing countries to identify local professional candidates for short term consultating; conduct on-site visits to developed countries to collect information from research centers; purchase initial wind tunnel and full-scale field test instrumentation; and commence library search of related subject documents.

NBSIR 74-583. **The role of passive film growth kinetics and properties in stress corrosion and crevice corrosion susceptibility**, J. Kruger and J. R. Ambrose, 88 pages (Sept. 1974). Order from NTIS as AD767326.

Key words: chloride; crevice corrosion; ellipsometry failure prediction; molybdenum; repassivation kinetics; stainless steels; stress corrosion; testing techniques.

A study of the effect of alloying chromium and molybdenum in ferritic stainless steels has been made using techniques to study repassivation kinetics (tribo-ellipsometry) and depassivation kinetics (a recently developed ellipsometry technique for studying optical changes occurring within a crevice). Results indicate that chromium additions affect both repassivation and depassivation processes while molybdenum appears to affect only the repassivation processes. A discussion is given of a generalized mechanism for localized corrosion which postulates that susceptibility to attack is determined by the competition between depassivation and repassivation processes.

Constant strain rate studies were performed using AISI 304 stainless steel exposed to acidified 1.ON NaCl solution (pH = 3.0). In this particular environment, repassivation kinetics measurements using the tribo-ellipsometric technique had shown

that the metal dissolution rates were rather large due to reduced film repair kinetics, indicating the possibility of susceptibility to stress corrosion cracking (SCC). Reduced time to failure and maximum sustained load at a one strain rate suggest a relationship between SCC, repassivation kinetics,,and rate of pure metal production.

A review of current approaches to the study of stress corrosion and a discussion of how these approaches can lead to new failure prediction tools is given.

NBSIR 74-586. **Calibration of platinum resistance thermometers using an intercomparison scheme,** R. M. Schoonover and H. H. Ku, 19 pages (Dec. 1974). Order from NTIS as COM 75-10525.

Key words: adjustment for trend; calibration; capsule type thermometers; intercomparison; IPTS-68; platinum resistance thermometers; wire-to-wire calibration.

In this report we describe a procedure for the calibration of capsule type platinum resistance thermometers, PRT(s), using one or more standard platinum resistance thermometers, SPRT(s), in the temperature range of 0-35 °C. These PRT(s) were designed to be used in density work through hydrostatic weighing where SPRT(s) cannot be used because of space and other limitations, but the procedure is thought to be generally useful in other applications as well.

The schedule of intercomparisons was designed to eliminate possible trends in temperature variations of the constant temperature bath setup. Results of calibration can be expressed either in terms of the two constants alpha (α) and delta (δ), or in a table relating $R(t)/R(0)$ to t_{68} within the range of calibrations.

The uncertainty of the values of t_{68} calibrated by this procedure is believed to be within 2 millidegrees Celsius, not including the uncertainty of the SPRT that is used as standard.

NBSIR 74-588. **Development of a bench test for Type X core gypsum board,** J. L. Houser, 26 pages (Dec. 1974). Order from NTIS as COM 75-10040.

Key words: building codes; construction materials; fire endurance ratings; fire tests; gypsum.

This paper describes the development of a test method for determining that the core material in a gypsum board sample qualifies as Type X. A 2 inch (5.08 cm) by 16 inch (40.64 cm) specimen is flexurally stressed during the test by suspending a weight from the cantilevered end of the test sample. The specimen is swiveled into the center of a two burner turbulent flame at an average temperature of 1,780 °F (971 °C). The burners are positioned from above and below. The test is terminated when the specimen either breaks or deflects through an arc three times the specimen thickness. Results show this method to be repeatable with a coefficient of variation equal to ± 8 percent for a given type of material from a single manufacturer.

NBSIR 74-590. **A study of the feasibility of establishing generic environmental test parameters for all consumer products,** S. D. Toner, 9 pages (Mar. 1975). Order from NTIS as COM 75-11434.

Key words: environmental tests; product safety.

A study was conducted to determine the feasibility of establishing a set of generic environmental test parameters that would be applicable to all types of consumer products, with a potential for developing injury producing hazards as a result of environmentally induced failure. It was concluded that this approach is not a practical one. It is apparent that the safeness of a product or type of product should be determined on the basis of simulated environmental tests appropriate to its specific end use.

NBSIR 74-591. **Some problems noted in the use of Taguchi semiconductor gas sensors as residential fire/smoke detectors,** R. W. Bukowski and R. G. Bright, 12 pages (Dec. 1974). Order from NTIS as COM 75-10101.

Key words: false alarm; fire detector; fire test; residential smoke detector; semiconductor gas sensor; sensor contamination.

This paper examines some aspects of Taguchi semiconductor gas sensors and their use as residential fire/smoke detectors based on theoretical and experimental considerations. It was found that these sensors have difficulty detecting fires involving complete combustion along with a greater than normal propensity to false alarm to other than fire conditions. Both of these problems raise serious questions as to the suitability of these sensors as residential fire/smoke detectors, at least at their present state of development.

NBSIR 74-595. **A procedure for estimating automobile fuel consumption on congested urban roads,** D. M. Levinsohn and J. T. McQueen, 20 pages (Aug. 1974). Order from NTIS as COM 75-10057.

Key words: automobile fuel consumption; congestion; energy conservation; fuel consumption; impact assessment; roadway operating environment; urban roads; vehicle characteristics.

Energy consumption is an important measure of the performance of a transportation system. To be able to accurately measure associated automobile fuel consumption will improve the evaluation of urban transportation alternatives. An estimated procedure is proposed that is designed to be particularly sensitive to automible fuel consumption in congested, peak hour traffic. This procedure is based upon vehicle attributes and roadway operating conditions which were determined through an extensive review of the auto fuel consumption literature. Vehicle attributes include characteristics of the automobile that affect fuel consumption. Roadway operating conditions comprise the types of driving to which the automobiles are subjected. Vehicles are classified by weight and model year. The proposed roadway classifications are expressway, arterial, and local street. For each vehicle type category, base fuel consumption rates are determined. These base consumption rates are then modified by adjustment factors which reflect the roadway operating conditions. The rates are multiplied by the vehicle miles of each vehicle category and summed over all categories to compute the total fuel consumption on the road under analysis. An example application of the procedure including sensitivity analyses is presented. The base fuel consumption rates can be obtained from EPA emissions test data. Research is required to determine the adjustment factors, particularly under conditions of extreme roadway congestion.

NBSIR 74-596. **Radiative heat transfer from products of combustion in building corridor fires,** K. Bromberg and J. G. Quintiere, 28 pages (Feb. 1975). Order from NTIS as COM 75-10209.

Key words: combustion products; full-scale fire; radiative heat transfer.

The contribution of radiative heat transfer from hot combustion products to corridor floors is examined. Data from full-scale corridor fire experiments is used to calculate emissivity and absorptivity of the combustion products. An empirical model based on attenuation by absorption is used to specify the absorption coefficient due to particulates in the products. In these experiments it is shown that radiation from the combustion products is just as significant as radiation from convectively heated walls and ceiling of the corridor. Calculations show that

he ratio of radiant heat transfer to the floor due to ceiling emis-ion to that by combustion product emission ranges from about .2 to 0.7. Also, molecular gas radiation and particulate radiation an both be significant for the combustion products. Calculations now that the emissivity of the gaseous combustion products lone would be about 0.3, but the inclusion of soot particles ields an emissivity for the total combustion product mixture of s high as 0.73, based on the experimental data considered.

IBSIR 74-597. **Piezoelectric accelerometer low-frequency response by signal insertion methods,** R. S. Koyanagi and J. D. Pollard, 33 pages (May 1975). Order from NTIS as COM 75-11069.

Key words: accelerometer; calibration; low frequency; signal insertion; vibration.

The purpose of this study was to compare the frequency esponse of selected piezoelectric accelerometers using a signal nsertion method to the response using traditional mechanical ibration tests. Signal insertion methods included "voltage inser-on" and "change insertion" techniques. The signal is inserted t series with the electrical low-side of the accelerometer by neans of a suitable series resistance. Commercially available in-ertion devices were used. Confidence in the use of insertion nethods is increased where there is agreement between the esults from insertion tests and mechanically excited tests.

IBSIR 74-600. **Thermodynamics of chemical species important to rocket technology,** C. W. Beckett, 200 pages (Oct. 1, 1974). Order from NTIS as ADA008935.

Key words: bibliography on spectroscopy of fluorides and oxides of the lanthanide series; calculation of dissociation energies; electrical resistivity; enthalpy of transition; graphite; infrared matrix isolation spectroscopy; melting point; radiance temperature; reaction of Ba(g) and excited ozone; reaction of Fe(g) and oxygen; review of literature on rate of effusion and mass-spectrometric data; scandium group and rare-earth gaseous monoxides; specific heat; total emittance; vanadium; zirconium.

Using a subsecond-duration transient technique the specific eat, electrical resistivity, and hemispherical total emittance ere simultaneously measured over the temperature range 1500-000 K for some grades of graphite. Similar measurements were ade on vanadium, and zirconium in the temperature range of 500-2100 K. Melting points and radiance temperature (at 650 m) are reported for zirconium and molybdenum. The tempera-re of the transition from the α-β phase of zirconium and the nergy difference of these phases has also been measured using he subsecond duration transient technique.

The products of the reaction of Fe(g) and 0_2 have been in-estigated and identified using the methods of infrared matrix olation spectroscopy. A preliminary report on the study of the eaction of Ba(g) with vibrationally excited ozone is also resented.

The dissociation energies of the scandium group and rare-arth gaseous monoxides are evaluated by reviewing the litera-re available on Knudsen effusion rates and mass-spectrometric ata. Criteria are discussed for choosing data for evaluation of issociation energies. A bibliography of the available literature n the spectroscopy of fluorides, oxides, and oxyfluorides be-onging to the lanthanide series is given.

IBSIR 74-602. **Efficient methods of extreme-value methodology,** J. Lieblein, 32 pages (Oct. 1974). Order from NTIS as COM 75-10048.

Key words: distribution of largest values; efficient estimators; extreme values; linear unbiased estimators; statistics; Type I distribution.

This report presents the essentials of modern efficient methods of estimating the two parameters of a Type I extreme-value distribution. These methods are an essential phase of the analysis of data that follow such a distribution and occur in the study of high winds, earthquakes, traffic peaks, extreme shocks and extreme quantities and phenomena generally. Methods are given that are appropriate to the quantity of data available—highly efficient methods for smaller samples and nearly as efficient methods for large or very large samples. Necessary tables are provided. The methods are illustrated by examples and summarized as a ready guide for analysts and for computer programming. The report outlines further work necessary to cover other aspects of extreme-value analysis, including other distribution types that occur in failure phenomena such as consumer product failure, fatigue failure, etc.

NBSIR 74-605. **Crush characteristics of automobile structural components,** D. C. Robinson, 65 pages (Jan. 1975). Order from NTIS as COM 75-10464.

Key words: automobile side impact; crush characteristics; displacement measurements; door structure; drop tests; dynamic crush tests; impact collisions; plastic deformation; static crush tests; strain measurements; structural components; test procedures.

Static and dynamic test procedures were developed for evaluating the crush characteristics of automotive structural components which perform a major structural function in side impacts. Laboratory tests were conducted on several 1969 to 1971 4-door intermediate size automobiles to evaluate the crush characteristics of some of their structural components. Static crush tests were conducted in the 12-million-lbf capacity universal testing machine at the National Bureau of Standards, employing its large working space. The dynamic tests were conducted using the monorails attached to the sensitive crosshead and the tie-down floor system which is incorporated in the foundation of this machine. The crush loads were applied perpendicular to the vehicle side for each of the tests. The response of the structural components was established based on the evaluation of displacement and/or strain measurements and detailed examination of the permanently deformed components following each test. Empirical factors were obtained which are useful for comparison of static and dynamic crush characteristics of a vehicle side door structure over a limited loading range. Further development of the test procedures is required in order to extend the range over which such results would be meaningful.

NBSIR 74-606. **Consumer product noise: A basis for regulation,** P. G. Weissler, G. A. Zerdy, and S. G. Revoile, 80 pages (Nov. 1974). Order from NTIS as COM 75-10340.

Key words: consumer products; criteria for safety standards; federal regulations; hearing impairment; hearing survey; noise emission; speech communication interference.

The Consumer Product Safety Commission is charged with the responsibility for promulgating safety standards to protect the public against unreasonable risks of injury associated with consumer products. There is a risk of injury from noisy products, directly by damage to hearing and indirectly by degradation of essential speech communication. This report develops criteria relevant to the specification of Safety Standards for noisy consumer products. Consumer product noise is discussed in relation to the existing body of knowledge regarding noise induced hearing loss and speech communication. Levels of product noise are identified that should protect against hearing impairment and against speech communication degradation. Methods of measurement for consumer product noise are described and a bibliography of standards relevant to the regulation of noisy consumer products is provided. A list of products that are potentially hazardous to the hearing of the operator is included with

typical levels and usage patterns. The list is based upon reported data and some measurements made at NBS. Possible discrepancies among noise regulations established by different governmental agencies are discussed with suggestions for obtaining uniformity.

NBSIR 74-608. **Procedure for measuring noise emission from power lawn mowers,** J. I. Adler, 19 pages (Nov. 1974). Order from NTIS as COM 75-10056.

Key words: emergency messages; hearing loss; lawn mowers; noise emission; noise pollution; product safety.

A procedure is described for measuring the noise emission from power lawn mowers. The procedure covers both walk-behind and riding mowers, including suggestions of maximum noise levels for protection from hearing loss and for reception of emergency messages. The procedure employs a microphone located near the ear of the operator and mounted on a back-pack worn by the operator.

NBSIR 74-610. **Investigation of procedures for determination of thermal performance characteristics of plastic piping used in housing,** M. Tryon, 36 pages (Nov. 1974). Order from NTIS as COM 75-10072.

Key words: chlorinated polyvinyl chloride; hardness; internal stress; polyvinyl chloride; thermal mechanical analysis (TMA); thermal properties; thermogravimetric analysis (TGA); thermoplastic pipe.

The rapid growth of the use of thermoplastic pipe for plumbing in housing has prompted a study to determine the critical factors affecting the performance of the pipe materials. The emphasis in this preliminary study is on thermal properties such as the softening point, relaxation of thermal stress, glass transition temperature, hardness-temperature relationship, and decomposition temperature. The techniques used were thermal mechanical analysis (TMA), thermogravimetric analysis (TGA), and hardness. Preliminary results obtained on several pipe samples of PVC and CPVC commercial samples are reported.

NBSIR 74-612. **Building and evaluation of a second polluted air delivery system,** G. P. Baumgarten, 11 pages (Nov. 1974). Order from NTIS as COM 75-10414.

Key words: air pollution; critical flow; laminar flow; nozzle; porous plug; sulfur dioxide concentration; carbon dioxide concentration.

The building and evaluation of a second configuration of a prototype SO_2 and CO polluted air delivery system (PADS) is discussed. The delivery system was built to deliver sulfur dioxide (SO_2) and carbon monoxide (CO) at a rate of 5 liters per minute. The design concentrations by volume were 1.0, 0.5, 0.1, and 0.04 parts per million (ppm) of SO_2 in air and 50, 20, and 2 parts per million of CO in nitrogen. It consists of a diluent air delivery system utilizing a critical flow sonic nozzle and three separate pollutant flow systems utilizing laminar flow porous plugs, one plug for each desired output concentration. The system is contained in a dispatch case and the gases are delivered to it from pressurized containers through detachable supply lines.

By maintaining specific upstream pressures on the critical flow nozzle and the laminar flow porous plugs, PADS 2 produced average output concentrations of: 0.95, 0.50, 0.117, and 0.057 ppm of SO_2; and 52.9 and 18.1 ppm of CO. These concentrations were determined by measurements with NBS calibrated analyzers. The expected output concentrations were 0.03, 0.52, 0.103, and 0.05 ppm of SO_2 and 51.2, 18.0, and 1.49 ppm of CO based on flow calibrations of the individual components. The uncertainty of the output concentration is estimated to be about 7 percent.

NBSIR 74-613. **Preliminary study of the slipperiness of flooring,** A. P. Cramp and L. W. Masters, 42 pages (July 1974). Order from NTIS as COM 75-10059.

Key words: floor slipperiness; resilient flooring; slipperiness standards; frictional tests; slip tests; coefficient of friction; human perambulation.

The National Commission on Product Safety reported in 1970, that falls in the home each year kill about 12,000 and injure 6,000,000 in the U.S.A. Slippery floors are listed as a large contributor to these very high casualty figures. Although there are some standardized test methods that are or might be suitable for such standards, there are no slipperiness standards for flooring. Thus, there is an immediate need for studies aimed at the development and establishment of such standards. Consequently, a preliminary study of floor slipperiness was sponsored by the Building Safety Section of the Center for Building Technology. The study included a state-of-the-art investigation on flooring slipperiness research and a laboratory evaluation of three existing test methods for measuring floor slipperiness. Samples of the three most commonly used resilient flooring materials, namely: vinyl asbestos, vinyl and linoleum were used in the study. The sliding material components for the frictional tests were leather and a commonly used styrene butadiene sole and heel rubber. The tests were performed both dry and wet. The results from this study were used in planning a large comprehensive study, which would lead to the development of accepted floor slipperiness standards. This report contains the results of the preliminary study.

NBSIR 74-614. **Mechanical tests of flammable liquid containers,** N. Halsey, A. F. Kirstein, and R. E. Snyder, 35 pages (Dec 1974). Order from NTIS as COM 75-11013.

Key words: consumer products; flammable liquid containers; gasoline cans; mechanical tests; product standards safety.

Because of the concern for safety in the storage and use of gasoline and other flammable liquids around the home, this study was made to determine if standards can be established to minimize the flammable liquid hazard by controlling or standardizing the containers. Attention was focused on performance standards for stability, leakage, carrying handle strength, and pour spout strength. In general, it was found that the technology involved in existing voluntary standards for safety cans could be applied to flammable liquid containers for home use for all of the above factors except pour spout strength.

NBSIR 74-618. **US/UK joint complementary research program in building, (wind loads, water supply, fire detection), July 1973 June 1974,** C. C. Raley, I. A. Benjamin, L. S. Galowin, and R. D. Marshall, 23 pages (Oct. 1974). Order from NTIS as COM 75-11014.

Key words: building technology; cooperation; fire safety hydraulics; wind loads.

This is a status report of the progress achieved under the "Joint Complementary Research Program" sponsored by the Building Research Establishment (UK) and the Institute for Applied Technology (US), during the period July 1973 through June 1974. The program includes three projects: Wind Loads on Buildings, Design of Water Supply and Drainage Installations in Buildings, and Fire Detection in Buildings, each of which is discussed in the report.

NBSIR 74-619. **Measurement methodology for determining the sound output of toy guns,** M. A. Cadoff and D. S. Blomquist, 17 pages (Aug. 1974). Order from NTIS as COM 75-10047.

Key words: children; consumer safety; guns; hearing damage; noise; standard apparatus; toys.

In recent years, a great concern has been expressed for consumer protection and safety, especially for children. As an outgrowth of this concern, acoustical testing of potentially-hazardous noise-producing toys has been carried out at the National Bureau of Standards for the Consumer Product Safety Commission under the authority of the Toy Safety Act of 1969. This report outlines a methodology which was developed to measure the noise levels of toy guns. In addition, the rationale and technical back-up for the methodology are discussed, and the regulations setting allowable noise levels for toy guns are given.

NBSIR 74-620. **An in-line density and viscosity sensor,** L. O. Olsen and F. W. Ruegg, 20 pages (Nov. 1974). Order from NTIS as PB246622.

Key words: capillary tubes; density sensor; flow nozzle; laminar flow; liquid properties; viscosity sensor.

In-line density and viscosity sensors for liquids are developed to utilize measurements of differential pressure across a nozzle and a coiled capillary tube respectively, with known flowrates through each provided by a flow generator. Theory and principles of operation and instructions for calibration and use of the sensors are discussed, along with design consideration for the sensors and associated equipment. A calibration of the sensors demonstrated that viscosity and density each could be measured with a computed standard deviation of one percent. Viscosity was varied over the range of about 1 to 11 centistokes whereas density of the fluids used was near 0.8 g cm^{-3}. Application of well known similarity considerations is used to make the results applicable to other liquid densities, provided influence of other liquid properties (high vapor pressure, for instance) does not interfere.

NBSIR 74-621. **Stability and strength of home playground equipment,** B. M. Mahajan, 39 pages (Dec. 1974). Order from NTIS as COM 75-10422.

Key words: home playground equipment; stability; strength; test; testing; tipping.

Stability tests were performed on some items of home playground equipment to measure the magnitude of the force, applied to generate tipping moment, required to start the tipping of the equipment.

Strength tests were conducted by loading certain components of home playground equipment with estimated loads to determine if the tested equipment had adequate strength.

NBSIR 74-623. **Stability and abuse tests of riding toys,** W. C. Brown and H. A. Baker, 87 pages (Jan. 1975). Order from NTIS as COM 75-10210.

Key words: abuse testing; dynamic stability; hazards; obstruction; riding toys; stairway; static stability; test weight; tilt angle; toy testing.

Stability and abuse tests were conducted on 88 riding toys in order to provide information which can be utilized to set realistic abuse performance levels for riding toys, as well as characterize the types of stability hazards associated with this class of toys. The results of these tests are summarized in tabular form and a description of the discrepancies encountered as well as photographs of these discrepancies are presented.

The appendices of this report contain photographs of each test specimen as well as the tabulated raw data for each test conducted.

NBSIR 74-624. **The Shirley Highway Express-Bus-on-Freeway Demonstration Project. A study of reverse commute service,** R. Waksman, 44 pages (Dec. 1974). Order from NTIS as COM 75-10412.

Key words: bus-on-freeway operations; choice and captive riders; cost allocation formula; incremental costs and revenues; reverse commute bus service; Shirley Highway; transportation planning.

Bus-on-freeway operations generally provide peak period commuter transit service to persons traveling from suburban residences through congested corridors to jobs in the major employment centers of metropolitan areas. In a few cases, peak period reverse commute operations may provide service to persons traveling from residences near the downtown employment centers to jobs in the suburbs. In early 1973, two major Shirley Highway Express-Bus-on-Freeway Demonstration Project reverse commute routes began service to office buildings in Northern Virginia.

An analysis of this reverse commute service revealed that it was a successful operation because it provided considerable benefits to its patrons and was slightly profitable to the bus operator on an incremental cost basis.

Four conditions which were important for the success of the service were found to be important for the success of reverse commute operations, in general. The conditions are as follows: (1) A given route should serve a concentrated, high employment area. (2) The route should be accessible to people currently working within the employment area and to captive riders who can fill jobs there. (3) It should be possible to fit most of the reverse commute trips into existing bus schedules. (4) It should be possible to pair with peak direction trips any trips that cannot be fit into existing bus schedules.

Using a procedure which incorporates these conditions, one employment area within the Shirley Highway Corridor was identified as having potential as a market for a reverse commute service.

NBSIR 74-625. **Examination of failed two inch steel pipe natural gas main, Columbia Gas Company, Spring Garden Township, York County, Pennsylvania,** T. R. Shives, 41 pages (Jan. 1975). Order from NTIS as PB243547.

Key words: brittle fracture; gas main pipe; impact; low carbon steel; stress corrosion cracking.

The Mechanical Properties Section of the National Bureau of Standards examined a length of a cracked two inch diameter plain carbon, welded steel natural gas main pipe at the request of the Office of Pipeline Safety. The pipe had a transverse crack extending about 85 percent of the circumference. The pipeline had suffered considerable mechanical damage in the vicinity of the failure, and the crack, which propagated in an essentially brittle manner, appeared to have initiated in a gouged area near the bottom of the pipe. There was a considerable amount of corrosion product on the surface of the pipe in the gouged area. The amount and distribution of corrosion product on the fracture surface indicated that the crack had formed in at least two stages, and that a crack was present prior to the time of failure. During the first stage, the crack may have penetrated the entire wall thickness of the pipe in one region opposite the crack origin near the bottom of the pipe. The likely mechanism of fracture for the first stage of the crack appears to be stress corrosion cracking. For the second stage of the crack, either stress corrosion cracking or impact appears to be the likely mechanism of failure.

NBSIR 74-626. **Semiconductor nuclear radiation detector studies—A final report,** A. H. Sher, 10 pages (Sept. 1974). Order from NTIS as COM 75-10411.

Key words: carrier trapping; gamma-ray detector; germanium; Ge(Li) detector; infrared response; silicon.

In response to a problem that arose with regard to the availability of germanium for lithium-drifted germanium detectors [Ge(Li) detectors], a comprehensive program was undertaken aimed toward the development of a method for the rapid specification of germanium quality for nuclear radiation detector use, and the determination of factors affecting germanium quality. Measurements on a large number of germanium crystals, most of which had been rejected for detector use, and intercomparison of these measurements and the methods employed, led to significant developments in the measurement of lithium mobility and driftability, carrier trapping, and semiconductor defect and impurity determination via an improved infrared response (IRR) technique. The present improvement of the infrared response technique resulted in the observation of a number of discrete energy levels lying within the forbidden gap of germanium unobserved in previous studies. It was possible to assign the proper position of energy levels detected by IRR in the upper or lower half of the energy gap. It was thus possible, in some instances, to determine the nature of the defects responsible for the observed energy level from results reported in the literature. The goal of developing a method for the rapid specification of germanium quality was achieved.

NBSIR 74-627. **The influence of ink on the quality of fingerprint impressions,** R. T. Moore, 16 pages (Dec. 12, 1974). Order from NTIS as COM 75-10134.

Key words: film thickness; film uniformity; fingerprint impressions; fingerprint readers; image quality; ink films; lubricity.

Tests were conducted on several types of ink to determine their influence on the quality of fingerprint impressions which they could produce. The thickness and uniformity of the film used to ink the fingers were found to be the most significant factor in providing high quality impressions. A method is described for metering out printer's ink and estimating whether or not a uniform film of near optimum thickness has been rolled out on a glass inking plate.

NBSIR 74-628. **Mass transport and physical properties of large crystals of calcium apatites: Studies of $Ca(OH)_2$ crystals for use in electrolytic conversion of calcium fluorapatite crystals to calcium hydroxyapatite,** A. D. Franklin and K. F. Young, 22 pages (Sept. 1, 1973-Aug. 31, 1974). Order from NTIS as COM 75-10514.

Key words: Ac impedance; calcium apatites; calcium hydroxide; crystal growth; electrolysis; interfacial polarization; ionic conduction; mass transport.

In order to convert single crystals of calcium fluorapatite to calcium hydroxyapatite, an electrolytic cell technique will be explored. To utilize such a technique, the cathode compartment must consist of a source of hydroxyl ions and a barrier to the flow of all others. $Ca(OH)_2$ has been selected for the cathode material, backed by a Pt electrode in an atmosphere containing H_2O and O_2. $Ca(OH)_2$ crystals have been grown and Ag as well as Pt electrodes applied to them. Their ac admittance as a function of temperature has been measured and analyzed. A Warburg contribution to the admittance was observed to depend upon the presence of O_2. Equivalent circuits have been generated from the data allowing us to tentatively characterize the electrical properties of the electroded crystal system.

NBSIR 74-629. **Thermal properties of selected plastic piping used in housing,** M. Tryon, 28 pages (Apr. 1975). Order from NTIS as COM 75-11281.

Key words: ABS; coefficient of expansion; CPVC; glass transition temperature; hardness; PB; polybutene; polyvinyl chloride; PVC; residual stress; thermoplastic piping.

In a study of four thermoplastic piping materials, the following performance-related properties were measured: coefficient of thermal expansion, glass transition temperature, residual stress, hardness, and hardness-temperature coefficient. The purpose of the study was to determine typical values of these properties for each of the piping materials. Results are given with recommendations for performance tests and changes in previously-proposed interim performance criteria.

NBSIR 74-631. **Analysis of proposed air drying process,** L. Greenspan, 11 pages (Dec. 1974). Order from NTIS as COM 75-10208.

Key words: absorption; drying; phosphorous pentoxide; water vapor.

NASA proposal No. 7401-6-01A by the GCA Corporation describes a proposed air drying process which has been analyzed. The drying process, intended to reduce the water vapor content of a stratospheric sample to below one part per million by weight, is based upon the removal of the water as it passes through a phosphorous pentoxide absorber. The analysis indicates that the method is feasible. Dependence on ram pressure to maintain flow through the absorber appears questionable and consideration should be given to other means.

NBSIR 74-632. **Comparison of accelerated aging of book papers in 1937 with 36 years natural aging,** W. K. Wilson and E. J. Parks, 96 pages (Dec. 19, 1974). Order from NTIS as PB246554.

Key words: accelerated aging; aging; natural aging; paper, permanent; paper, stability; permanent papers; record papers; stability of paper.

A group of 36 book papers made in the NBS paper mill in 1937 were tested in 1937 before and after accelerated aging for 72 hours at 100 °C, and in 1973 after 36 years of natural aging. The data show that fairly good correlations exist between accelerated aging and natural aging when changes in alpha cellulose, copper number and, to a lesser extent, tearing strength, were used as criteria of change. pH is a reasonably good criterion of stability. It appears that zero span tensile strength, wet strength as a percentage of dry strength, and brightness are useful criteria for evaluating the aging of paper. When data in this report are compared with data from earlier reports, it appears that dry accelerated aging at 100 °C more nearly corresponds to natural aging than accelerated aging at 90 °C and 50 percent relative humidity.

NBSIR 74-633. **The NBS computerized carpool matching system User's guide,** J. F. Gilsinn and S. Landau, 64 pages (Dec 1974). Order from NTIS as COM 75-10691.

Key words: carpool matching; carpools; computer programs; transportation; urban transportation.

This report documents the NBS computerized carpool matching programs and the procedures used in maintaining the coordinate data base required by the matching system. The report includes flowcharts, input/output formats, and program listings for the programs, plus details of the manual process for coordinate coding. The matching program produces, for each person desiring it, a list of others residing within a pre-specified distance of him, and is thus applicable to a single work destination having primarily one work schedule. The system is currently operational on the National Bureau of Standards' UNIVAC 1108 computer and was run in March of 1974, producing lists for

bout 950 employees in less than four minutes computer time. ubsequent maintenance of the system will be carried out by the IBS Management and Organization Division.

IBSIR 74-634. **Method of testing for rating thermal storage devices based on thermal performance,** G. E. Kelly and J. E. Hill, 45 pages (May 1975). Order from NTIS as COM 74-10685.

Key words: solar energy; standard; standard test; thermal performance; thermal storage; thermal test.

A study has been made at the National Bureau of Standards of ie different techniques that could be used for testing thermal orage devices and rating them on the basis of thermal per-rmance. This document outlines a proposed standard test ocedure based on that study. It is written in the format of a andard of the American Society of Heating, Refrigerating, and ir Conditioning Engineers and specifies the recommended ap-ratus, instrumentation, and test procedure.

BSIR 74-635. **Method of testing for rating solar collectors based on thermal performance,** J. E. Hill and T. Kusuda, 63 pages (Dec. 1974). Order from NTIS as COM 75-10276.

Key words: solar collector; solar energy; solar radiation; standard; standard test; thermal performance.

The National Bureau of Standards has made a study of the dif-rent techniques that could be used for testing solar collectors d rating them on the basis of thermal performance. This docu-ent outlines a standard test procedure based on that study. It is itten in the format of a standard of the American Society of eating, Refrigerating, and Air Conditioning Engineers and ecifies the recommended apparatus, instrumentation, and test ocedure.

BSIR 75-637. **Note on simplified estimators for type I extreme-value distribution,** J. Lieblein, 14 pages (Dec. 1974). Order from NTIS as COM 75-10055.

Key words: bias; efficiency; extreme values; linear unbiased estimators; simplified estimators; statistics; type I distribution.

Methods for extreme-value analysis (for the Type I extreme-lue distribution) that have optimum properties involve up to 20 antities (depending on sample size) whose values are known 6 decimal places. The present note shows how to modify these much simpler values involving 2 decimal places that are more nvenient to use yet sacrifice very little of the optimum fea-es.

BSIR 75-639. **Optical materials characterization,** A. Feldman, D. Horowitz, R. M. Waxler, I. Malitson, and M. J. Dodge, 17 pages (Jan. 1975). Order from NTIS as COM 75-10135.

Key words: coefficient of thermal expansion; elastic constants; infrared laser window materials; photoelasticity; polycrystalline ZnSe; refractive index; stress-optical constants; thermal coefficient of refractive index.

We have measured the following parameters of chemical vapor posited polycrystalline ZnSe (CVD ZnSe): Refractive index d change of index of refraction with temperature (dn/dT) over e wavelength range 0.5 μm to 18 μm using the method of nimum deviation; the coefficient of linear thermal expansion d dn/dT at 10.6 μm using Fizeau interferometry; and the stic moduli and photoelastic moduli using Fizeau and yman-Green interferometry. A sensitive technique has been veloped for measuring stress-optical constants of materials t exhibit a small stress-optical effect.

NBSIR 75-641. **Performance of mobile homes data acquisition and analysis methodology,** J. H. Pielert, W. E. Greene, Jr., L. F. Skoda, and W. G. Street, 75 pages (Feb. 1975). Order from NTIS as COM 75-11209.

Key words: construction; Hurricane Agnes; housing; mobile homes; mobile home parks; performance data; regulatory process; standards.

In a study at the National Bureau of Standards (NBS), funded by the Department of Housing and Urban Development (HUD), methods for inspecting mobile homes to identify performance problems, recording the problems and analyzing the problem data were developed. Maintenance work orders for 2881 mobile homes, a part of 12,500 provided by HUD for emergency housing in the aftermath of Hurricane Agnes, at Wilkes-Barre, Pa., were reviewed and computer coded by an interdisciplinary team of engineers. Also, performance data were obtained from State and other Federal agencies for over 967 privately owned mobile homes. A second task was the field inspection of 257 mobile homes to assist in the determination of the causes and consequences of the problems identified in the data acquisition task. Computer techniques were developed to process the data and print out problem summation tables, graphs to establish trends, compile data on obvious problems and ferret out those problems which may not be obvious. This first report documenting the data acquisition and analysis methodology will be followed by a series of reports which will present results and relate them to current standards, the regulatory and insurance processes.

NBSIR 75-647. **Mechanical tests of FAA-E2491 airport in-pavement approach and threshold lights,** D. C. Robinson, 26 pages (Jan. 1975). Order from NTIS as COM 75-10418.

Key words: airport approach and threshold lights; glass prism; impact tests; light bases; optical cover assembly; photometric measurements; static tests.

Static and impact load tests were performed on two style FAA-E-2491 airport in-pavement approach and threshold lights which were mounted in light bases encased in concrete. Static tests were conducted using either a 6-inch diameter steel plate or a rubber pad through which loads were applied to the center of the light optical cover assembly. Drop tests were conducted using a 5-lb steel ball which was directed to impact at various locations on the optical cover assembly. The old style lights were found to comply with load requirements for the current specification. The maximum load sustained by both style lights when loaded through a rubber pad was about two-thirds of the maximum load sustained when loading directly through the steel plate. A discussion is given of the photometric measurements of the light beam displacement measured during the load tests, the deflections and strains of two new style lights measured under two loading conditions and the test procedures for determining the performance of approach and threshold lights.

NBSIR 75-649. **Computer applications at the Ecuadorian Institute of Standardization (INEN): Observations and recommendations,** J. Hilsenrath, 16 pages (Apr. 1975). Order from NTIS as PB241237.

Key words: computer applications; OMNITAB II: Minitab; statistical computing; text editing.

This report contains specific suggestions for computer applications at the Ecuadorian Bureau of Standards (INEN). The suggestions, based on observations and discussion during a 10-day visit by the author in Quito, Ecuador, cover editing and typesetting of Ecuadorian standards, data storage and retrieval, and statistical analysis of experimental data.

NBSIR 75-651. **Procedural options to reduce the risk of injury from products installed in residences,** S. W. Stiefel, C. W. Hand, and D. W. Corrigan, 94 pages (June 1975). Order from NTIS as COM 75-11211.

Key words: building codes; Consumer Product Safety Act; product safety; residence-related products; residential safety; safety implementation approaches; safety standards.

The Consumer Product Safety Commission's (CPSC) list of consumer products with high relative incidence of reported injuries includes many products which are integral parts of the consumer's residence, such as stairs, doors, architectural glass, furnaces and water heaters. The safety aspects of these products are influenced by on-site construction practices and design considerations which are regulated through local building codes. The problem is to identify operational methods the CPSC can employ in dealing with unreasonable hazards associated with component parts of residential units.

This report identifies, for products installed in homes, (1) the product history stages, (2) institutional groups, (3) hazard sources, and (4) countermeasures available to the CPSC. It structures relationships among these four elements for evaluating the impacts of alternative countermeasures. Current mechanisms for control of products installed in homes are presented and sixteen potential countermeasures are postulated.

NBSIR 75-652. **Procedures for estimating sound power from measurements of sound pressure,** C. I. Holmer, 78 pages (July 1975). Order from NTIS as COM 75-11399.

Key words: air compressors; error of sound power measurement; noise; noise measurement; sound power level; standard test procedures for sound power measurement.

This report describes investigations of the accuracy and precision of various measurement methodologies for determining the estimated sound power output of "large" machines in the free field over a reflecting plane. One purpose of this investigation is to place empirical error bounds on many of the free field measurement procedures currently proposed or in use; and in particular, compare the results of "near-field" and "far-field" measurements. The sources used for the investigation included 17 portable air compressors of various types (powered by internal combustion engines), a "reference" sound source, and a loudspeaker driven by a pure tone source. The data recorded include sound pressure level (A-weighted, linear, and 1/3-octave band) on an 84 point hemispherical array of seven metre radius, and "near-field" measurements, sampled every square metre, on a rectangular surface one metre from the machine surface. These data were reduced to provide information on the deviation of "near field" sound power determinations from "far-field" power level (using subsets of the data as appropriate to various methodologies). The measured data for seventeen sources suggests that the value of a sound power estimate based on "near-field" sound pressure level measurements may be an upper bound to the sound power level estimated from far field measurements, subject to the limitations of sampling error. Estimates of total achievable measurement error of A-weighted sound power level of near field determinations relative to far field determinations are made for several measurement methodologies, based on the experimental data.

NBSIR 75-653. **Measurement methodology and supporting documentation for portable air compressor noise,** C. I. Holmer, 48 pages (Jan. 1975). Order from NTIS as PB248097.

Key words: acoustics; air compressor; internal combustion engine; noise; sound power level; sound pressure level.

This report presents recommendations and supporting rationale on a measurement methodology for portable air compressors. The methodology provides for the determination of A-weighted sound power level or the equivalent weighted sound pressure level at a reference distance. A-weighted level is used because of its correlation with community response to noise from internal combustion engine noise. It is recommended, however, that the spectra associated with the regulated source be monitored in some manner to insure that the spectra remain similar to those for which A-weighted sound level retains good correlation with community response. The methodology uses weighted sound level measurements at eight positions on a curved surface surrounding the source at a distance of one metre from the surface of the machine. Data recorded at these positions are used to calculate the average weighted sound pressure level of the machine on the measurement surface. This is combined with the area of the measurement surface to give the sound power level of the machine. From this value, a rating sound pressure at a rating distance may be calculated by subtracting a constant value. Procedures which permit the rapid estimation of A-weighted sound level are included. These are applicable for estimation of A-weighted sound level in a variety of circumstances when the sound power or equivalent sound pressure level at a reference distance is known.

NBSIR 75-654. **NBS interagency transducer project—A project report,** P. S. Lederer and J. S. Hilten, 15 pages (Feb. 20, 1975). Order from NTIS as COM 75-10367.

Key words: calibration; dynamic; photo flashbulb; pressure; pressure measurement; pressure transducer; thermal transient; transducer.

A method is being developed to apply short-duration thermal transients to pressure transducers and to observe the effects of these transients on transducer performance. The method consists of monitoring pressure transducer output as the transducer is exposed to radiation resulting from the ignition of a photographic flashbulb or from the discharge of an electronic flash. During this reporting period, the work has been exploratory in nature to determine values for method parameters. Thermal energy pulses as high as 0.4 J lasting 4 ms have been generated using an electronic flash; pulses as high as 1 J lasting 18 ms have been generated using No. 22 flashbulbs.

Work being performed for other agencies is also described briefly.

NBSIR 75-658. **Electron microscopic observations of microcracking about indentations in aluminium oxide in silicon carbide,** B. J. Hockey and B. R. Lawn, 39 pages (Jan. 1975). Order from NTIS as AD-A007445.

Key words: brittle solids; dislocation networks; electron microscopy; healing; indentations; microcracking; moiré patterns.

Transmission electron microscopy is used to examine the nature of microcracking about small-scale indentations in two highly brittle solids, sapphire and carborundum. The observed crack geometry is discussed in terms of an earlier model of indentation fracture beneath a point force, in which both loading and unloading half-cycles contribute to the crack growth. The residual interfaces are characterised mainly by moiré patterns sometimes by dislocation networks. These observations are discussed in relation to spontaneous closure and healing mechanisms, and the "lattice mismatch" necessary for the production estimated at about one part in a thousand. It is shown that cleavage steps comprise the main source of obstruction to lattice restoration across the interfaces. Mechanical and therm

eatments of the indented surfaces are found to influence the ex-nt of the residual cracking. Some practical implications of the bservations are discussed.

BSIR 75-659. **A new mode of chipping fracture in brittle solids, and its application in a model for wear under fixed abrasive conditions. I. Mode of chipping fracture. II. Wear model,** B. R. Lawn, 49 pages (Feb. 1975). Order from NTIS as COM 75-10515.

Key words: abrasion; brittle solids; brittle surfaces; chipping; fracture; hardness; indentation; residual stress; stress analysis; wear rate.

A description is given of the mode of chipping fracture ob-rved in highly brittle solids. It is pointed out that residual resses about indentation deformation centers play a vital role. he implications of this mode in a number of mechanical nenomena are discussed.

An explicit model for the wear of brittle surfaces under fixed brasive conditions is presented in terms of indentation fracture ncepts. The predicted wear rate for glass agrees with that ob-rved experimentally to within an order of magnitude. Some im-ications concerning the parameters which influence the abra-on process, particularly the hardness, are discussed.

BSIR 75-660. **Voluntary labeling program for household appliances and equipment to effect energy conservation: Annual report for calendar year 1974,** B. J. McGuire and E. A. Vadelund, 46 pages (Feb. 1975). Order from NTIS as COM 75-10609.

Key words: consumer information; consumer products; energy conservation; energy efficiency; energy use; household appliances; household equipment; labeling; residential.

The Voluntary Labeling Program for Household Appliances d Equipment to Effect Energy Conservation was established response to an April 18, 1973 Presidential directive. Final ocedures for the program became effective October 26, 1973. nly major energy consuming household appliances and equip-ent are covered. Purposes of the program are to encourage anufacturers to place energy efficiency labels on their ap-iances and to encourage consumers to utilize this information making purchase decisions.

Specifications containing labeling requirements for each type product are developed by NBS with assistance from con-mers, retailers, manufacturers and interested Federal agen-es. During the first full year of program operation, final specifi-tions for labeling room air conditioners and proposed specifi-tions for labeling refrigerators, combination refrigerator-eezers, and freezers were issued. Two consumer information mphlets were published and other consumer information and ucation activities were undertaken. Labeling specifications for ater heaters, clothes washers and dryers, and ranges and ovens ere under development. This was accomplished, with sistance from manufacturers, retailers, consumers and other encies, by a staff of six funded at a level of $375,000 per year.

At year's end, twenty-four room air conditioner manufacturers d private brand labelers, representing an estimated 95 percent U.S. sales of this appliance, were participating in the program.

BSIR 75-661. **Strength degradation of brittle surfaces: Sharp indenters,** B. R. Lawn, E. R. Fuller, and S. M. Wiederhorn, 38 pages (May 1975). Order from NTIS as COM 75-10763.

Key words: brittle solids; ceramic surfaces; degradation; fracture; indentation; strength.

A theory of strength loss for brittle surfaces in contact situations, developed in a previous paper for "blunt" indenters, is here extended to the case of "sharp" indenters. A prior fracture mechanics analysis of crack growth beneath ideal cone indenters serves as the basis for predetermining the prospective surface degradation of ceramic components in service. Compared to blunt indenters, severe degradation can occur at the lower contact loads. However, at high loads the extent of degradation becomes remarkably insensitive to indenter geometry. Essential theoretical predictions are verified by bend tests on glass slabs. The effect of indenter "sharpness" and initial specimen surface flaw state are investigated systematically, along with some secondary rate effects in the contract process. The possibility of minimizing degradation via adjustment of material parameters (including hardness) or surface condition (e.g., residual stresses, frictional properties) is briefly discussed.

NBSIR 75-662. **Sulphur dioxide reference materials,** J. K. Taylor and E. R. Deardorff, 16 pages (Feb. 1975). Order from NTIS as COM 75-10420.

Key words: air pollution; chemical analysis; pararosaniline method; quality control; reference materials; sulfur dioxide.

The development of reference materials to serve for quality control and performance evaluation of measurements of sulfur dioxide by the pararosaniline method is described. Powder samples consisting of sodium sulfite dispersed in mannitol can be prepared to evaluate measurements for the concentration levels of ambient interest. The samples are sufficiently stable in routine use, with a service life of at least three months. By the use of a series of five samples of graded sulfite content, measurement errors greater than five percent are significantly detected. A detailed procedure for preparation of the samples is included. Preliminary studies of an alternate method for preparation of quality control samples, by a freeze-drying process are also described.

NBSIR 75-664. **Strength degradation of brittle surfaces: Blunt indenters,** B. R. Lawn, S. M. Wiederhorn, and H. H. Johnson, 40 pages (Feb. 1975). Order from NTIS as ADA007447.

Key words: brittle solids; ceramic surfaces; cracks; degradation; fracture; Hertzian; indentation; strength.

Indentation fracture mechanics is used to develop a theoretical basis for predetermining the strength properties of brittle surfaces in prospective contact situations. Indenters are classified as "blunt" or "sharp," of which only the first is considered in the present work. The classical Hertzian cone crack conveniently models the fracture damage incurred by the surface in this class of indentation event. Significant degradation is predicted to occur at a critical contact load; however, with increasing load beyond this critical level the degradation rate becomes relatively slight. Bend tests on abraded glass slabs confirm the essential features of the theoretical predictions. The role of controlling variables in the degradation process, notably starting flaw size and indenter radius, is systematically investigated. An indication is also given as to optimisation of material parameters. The analysis leads to some novel suggestions concerning surface preparation procedures that might be followed in order to minimize strength losses.

NBSIR 75-665. **Point-to-Point Trip Management Program (preliminary analysis),** W. G. Kienstra and D. J. Minnick, 26 pages (Feb. 7, 1975). Order from NTIS as COM 75-10421.

Key words: computers; information systems; mass transportation; telephone systems.

This preliminary analysis of Point-to-Point Trip Management (PTPTM) was prepared for the Urban Mass Transit Administra-

tion in Washington, D.C. PTPTM is concerned with providing prospective riders of mass transit with the necessary detailed information for particular trips. This report contains the results of a literature search on automation in the telephone information center, and analyzes the data collected from 29 existing centers. Additionally, on-site visits were made to three operational centers, and tapes of actual telephone inquiries and responses were obtained and analyzed. The use of microfiche and computers are examined as an aid to the operators in these centers. Total automation of these centers is also discussed. Conclusions and recommendations for further study in this area, and an annotated bibliography, are also part of this report.

NBSIR 75-666. **Post optimality and parametric analysis with the National Bureau of Standards' linear programming subroutine RVSMPX,** T. B. Ayers, 47 pages (Feb. 1975). Order from NTIS as COM 75-11381.

Key words: algorithms; linear programming; parametric programming; post-optimality analysis.

This report is a sequel to NBS Report 10695 (February 1972), "The National Bureau of Standards' Linear and Quadratic Programming Subroutines," which documented one phase of an effort to provide users, of the facility operated by the National Bureau of Standards' Computer Services Division, with reliable, clearly-described solution algorithms for selected frequently-arising classes of special mathematical problems. The present report presents subroutines which perform post-optimality analysis and parametric programming studies on linear programming problems solved by the National Bureau of Standards' RVSMPX subroutine. (The present versions of these codes use internal storage only).

NBSIR 75-667. **Interaction of blood proteins with solid surfaces,** R. R. Stromberg, B. W. Morrissey, L. E. Smith, W. H. Grant, and C. A. Fenstermaker, 42 pages (Jan. 15, 1975). Order from NTIS as PB241267.

Key words: adsorption; blood protein; bound fraction; ellipsometry; implants; polymer adsorption; protein adsorption; synthetic implants.

The adsorption of blood proteins on surfaces has been investigated in order to develop a detailed understanding of the initial series of events that occur when a synthetic material is implanted in the cardiovascular system. The overall objective of the investigation is to help provide a rational basis for the characterization and design of materials and the development of test methods. The relationship between surface charge and protein-surface interaction was investigated quantitatively by in situ ellipsometry to determine the molecular extension and adsorbance of fibrinogen, serum albumin, and γ-globulin on platinum as a function of impressed surface potential. For all three proteins, no change in adsorbance from the value at rest potential occurred as the surface potential was progressively made more anodic until a critical potential was attained, at which time the adsorbance increased significantly. The changes in extension observed as a result of changes in induced surface potential indicated, however, that conformational changes in the adsorbed layer were occurring as a result of surface potential. The determination of the bound fraction (fraction of carbonyl groups directly in contact with the surface) and extension of adsorbed γ-globulin and β-lactoglobulin as a function of solution concentration indicate conformational changes with surface population. Similar measurements on γ-globulin crosslinked prior to adsorption indicate that the native conformation exists at low surface coverage. Investigation of the rates of desorption of albumin from silica into buffer indicates a fast initial desorption followed by a considerably slower desorption removing most, but not all, of the adsorbed protein during the time periods investigated.

NBSIR 75-672. **A preliminary approach to performance requirements and criteria for electrical connections in residential branch circuit wiring,** W. J. Meese, R. L. Cilimberg, and A. A. Camacho, 37 pages (Mar. 1975). Order from NTIS as COM 75-10338.

Key words: branch circuits; contact resistance; electrical codes; electrical connections; fire safety; housewiring; performance testing.

During the Operation BREAKTHROUGH Research and Demonstration program the U.S. Department of Housing and Urban Development became concerned with the inability to properly evaluate innovative electrical connections. Innovation in electrical connections has been very slow because of the long life requirements, stringent fire safety requirements, long established conventional practices and evaluation procedures and lack of a performance base for describing requirements. This preliminary report presents the framework for a proposed method to evaluate electrical connections on a performance basis and supplements information contained in a previous report on current technology of electrical connections used in residential branch circuit wiring. Innovations involving electrical connections may lead to significant advancements in housing construction if it can be demonstrated that functional and safety requirements over the expected life of electrical connections were adequately satisfied. Research is needed to enable prediction of long-term performance of electrical connections based on the results of accelerated performance tests.

NBSIR 75-673. **Development of a fire test method for flexible connectors in air distribution systems,** L. A. Issen, 31 pages (April 1975). Order from NTIS as COM 75-10921.

Key words: aluminum; ducts; fire tests; flexible connectors; furnace pressures; glass fiber; heat ventilating and air conditioning systems; high-rise buildings; optical density; steel; terminal units.

The report describes fire tests on four flexible connectors of the type used in air conditioning systems. Four flexible connectors (aluminum, felted glass fiber, steel, and woven glass fiber) were exposed to a standard ASTM E-119 fire test. The results were in agreement with previous results in which a different sized branch duct was used in the assemblies. The results indicated a need to control furnace pressures. The test results were used to develop a proposed test method for fire testing flexible connectors. This proposed test method is described in the report.

NBSIR 75-675. **Evaluation of x-ray fluorescence analysis for the determination of mercury in coal,** R. L. Myklebust, M. M. Darr, and K. F. J. Heinrich, 20 pages (Dec. 1974). Order from NTIS as COM 75-10686.

Key words: background; mercury in coal; trace analysis; x-ray fluorescence; x-ray spectrography.

Limits of detection for mercury in coal have been determined on both a wavelength-dispersive and an energy-dispersive x-ray spectrometer. They are between 2 and 3 ppm under best conditions for both spectrometers. Techniques for reducing the background intensity measured by the energy-dispersive system are discussed along with methods of preparing coal specimens for analysis in both instruments.

NBSIR 75-677. **Hazard assessment of aluminum electrical wiring in residential use,** E. D. Bunten, J. L. Donaldson, and E. McDowell, 58 pages (Dec. 1974). Order from NTIS as COM 75-10516.

Key words: aluminum wire; consumer product safety; electrical failures; electrical fires; electrical wiring; fire hazard

In the mid-1960s, aluminum wire began to be used in significant quantities for residential branch-circuit wiring. Reports of problems from various localities in the U.S. raised serious concern and controversy as to the safety of this application. An official determination on this matter is within the jurisdiction of the Consumer Product Safety Commission. This report reviews the history of the use of aluminum in residential wiring and describes the characteristics essential to data to be used to evaluate the performance of aluminum wiring in the field. The examination of existing field data shows that no available data have the characteristics necessary to develop a reliable estimate of the level of risk to consumers associated with aluminum wiring. Neither can the available data be used to establish the relative risk of aluminum compared to copper wiring. There is only a gross estimate of the extent to which aluminum wiring is now in use in U.S. residences. Statistically sound estimates of risk would be possible only after data collection on a large scale.

NBSIR 75-678. **Analysis of construction systems for the thermal classification of residential buildings,** S. T. Liu, 59 pages (Nov. 24, 1975). Order from NTIS as PB248687.

Key words: building classification; building thermal mass; building thermal performance; building thermal time constant; housing systems; industrialized housing; mass per unit area; Operation BREAKTHROUGH; U-value.

This report is the result of a study to classify various kinds of residential buildings in relation to their thermal behavior. A collection of various building data and construction systems taken from the proposals of 18 of the 22 Housing System Producers participating in the Department of Housing and Urban Development (HUD) Operation BREAKTHROUGH Program is presented. Thermal performance parameters of buildings, such as: U-value, thermal mass, thermal time constant, and mass per unit area were computed and analyzed. The report recommends one way in which construction systems could be classified. Since the housing systems studied represented a cross section of the conventional residential construction systems in the building industry, it is felt that a realistic classification procedure for typical residential buildings can be established and based upon the parameter: mass per unit area. A more refined procedure of subviding the building within each mass class on the basis of the building thermal time constant is also discussed.

NBSIR 75-679. **Measurements of the behavior of incidental fires in a compartment,** J. B. Fang, 29 pages (Mar. 1975). Order from NTIS as COM 75-10419.

Key words: buildings; combustibility; fire intensity; flames; furnishings; heat release; ignition; smoke; thermal radiation; upholstery; waste receptacle.

A variety of upholstered chairs and wood cribs were burned within a ventilated compartment. The experimental measurements of weight loss, smoke concentration, temperature and heat flux levels are summarized. A reproducible fire obtained from burning a standardized wood crib array was found to be capable of representing the essential features of incidental fires of moderate intensity.

NBSIR 75-680. **Mobile home construction standards adopted by state regulatory programs—an analysis,** P. W. Cooke, L. P. Zelenka, and H. K. Tejuja, 107 pages (Mar. 1975). Order from NTIS as COM 75-10423.

Key words: enforcement; legislation; mobile homes; regulation; standards; state-of-the-art study.

This study examines the extent to which the nationally recognized standard for the construction of mobile homes (i.e., ANSI Standard A119.1/NFPA 501B) has been adopted and amended by the individual States that have implemented enforcement programs for the regulation of mobile homes. Summary data is presented on the existing status of the various versions of the standard adopted in each State. State-adopted amendments to the technical requirements in the national standard are compiled by State and construction discipline for comparative analysis.

NBSIR 75-682. **Basic considerations of densitometer adjustment and calibration,** R. E. Swing, 18 pages (Feb. 3, 1975). Order from NTIS as COM 75-10524.

Key words: calibration; calibration table; densitometer; densitometry; optical density; optical density standard.

The adjustment and calibration of a densitometer are considered. This is accomplished through the use of physical measurement standards with a procedure appropriate for the instrument, and brings the instrument response in line with measurements traceable to NBS. The difference between primary and secondary physical measurement standards for diffuse (visual) density is discussed. A calibration table is suggested for best use of the instrument and a computer program (BASIC language) is provided that will calculate and print a table relating instrument reading to diffuse (visual) density.

NBSIR 75-685. **Improved ultrasonic standard reference blocks,** D. G. Eitzen, G. F. Sushinsky, D. J. Chwirut, C. J. Bechtoldt, and A. W. Ruff, 83 pages (Apr. 1975). Order from NTIS as COM 75-10690.

Key words: aluminum ultrasonic standards; ASTM-type reference blocks; fabrication of reference blocks; immersion testing; longitudinal waves; metallurgical variables; nondestructive testing; pulse-echo; steel ultrasonic standards; titanium ultrasonic standards; ultrasonics.

A program to improve the quality, reproducibility and reliability of nondestructive testing through the development of improved ASTM-type ultrasonic reference standards is described. Reference blocks of aluminum, steel, and titanium alloys are to be considered. Equipment representing the state-of-the-art in laboratory and field ultrasonic equipment was obtained and evaluated. RF and spectral data on ten sets of ultrasonic reference blocks have been taken as part of a task to quantify the variability in response from nominally identical blocks. Techniques for residual stress, preferred orientation, and micro-structural measurements were refined and are applied to a reference block rejected by the manufacturer during fabrication in order to evaluate the effect of metallurgical condition on block response. New fabrication techniques for reference blocks are discussed and ASTM activities are summarized.

NBSIR 75-687. **Effective use of computing technology in vote-tallying,** R. G. Saltman, 140 pages (Mar. 1975). Order from NTIS as COM 75-11137.

Key words: computer security; computing technology; election administration; public administration; state and local government; systems analysis; technology utilization; vote-tallying.

The results of a systems analysis and evaluation conducted on the role of automatic digital processing in vote-tallying are presented. Included in the report are descriptions of hardware, software, and administrative problems encountered in fourteen elections in which electronic computing technology was utilized.

Methods of assuring more confidence in the accuracy and security of the vote-tallying process are presented and described. These methods include aids to audits of calculations, physical controls over ballots and computer records, and guidelines for the use of computer programs, computer facilities, and teleprocessing. Methods of improving the election preparation process also are presented and described. These involve the

development and implementation of design specifications and acceptance tests for computer programs, election equipment and supplies, and guidelines for pre-election checkout of vote-tallying systems and for assurance of management control.

Institutional factors are discussed which should be considered if improved accuracy and security controls and more effective election preparations are to be implemented. Recommendations for additional research and other activities including a possible Federal role are provided.

NBSIR 75-688. **Performance of mobile homes—A field inspection study,** L. F. Skoda, J. H. Pielert, W. E. Greene, and W. G. Street, 119 pages (June 1975). Order from NTIS as COM 75-11222.

Key words: enforcement process; field inspection; house trailers; housing; Hurricane Agnes; mobile homes; performance data; standards.

A field inspection study of mobile homes was conducted for the Department of Housing and Urban Development. The objective of the study was to evaluate the causes of mobile home problems by physically inspecting available units at various locations in the United States. A total of 257 units were inspected consisting mostly of mobile homes purchased by HUD and used as temporary housing for victims of the 1972 Hurricane Agnes disaster. The total number of problems found was 3,528 for the 257 units inspected. Of these problems, 2120 were directly related to inadequacies in the ANSI A119.1 Standard for Mobile Homes or the mobile home enforcement process (plan review, certification of designs, plant inspection), 934 were routine maintenance problems, and 374 were attributed to mechanical/electrical appliances and equipment. This report presents a computer listing of all problems plus photographic examples of observed problems.

The number of mobile homes included in this study is small when compared to the total number of mobile homes now in use in the United States. Additionally, this was a problem oriented study and did not attempt to document the many areas of satisfactory mobile home performance.

NBSIR 75-689. **The Shirley Highway Express Bus-on-Freeway demonstration project/a study of park-and-riding,** J. T. McQueen, G. K. Miller, and C. Harrison, 51 pages (Mar. 1975). Order from NTIS as COM 75-11190.

Key words: bus-on-freeway operations; commuter surveys; mode choice decisions; park-and-ride; Shirley Highway; transportation planning.

The market for fixed route transit operations is not limited to travelers within walking distance of transit stops. This was demonstrated by the Shirley Highway Express-Bus-on-Freeway Project as project promoted park-and-ride operations led to sizable increases in bus patronage: Park-and-riders, commuters who traveled by auto to a bus stop and then by bus to work, greatly expanded the market for the fixed route bus service in the Shirley Highway Corridor area.

This report presents results of a study of the successful park-and-ride operation within the Shirley Highway Corridor area: Suburban fringe parking lots coupled with the high speed buses of the Shirley Highway Express-Bus-on-Freeway Project. Demographic characteristics of the park-and-riders as well as characteristics of their present park-and-ride and previous commute trips are examined. Factors important in the commuters' decisions to park-and-ride are identified. The report also describes the survey procedures used in the study.

NBSIR 75-690. **A compilation of problems related to the performance of mobile homes,** W. G. Street, W. E. Greene, J. H. Pielert, and L. F. Skoda, 86 pages (Apr. 1975). Order from NTIS as COM 75-11207.

Key words: computer techniques; enforcement process; housing; Hurricane Agnes; mobile home parks; mobile homes; performance data; standards.

Performance of mobile homes as housing units is of broad concern to mobile home owners. This study report prepared at the National Bureau of Standards (NBS) and funded by the Department of Housing and Urban Development (HUD) presents mobile home problem data obtained from two separate data sources. The first data base for 2881 units was selected from maintenance records retained by HUD on 12,500 mobile homes used as emergency housing following the Hurricane Agnes disaster at Wilkes-Barre, Pennsylvania. The second source consisted of data for 967 privately-owned units collected from the files of various Federal, state, and private agencies responsible for regulation or consumer protection functions with regard to mobile homes. The mobile home performance problem data was processed using computer techniques to produce problem summation tables which facilitated evaluation. Although the mobile home problems experienced in various categories are highlighted in this report, no attempt was made to relate these results to current standards, regulatory or mortgage insurance (durability) processes. Analyses of this kind are planned for future reports in this series.

NBSIR 75-691. **A characterization and analysis of NBS corridor fire experiments in order to evaluate the behavior and performance of floor covering materials,** J. G. Quintiere, 89 pages (June 1975). Order from NTIS as COM 75-11015.

Key words: corridor fire spread; energy release rate; fire induced flow; flame propagation; flashover; floor coverings; radiant heat flux.

Data is presented for four fire experiments which examine the fire propagation from a room fire to a floor covering material in a corridor. The four floor covering materials include a nylon and an olefin carpet, vinyl sheet, and red oak flooring. Limited flame spread occurred for the vinyl sheet material; however, the three other materials involved full fire propagation in the corridor. The data are analyzed to examine the factors influencing fire propagation. Included in this analysis is the rate of energy contribution from the room fire and floor covering material, the rate of flame spread, heat transfer to the floor covering, and flow interactions between the room and corridor. A review of previous related experiments is also presented.

NBSIR 75-692. **A minicomputer-based system for the measurement and analysis of community noise,** R. L. Fisher, D. S. Blomquist, J. S. Forrer, and D. M. Corley, 106 pages (May 1975). Order from NTIS as PB250385.

Key words: community noise; computer interface; instrumentation; minicomputer; noise.

An operating system for the measurement and analysis of community noise was turned over to the Army for their use in February 1975, thus accomplishing the transfer of technology developed by NBS to the Bioacoustics Division, U.S. Army Environmental Hygiene Agency. This report documents the hardware and software packages prepared by NBS in support of this system.

NBSIR 75-693. **Measurement methodology for determining the sound output of model airplanes and noise producing bicycle attachments,** M. A. Cadoff and W. A. Leasure, Jr., 24 pages (Apr. 1975). Order from NTIS as COM 75-11194.

Key words: bicycle attachments; children; consumer safety; model airplanes; noise; toys.

n recent years, a great concern has been expressed for con-ner protection and safety, especially for children. As an out-wth of this concern, acoustical testing of potentially-rardous noise producing toys has been carried out at the Na-nal Bureau of Standards for the Consumer Product Safety mmission under the authority of the Toy Safety Act of 1969. is report outlines a methodology which was developed to mea-e the noise levels of model airplanes and noise producing ycle attachments. The technical back-up and rationale for the velopment of the methodology are discussed. In addition, data en using the proposed methodology are presented.

SIR 75-696. **Proceedings of GSA/ETIP Symposium on Procurement Practices, May 29-31, 1974,** 96 pages (Jan. 1975). Order from NTIS as COM 75-10527.

Key words: ETIP; incentives; innovation; procurement; product improvement; specifications.

The topic of the symposium was "Government and Indus-– A Joint Effort Toward Technological Innovation in oduct Development for Government and Public Procure-nt." The general objectives of the symposium were to open vernment-industry dialogue on ways to encourage technologi-innovation in the development of products purchased by the deral Government; to explore methods of developing a "spin-' effort so that the consumer marketplace might benefit from h innovations; to set up a procedure for analyzing the effect the consumer marketplace and to establish procedures for tinuing a government-industry dialogue. The plenary session vided participants with information designed to generate di-gue and to develop source material. Workshops were or-nized to consider specific product grouping in: Office achines (typewriters, calculators, copiers, and microfiche); rniture (wood and metal office types); Containeriza-n/Packaging; ADP-Peripheral/Supplies; Instrumentation (op-al and electrical measuring devices); Electrical Equipment pliances and powered hand tools); Automotive Products ter market replacement parts and tires); Photographic and dio Visual; Chemical (coatings, cleaning agents and deter-nts).

SIR 75-697. **Consideration in the use of sampling plans for ef-ecting compliance with mandatory safety standards,** V. L. Broussalian, A. J. Farrar, U. W. Lyons, C. O. Muehlhause, M. J. Natrella, J. R. Rosenblatt, R. D. Stiehler, and J. H. Winger, 18 pages (June 1975). Order from NTIS as COM 75-10920.

Key words: quality assurance; regulation; safety standards; sampling plan; sampling scheme.

Various means available to a regulator for gaining compliance h mandatory safety standards are examined. Particular atten-n is given to his option of mandating a sampling plan or eme along with the standard. It is concluded that this option well as the others identified are all viable under suitable condi-ns and should be available to the regulator for his possible ap-cation on a case by case basis.

SIR 75-699. **The calibration of photographic edges at NBS,** R. E. Swing, 37 pages (Apr. 22, 1975). Order from NTIS as COM 75-11016.

Key words: acutance; calibration; computer programs; microdensitometry; photographic edges; transfer function.

The method by which photographic edges made at NBS are ibrated is presented and discussed in some detail. The pro-ms associated with the computational aspects of the analysis listed, covered in narrative form, and their limitations and op-ns are presented. The possible use of these edges to determine crodensitometer transfer function is discussed and limitations and relative error of all the calculations and procedures are covered in detail. Program listings are in BASIC language.

NBSIR 75-700. **Results of full-scale fire tests with photoelectric smoke detectors,** R. W. Bukowski and R. G. Bright, 55 pages (Sept. 1975). Order from NTIS as COM 75-11280.

Key words: fire detectors; ionization chamber smoke detectors; photoelectric smoke detectors; smoke detectors; Taguchi gas sensors.

In February 1974, a series of full-scale fire tests were conducted to determine whether photoelectric-type smoke detectors could respond to the same types of fires used to assess the performance of ionization-type smoke detectors. The types of fires employed in the tests are the same as those outlined in Underwriters' Laboratories, Inc., Standard No. 167. In addition to the UL-167 standard fires, fires involving polyurethane (flaming mode) and cotton (smoldering mode) were added to the test series. One detector, utilizing a Taguchi gas sensor (TGS), was included in the test series for evaluation purposes. The test results indicated that the better photoelectric smoke detectors, i.e., those having little obstruction to slow-moving smoke can, in general, detect the same test fires as the ionization chamber smoke detectors in approximately the same time scale. For the smoldering cotton fire, the photoelectric detectors were significantly faster than the ionization chamber detectors. The TGS fire detector was unable to detect most of the test fires.

NBSIR 75-701. **Evaluation of smokeproof stair towers and smoke detector performance,** F. C. W. Fung and R. H. Zile, 23 pages (Sept. 1975). Order from NTIS as COM 75-11282.

Key words: high-rise buildings; photoelectric smoke detector; smoke control; smoke movement simulation; smokeproof tower.

A study was made by the National Bureau of Standards to evaluate the effectiveness of a smokeproof stairwell tower installed in a high-rise apartment building. Tests were also made of photoelectric-type corridor smoke detectors. A quantitative experimental technique of smoke simulation and smoke movement measurement was used. Factors diminishing the effectiveness of the stair towers, preventing smoke infiltration and limiting the response of the detectors, are noted.

NBSIR 75-702. **Design criteria for firefighters' turnout coats,** J. W. Eisele, 37 pages (Oct. 1975). Order from NTIS as COM 75-11433.

Key words: firefighters; firefighter's turnout coats; protective clothing.

These design criteria cover requirements for the sizing, construction, outer shell, inner linings, weight, and thickness for firefighters' turnout coats as well as test methods, labeling requirements, and design considerations. Included also is a list of options and other items of concern to potential users of the criteria and a sample purchase specification to be used in conjunction with the criteria.

NBSIR 75-703. **A failure hypothesis for masonry shearwalls,** F. Y. Yokel and S. G. Fattal, 38 pages (May 1975). Order from NTIS as COM 75-11278.

Key words: brick; failure; failure theories; masonry; shear strength; shear test; shear walls; stress distribution; stresses; structural engineering.

Various failure hypotheses for wall panels subjected simultaneously to diagonal compressive load and to vertical compressive edgeload are compared with the results of thirty-two tests on four types of brick masonry walls which were published elsewhere. It is concluded that failure can occur by joint separa-

tion or by splitting. A failure hypothesis is advanced which is shown to be in good agreement with the test results examined.

NBSIR 75-705. **Thermal and flow characteristics of the ASTM E 84 tunnel test method,** J. G. Quintiere and J. W. Raines, 38 pages (Sept. 1975). Order from NTIS as COM 75-11217.

Key words: ASTM E 84; carpets; energy balance; flame spread; mass balance; test method.

Five experiments were conducted using an ASTM E 84 tunnel test facility. These included a calibration test, three standard tests involving carpet materials, and one test in which a carpet material was tested on the floor of the duct. In addition to the measurements recorded during a standard test, instrumentation was added to measure inlet air velocity, temperature within the test section of the duct, and heat flux. From these measurements mass and energy balances were determined for each experiment. The results indicate that inlet air mass flow rate dropped during a test and appears to depend on the extent of burning in the duct. The energy balance results indicate that for the calibration run about half of the energy of the gas burner is lost by radiation and convection to the walls in the test section of the tunnel. During combustion of a test specimen, significant energy losses occur in the last 9 feet of the test section even after the flame tip has reached the exit of the tunnel.

NBSIR 75-706. **Calculations of radiant heat flux in the proposed floor covering flame spread test apparatus,** J. Quintiere and K. Bromberg, 21 pages (Dec. 1975). Order from NTIS as PB248640.

Key words: floor covering; heat flux; radiant panel test method.

Calculations have been made to determine the radiant heat flux distribution to the test specimen in the proposed radiant panel flame spread test for floor covering materials. Comparison with measured heat flux indicates a significant heat transfer contribution from the enclosure of the test apparatus. Also, nonuniformities in the temperature of the radiant panel affect the resultant flux distribution. Based on these results, it is expected that two similar test apparatuses would not have identical heat flux profiles along the specimen. Additional calculations were made to illustrate possible heat flux profiles capable with the present apparatus under various panel temperatures and orientations.

NBSIR 75-707. **Tamper-resistant televisior surveillance system,** O. B. Laug and K. W. Yee, 38 pages (May 1975). Order from NTIS as COM 75-11017.

Key words: safeguards; surveillance; tamper-resistant; television.

This report describes a tamper-resistant television system. This system will be part of a larger system used for verifying compliance with certain international arms control or safeguard agreements. This work is part of a joint U.S.-Canada safeguards research program to develop and evaluate tamper-resistant, tamper-indicating techniques and instrumentation that might be applicable in safeguarding reactors or other nuclear facilities. The principal design objectives are to provide a system capable of unattended operation, data storage capacity for a period up to 90 days, and resistance to deception by insertion of false video information on the transmission line or substitution of false scenes in the camera's field of view. These objectives are accomplished by utilizing commercial high-resolution closed-circuit TV and photography coupled with a video encoding technique which permutes the luminance signal in a different pattern for each recorded picture. Motion detectors, utilizing the video signal, provide the ability to selectively record pictures when motion occurs in preselected areas, and protect the system against insertion of false scenes. The incorporation of these addi tional features adds comparatively little complexity to ordinar closed circuit TV while greatly increasing its effectiveness as surveillance tool for safeguards applications.

NBSIR 75-708. **Development of a dynamic pressure calibratio technique—A progress report,** C. F. Vezzetti, J. S. Hilten, an P. S. Lederer, 20 pages (June 5, 1975). Order from NTIS a COM 75-10817.

Key words: calibration; dynamic; liquid column; pressure sinusoidal pressure; transducer.

Work continues on the development of a method of producin sinusoidally varying pressures of at least 34 kPa zero-to-pea with amplitude variations within ± 5 percent up to 2 kHz for th dynamic calibration of pressure transducers.

Sinusoidally varying pressures of 34 kPa zero-to-peak hav been produced, to date, between 40 Hz and 750 Hz by vibratin a 10-cm column of a dimethyl siloxane liquid at 36 g_n zero-to peak. Damping of the liquid column was accomplished b packing the fixture tube with a number of smaller diameter tube

NBSIR 75-710. **A small-scale enclosure for characterizing the fir buildup potential of a room,** W. J. Parker and B. T. Lee, 2 pages (June 1975). Order from NTIS as COM 75-11030.

Key words: fire growth; fire tests; flashover; room fire scale models; thermal radiation.

A 0.76 by 0.76 m (30 by 30 inch) enclosure with a 0.61 m (2 inch) high ceiling was used to model some fires in a $3 \times 3 \times 2.4$ (10 × 10 × 8 ft) burnout room. Temperatures, oxygen concentra tions, air velocity, and conductive and radiative heat fluxes wer measured. The highest average air temperature in the upper pa of the room was taken as a measure of the fire buildup potenti of the room. Upper air temperatures attained in the model wer similar in most cases to those in the full-scale compartmen From energy balance considerations this air temperature was re lated to the oxygen depletion in the room and was shown to co relate well with the oxygen content of the combustion gas and a exhausting from the model and full-scale room fires.

NBSIR 75-711. **Site analysis and field instrumentation for a apartment application of a total energy plant,** J. B. Coble and F R. Achenbach, 65 pages (May 1975). Order from NTIS a COM 75-10689.

Key words: air conditioning; air pollution; central utilit systems; data acquisition system; efficiencies; electric power; energy conservation; energy costs; fuel utilizatio heat recovery; total energy systems; utilities for housin utility system performance.

Under sponsorship of the Department of Housing and Urba Development, the National Bureau of Standards develope criteria in a feasibility study to select a site for, and to evaluat the requirements of a total energy system on one or mo OPERATION BREAKTHROUGH housing sites. The tot energy system produces its own electrical, heating and coolir energy services independent of the local utility system. S OPERATION BREAKTHROUGH sites were selected for th feasibility study: Jersey City, N.J.; Macon, Ga.; Memphi Tenn.; Indianapolis, Ind.; St. Louis, Mo.; and Sacramento, Cal Ranking parameters for final selection were: number of dwellir units, density of dwelling units, climatic factors, energy utiliz tion, owning and operating costs, and developer's attitude.

The Jersey City site was chosen as the location for the install tion, evaluation, and field study of the total energy system. Th site covers six acres, has four apartment buildings containing 4

dwelling units, a 50,000-sq.ft commercial building, an elementary school, a swimming pool, and the total energy plant.

The buildings and the total energy plant are being extensively instrumented to provide data on fuel utilization, system efficiencies, electrical and thermal energy generation, energy utilized and rejected. The environmental impact of the total energy plant with respect to noise, vibration, air pollution, and esthetics is under evaluation. The installed system will be compared with several types of conventional energy systems.

NBSIR 75-712. **Solar heating and cooling in buildings: Methods and economic evaluation,** R. T. Ruegg, 47 pages (July 1975). Order from NTIS as COM 75-11070.

Key words: economic optimization; HVAC systems; life-cycle cost analysis; solar energy; solar heating and cooling.

This report addresses economic issues important to the design, and evaluation of solar heating and cooling systems in buildings. It explains and illustrates with simple, but realistic examples the use of life-cycle cost analysis and benefit-cost analysis to evaluate and compare the economic efficiency of solar and conventional energy systems. It also explains the conditions for making cost-effective tradeoffs in solar system/building design. By presenting the basic methods and assessing the appropriateness of alternative assumptions, the paper provides a resource document for researchers and analysts.

NBSIR 75-713. **A file management system for a laboratory automation facility,** P. S. Shoenfeld and L. J. Kaetzel, 54 pages (June 1975). Order from NTIS as COM 75-11134.

Key words: data acquisition; file system; laboratory automation; multiprogramming; operating system; real-time.

The National Bureau of Standards' Analytical Chemistry Division operates a centralized laboratory automation facility built around a multiprogrammed minicomputer. A file manager was developed which allows the dynamic creation and manipulation of sequential disk files. Although the system was developed for real-time data acquisition, it is a general purpose addition to the computer's operating system and may be used for a variety of applications. A new operating system function was developed to allow the queued scheduling of programs. This is used to achieve more efficient multiprogramming. A comprehensive file utility package is also provided.

NBSIR 75-714. **Report on test on a sample of non-standard size baby cribs,** R. Pierson, Jr., R. I. Beall, and J. A. Huckeba, 33 pages (June 1975). Available from the author, NBS, Washington, D.C. 20234.

Key words: baby cribs; children's furniture; product safety; product testing; safety regulations; standard development.

A sample of non-standard size baby cribs was tested for compliance with the Consumer Product Safety Commission's Proposed Regulation for Non-Standard Size Baby Cribs in order to evaluate the Proposed Regulation, especially the tests and test procedures. The test procedures were found to be easy to interpret and to carry out. This report presents the results obtained from testing the cribs for compliance with the Proposed Regulation, a detailed description of some of the hazards, and some evaluative comments on the Proposed Regulation.

NBSIR 75-715. **The implementation of a provision against progressive collapse,** F. Y. Yokel, J. H. Pielert, and A. R. Schwab, 23 pages (Aug. 1975). Order from NTIS as COM 75-11208.

Key words: building systems; housing systems; large-panel structures; precast concrete construction; progressive collapse; structural design; structural joints.

The design solutions used by five U.S. precast concrete housing systems to comply with a provision against progressive collapse are studied and compared. Some common characteristics of the design solutions are identified.

NBSIR 75-716. **Proceedings of procurement practices symposium, Federal, State and local, January 28-30, 1975,** T. J. Fody and J. G. Berke, 168 pages (May 1975). Order from NTIS as COM 75-11210.

Key words: certification programs, ETIP; incentives; innovation; life cycle costing; procurement; product testing; specifications; unsolicited proposals.

The general objectives of the conference are to recommend ways to encourage information interchange and interaction between federal, state and local procurement levels and industry; to explore the use of special incentives such as life cycle costing, value incentives clauses, and unsolicited proposals as a means to promote innovation in products purchased by all levels of government; to establish the interrelationship between marketing, R&D and procurement and develop approaches to acquire the latest technology through the procurement process; to explore various product testing and evaluation efforts such as certification programs, tests by independent, company owned and association laboratories, university and government laboratories. Workshops were organized to consider procurement mechanisms, information interchange, testing and evaluation of products, and the interrelationship between marketing, R&D and procurement. Workshops were grouped as follows: (1) Procurement Incentives, (2) Interaction and Information Interchange, (3) Marketing, R&D and Government Procurement Cycles, (4) Product Testing and Evaluation, (5) Qualified Products Lists and Bid Samples, (6) Qualified Manufacturers, (7) Methods and Techniques of Contracting.

NBSIR 75-718. **Report of fire test on an AM General Metro Bus,** E. Braun, 21 pages (June 1975). Order from NTIS as COM 75-10750.

Key words: AM General Bus; arson; critical radiant flux; fire retardant; flammability; flooring radiant panel test; Metro; motor vehicle safety standard 302; urethane.

The Center for Fire Research at the National Bureau of Standards has conducted a study of the fire safety of a bus supplied by the Washington, D.C., Metropolitan Transit Authority. The objectives of the work were: (1) to determine the minimum ignition from source necessary to initiate a fire in the bus, and (2) to determine the means by which a fire, once started, is most likely to grow and spread.

A series of small-scale laboratory tests were run in addition to the three full-scale tests. Tests showed that accidental ignition by a cigarette or dropped match is unlikely. However, the seat can be ignited with one or two matches, if applied at the proper location, as by an arsonist. In full-scale tests, ignition of the seat occurs readily with the following ignition sources: (1) a small bag of paper trash on the seat, (2) a newspaper under the seat, (3) if the contents of a can of lighter fluid is poured on the seat.

Fire growth and spread in the bus is primarily through involvement of the seat cushioning. Fire spreads from seat to seat with little direct involvement of other interior materials. In all three tests, between one and two minutes after the urethane ignited, dense smoke filled the bus space seriously reducing visibility. Spread of fire beyond the seat of origin is not necessary for the level of smoke to be formed.

NBSIR 75-719. **A compliance testing system for NILECJ,** R. Mills, 24 pages (Feb. 1976). Order from NTIS as PB251410.

Key words: acceptance testing; compliance testing; laboratory evaluation; performance testing; qualified products lists; testing.

In order to assure that NILECJ equipment standards have the impact intended, a Compliance Testing and Laboratory Accreditation program is needed to establish which items available on the market do, in fact, meet the requirements of the standards. This report contains recommendations for such a NILECJ program. In brief, the proposed program would (a) result in a body of qualification and acceptance test data, (b) establish a list of testing laboratories competent to perform these tests, and (c) set up a "compliance information system" for the dissemination of this information to officials in the criminal justice system.

NBSIR 75-721. **Economic objectives of utility companies and developers in evaluating a MIUS,** B. J. Bartter, 39 pages (Nov. 1975). Order from NTIS as PB246864.

Key words: economic incentives; housing development; integrated utilities; utilities.

This report provides information to the Department of Housing and Urban Development-Modular Integrated Utility System (HUD-MIUS) program about the *economic* decision-making process for implementation of a MIUS by utility companies, developers, and a combination of these two groups.

Information was obtained through informal telephone interviews from these participant groups about their economic analysis of utility investment alternatives. The content of these conversations was synthesized into economic criteria which are perceived by each participant to be most important in evaluating alternative utility investments. From the analysis of these economic criteria, the possible combinations of participants and roles in the implementation of a MIUS are specified. These combinations are ranked, according to the degree of likelihood that each method will actually be employed.

The conclusion of this report is that a MIUS is most likely to be implemented by a governmental body, such as a municipal utility or governmental developer.

NBSIR 75-722. **Closure testing equipment instruction manual,** M. S. Morse, 42 pages (Oct. 1975). Order from NTIS as PB248641.

Key words: bottle caps; child protection; closure testing; containers; medicine bottles; poison packaging.

The NBS Closure Testing Equipment is designed to make accurate measurements of the critical parameters of the "child-proof" closures required by the Poisoning Prevention Packaging Act of 1971. In general, these parameters are defined as the forces necessary to open these closures, either in the manner by which the closure was designed to be opened, or in an undesired manner. This manual discusses the design and construction of the testing instrument and gives detailed instructions for its operation.

NBSIR 75-723. **Aluminum branch circuit wiring in residences summary report for the Consumer Product Safety Commission January-September 1974,** J. Rabinow, 91 pages (June 1975). Order from NTIS as COM 75-10753.

Key words: aluminum wire; consumer product safety; current cycle testing; electrical connection failure; electrical receptacles; residential wiring.

This report is a compendium of information on aluminum wiring in residences, originally prepared for the Consumer Product Safety Commission. It contains a summary of experimental research carried on at the NBS laboratories on the problems of terminating aluminum wires to screw connections as well as other pressure connectors. Since this report is an overview of the technical aspects of the aluminum wiring problem, it also contains a review by NBS staff members of available material furnished by Underwriters Laboratories and Battelle Institute. Both of these institutions are major contributors to this particular field of information.

The report also includes abstracts by NBS staff of some four volumes of testimony taken at public hearings at Washington, D.C. and Los Angeles, California during the spring of 1974. Additional information on the pertinent physical properties of aluminum, information on failure mechanisms, possible corrective actions, connector cycling tests, etc., is given in a brief literature survey and two relevant memoranda on the subject. The report concludes with a fairly extensive bibliography.

NBSIR 75-729. **Nondestructive tests to determine concrete strength—A status report,** J. R. Clifton, 39 pages (July 1975). Order from NTIS as PB246858.

Key words: compressive strength; concrete; flexural strength; formwork removal; nondestructive testing; surface hardness.

Individual and combined nondestructive test methods have been critically reviewed as potential methods to determine safe formwork removal times. The techniques reviewed are the Windsor probe, the Schmidt Rebound Hammer, pull-out measurements, push-out cylinders, ultrasonic pulse velocity measurements, and the maturity and equivalent age concepts. The individual methods themselves do not give good estimates of the in situ strengths of concretes and it is recommended that future research emphasize combined methods.

A proposed research program which emphasizes combined nondestructive test methods has been developed.

NBSIR 75-730. **Equilibrium penny-like crack in indentation fracture,** B. R. Lawn and E. R. Fuller, Jr., 28 pages (Sept. 1975). Order from NTIS as COM 75-11461.

Key words: contact fracture; degradation; Hertzian cracks; indentation fracture; median vents; penny crack.

A study is made of the mechanics of two basic types of indentation fracture, *cone cracks* ("blunt" indenters) and *median cracks* ("sharp" indenters). The common feature which forms the central theme in this work is that both crack types, in their well-developed stages of growth, may be regarded as essentially "penny-like." On this basis a universal similarity relation is derived for equilibrium crack dimension as a function of indentation load. Experimental measurements confirm the general form of this relation. A more detailed fracture mechanics analysis is then given, to account for additional, contact variables evident in the data. Notwithstanding certain analytical limitations, the study serves as a useful basis for investigating a wide range of contact-related problems, both fundamental and applied, in brittle solids.

NBSIR 75-731. **A study of air-gap breakdown at 28.5 kilohertz,** F. R. Kotter, 42 pages (June 20, 1975). Order from NTIS as COM 75-11071.

Key words: air gap; electrical breakdown; insulator flashover; lightning protection; VLF antenna; voltage breakdown.

Measurements of the electrical breakdown of both quasi-uniform and highly nonuniform-field air gaps at a frequency of 28.5 kHz are reported. Gaps between a variety of electrode geometries ranged from a few centimeters to over two meters in length.

Breakdown voltages significantly below the corresponding 60 Hz values were observed with electrodes for which appreciable pre-breakdown discharges occurred, and a pattern of "anomalous" flashovers at considerably lower than the normal breakdown voltages was noted with quasi-uniform field gaps. The results obtained appear to correlate well with the data found in the literature for higher frequencies but lower voltages.

On the basis of the gap behavior observed, a prototype protective gap system designed for application to the tower base insulator assembly of a VLF (15 to 30 kHz) radio transmitter was tested and found satisfactory.

NBSIR 75-732. **NBS InterAgency transducer project—A project report,** P. S. Lederer, J. S. Hilten, and C. F. Vezzetti, 23 pages (June 27, 1975). Order from NTIS as COM 75-11022.

Key words: calibration; dynamic, electronic flash; photoflash bulb; pressure; pressure transducer response; thermal transient; transducer.

The continuing development of a test method for evaluating the effects of short-duration thermal radiant-energy transients on pressure transducer performance is described. The method consists of monitoring pressure transducer output as the transducer is exposed to radiation resulting from the ignition of a photographic flashbulb or from the discharge of an electronic flash. Precision of the method is to be at least adequate for the method to serve as a first-cut screening test. During this reporting period, the following three parameters were investigated for each of three radiation sources: (1) the amount of energy per unit area available as a function of distance from the source, (2) the response of a selected transducer as a function of distance from the source, and (3) flash duration. Repeatability of the method for each source was determined. Work being performed for other agencies is also described briefly.

NBSIR 75-733. **An evaluation of proposed safety requirements for infants' pacifiers,** S. D. Toner and H. A. Baker, 20 pages (Aug. 1975). Order from NTIS as COM 75-11139.

Key words: consumer products, CPSC proposed regulation; pacifiers; product safety; safety requirements; safety testing.

This report is concerned with a review of a regulation proposed by the Consumer Product Safety Commission on the safety of infants' pacifiers. In addition, the results of a laboratory evaluation of the efficacy of various requirements and testing procedures are given.

NBSIR 75-734. **Report on an investigation of the high speed hazards of steel belted patrol tires on police patrol cars,** J. J. Collard, 51 pages (June 1975). Order from NTIS as COM 75-11212.

Key words: certification of steel belted radial tires; high speed radial tire hazard; radial tire failures.

Two police fatalities and one permanent disability have been caused by catastrophic failures of steel belted radial ply tires during high speed police operations. More than 200 other failures were reported by one State highway patrol department. The report recommends that police departments use caution in selecting tires for patrol cars, and that tire manufacturers be required to provide evidence that the tires sold for police use have been tested and certified at speeds of at least 125 miles per hour.

NBSIR 75-735. **An expandable total energy data editor,** R. H. F. Jackson, 151 pages (Aug. 1976). Order from NTIS as PB256295.

Key words: computers; data editing; energy conservation.

This report documents the Total Energy Data Editor, a computer program developed to process the data to be collected by the ongoing Total Energy Project at the National Bureau of Standards. Consisting of a mix of FORTRAN and RAYTHEON machine language subroutines, the Editor is a powerful, interactive program written to be run on a Raytheon 704 minicomputer with two tape drives and a disk pack. Since this document is also meant as a user's manual, it includes a dictionary of commands, complete discussions and listings of individual subroutines, as well as an explanation of the workings of the program.

NBSIR 75-736. **Fire research publications, 1974,** N. H. Jason, 11 pages (June 1975). Order from NTIS as COM 75-11018.

Key words: bibliographies; building fires; construction materials; fire departments; fire tests; flame spread test; flammability tests; flammable fabrics; Operation BREAKTHROUGH; protective clothing.

"Fire Research Publications, 1974" is a supplement to the previous editions which covered the years 1969-1972 (NBSIR 73-246) and 1973 (NBSIR 74-511). Only publications prepared by the members of the Center for Fire Research (CFR), by National Bureau of Standards (NBS) personnel under contract or grant to the CFR, or by NBS personnel or external laboratories under contract or grant from the CFR are cited. Articles published in NBS house organs also are cited.

NBSIR 75-737. **Mathematical methods of site selection for electronic message systems (EMS),** C. Witzgall, 44 pages (June 1975). Order from NTIS as COM 75-11472.

Key words: communication; cost-benefit; deployment; electronic transmission; facility location; mail; mathematical programming; message network synthesis; network optimization; satellite; service improvement.

The concept of electronic message (mail) transmission has been the subject of several feasibility studies during the past decade. It requires the installation of electronic message handling facilities at selected locations. If transmission is to be via communications satellite, then any such facility can transmit to and receive from any other one. In this report, the mathematical aspects of choosing the number and locations of these facilities are examined. An inventory of solution methods is presented, along with recommendations as to which among them should be employed or developed further.

NBSIR 75-738. **A method and means of calibrating an air-bearing force plate for use with a towed pavement friction test trailer,** R. W. Kearns and J. F. Ward, 40 pages (Dec. 1974). Order from NTIS as COM 75-11279.

Key words: calibration procedures; force plate; pavement skid resistance; skid accident reduction; tire-pavement interface forces.

The equations for the variation of the external forces acting at the tire-pavement interface of a symmetrical two-wheeled towed trailer are given. Estimates, derived from experimental results, have been made for the displacement of the tire-plate interface with respect to the ground of an unrestrained locked test tire on the trailer. A description of the force plate calibration test frame, instrumentation and test method is given. The means of applying simultaneous vertical (normal) and horizontal (longitudinal) forces at the contact surface of the air-bearing plate in accordance with the equations are discussed. The change in force plate output with changes in the dimensions of the trailer calibrated in-turn with the force plate are given. A method of locating the coordinate axes of the internal force sensors with respect to level is given. Consistent application of these methods to both the force plate and trailer transducer calibrations results in reduced vertical-to-horizontal cross-axis differences.

NBSIR 75-739. **Development of specifications for archival record materials,** W. K. Wilson and E. J. Parks, 19 pages (Mar. 1975). Order from NTIS as COM 75-11189.

Key words: accelerated aging; natural aging; permanence; record materials; record papers; stability.

A specification for copies from office copying machines for permanent records has been prepared and is progressing through a standards organization. A project on the effects of 36 years of natural aging on a group of book papers of known composition was completed and reported. Work on the accelerated aging of handsheets at various relative humidities is incomplete, but data already obtained show that a low relative humidity is desirable in an accelerated aging procedure. Data on the sorption of oxygen by papermaking pulp at elevated temperatures are inconclusive.

NBSIR 75-740. **Piezoelectric polymer transducer for impact pressure measurement,** A. S. DeReggi, 39 pages (July 1975). Order from NTIS as COM 75-11127.

Key words: calibration; construction; impact; interface; piezoelectric polymer; polymer; pressure; pressure transducer; theory; transducer.

Described are development efforts relating to the design, construction, and calibration of a piezoelectric polymer transducer for the recording of pressure transients developed over the interface between two bodies as a result of impact. A bilaminate design was selected which uses electrically poled sheets of 25-μm poly(vinylidene fluoride) as the active material. The intended primary response of the transducer is to compression in the thickness direction, which is produced by either hydrostatic or normal pressure; the transducer was also found to respond to extension in the membrane direction. Individual-sheet activity in the thickness-compression mode is approximately 15 pC/N, resulting in a bilaminate transducer pressure response of 4.5 μV/Pa(30 mV/psi). Instructions for poling sheets and for constructing transducers are given in detail. Static and dynamic methods for characterizing transducer output are described. In particular, in order to simulate field conditions in which the transducer may bend or stretch, or both, during impacts, a drop-test procedure with curved impactors has been devised and a theoretical analysis (simplified to the extent of considering the membrane-stress contribution negligible) has been developed to yield the interface pressure.

NBSIR 75-741. **Mechanistic studies of triphenylphosphine oxide-poly (ethyleneterephthalate) and related flame retardant systems,** J. W. Hastie and C. L. McBee, 45 pages (Aug. 1975). Order from NTIS as COM 75-11136.

Key words: flame retardancy; mass spectrometry; optical spectroscopy; phosphorus; polyester.

A combination of mass spectrometric and optical spectroscopic studies has been made to establish a mechanism for phosphorus controlled flame retardancy in thermoplastics. It is shown that a vapor phase mode of flame inhibition can account for the known flame retardancy effect of triphenylphosphine-oxide in polyester substrates.

NBSIR 75-742. **Mixed oxides for fuel cell electrodes,** U. Bertocci, M. I. Cohen, W. S. Horton, T. Negas, and A. R. Siedle, 56 pages (Jan. 1976). Order from NTIS as PB248744.

Key words: electrocatalysis; fuel cells; mixed oxides; oxygen reduction; phosphoric acid; ternary metal-sulfur arrays; transition elements; triphenylphosphine; tungsten bronze.

Studies of mixed oxides were made in order to determine if such materials could act as oxygen-reducing electrocatalysts in an acid fuel cell. Included were strontium and barium cobaltates and manganates with and without added titanium; lanthanum titanates, with and without calcium or strontium; calcium, strontium, and barium ruthenates; and mixed oxides of the systems Ti-Ta-O, V-Nb-O, Ce-Ta-O, Pr-Ta-O, Ce-Nb-O, and Ce-Pr-Ta-O. Choices were based upon producing variable valence and upon conferring stability at elevated temperatures ($\leq$ 150 °C) in phosphoric acid. Barium ruthenate and the systems Ti-Ta-O, V-Nb-O, V-Ta-O, Ce-Ta-O, were hot-acid stable. The thermal reactions of $CeTaO_{4+x}$ with $O \leq x \leq 0.5$ were studied in air up to about 1960 °C.

Potentiodynamic and galvanostatic studies are reported on materials from the Ti-Ta-O system, TiO_2 as grown, TiO_2 reduced with hydrogen, TiO_2 with 0.1 percent Nb, lanthanum titanates with and without calcium or strontium, a tungsten bronze, barium ruthenate, and strontium titanate with 0.03 and with 0.15 percent Nb.

Preparation of inorganic compounds with ternary metal-sulfur arrays similar to the arrays in nitrogen reductase was attempted. The following were made: $(Ph_3P)_4Cu_2W_2S_6$, $(Ph_3P)_6Ag_5W_2S_6O_2$, and $[(Ph_3P)_3Ag]_2W_2S_6$, where Ph_3P refers to the triphenylphosphine moiety. Also prepared were $(Ph_3PAu)_2W_2S_4$, $(Ph_3AsAu)_2WS_4$, $(diphos)NiWO_2S_2$, $(diphos)_2Pd_3W_2S_6O_2$, and $(Ph_3P)_3PtW_2S_6O_2$, where "diphos" refers to 1,2-bis(diphenylphosphino)ethane.

NBSIR 75-744. **Proposed implementation for development of user-terminal protocols for computer network access,** A. J. Neumann, 16 pages (July 1975). Order from NTIS as COM 75-11072.

Key words: command languages; computer; man-machine systems; networks; system commands; user protocols.

This report summarizes activities undertaken at the National Bureau of Standards in the area of User-Terminal Protocol Standardization with support from the National Science Foundation, during the latter part of 1974 and 1975. Also discussed are present status of related standardization activities in areas of command languages, terminal keyboards, and terminology. Legal implications of standardization are indicated, and establishment of a Federal Task Group for Standardization is proposed to work under the Federal Information Processing Standards Coordinating and Advisory Committee (FIPSCAC).

NBSIR 75-745. **A model for salmon fishery regulatory analysis** F. C. Johnson, 33 pages (July 10, 1975). Order from NTIS as PB247657.

Key words: fisheries; fishery; fishery modeling; mathematical modeling; regulatory analysis; resource management; salmon fisheries; salmon fishery modeling; simulation; State of Washington; Washington State; Washington State Fisheries.

The salmon fishery modeling project is a joint State-Federal program for the development of improved techniques for analyzing the economic and biological effects of regulatory changes in the Pacific Coast salmon fisheries. This interim report covers the second segment of the project – the implementation of a multi-species, multi-stock fishery analysis model. This segment of the project was sponsored by the Washington State Department of Fisheries under Service Contract No. 588.

NBSIR 75-746. **Preparation of reference data sets for character recognition research.** M. L. Greenough and R. M. McCabe, 5 pages (June 30, 1975). Order from NTIS as COM 75-11437.

Key words: character recognition; context research; data bases; optical character recognition; pattern recognition; reading machines.

A reference data set contained on magnetic tape has been enerated for research in optical character recognition and re-ated fields. The data set contains video data in 16 levels for each oint in a 24 × 24 scanning grid, applied to approximately 30 000 haracters. The input material, on some 2200 simulated address ailpieces, includes a range of character quality from excellent o poor.

The data set was prepared by first microfilming the address elds and printing positive transparencies. Then preselected haracters were scanned in the NBS FOSDIC. Through the use f calibrated gray scales which were filmed and scanned along ith the addresses, corrections were applied to assure linearity f overall response.

A second reference data set was also prepared from the same put material of simulated mailpieces. Through analysis of the cognition results printed out during runs on one address ader, details of identification on both alphabetic and numeric cognition modes were noted. These were encoded into six-haracter groups on the data tapes, formatted to provide one ch group for each input character in the original addresses. ecognition results are shown for approximately 110 000 input haracters.

BSIR 75-747. **Building energy authority and regulations survey: State activity,** R. M. Eisenhard, 25 pages (June 1975). Order from NTIS as COM 75-11131.

Key words: authority; building; energy; legislation; regulations; state.

Information describing the status of State regulations and uthority to regulate energy use in new and existing buildings is resented in tabular form. The tables reference available infor-ation on pending bills, acts, or general authority which is em-odied in a State Building Code Act. Programs relating to solar nergy, insulation, and other building energy items are also sted.

BSIR 75-748. **Power saws: A review of injury data and power saw industry survey,** V. J. Pezoldt and J. J. Persensky, 95 pages (July 1975). Order from NTIS as COM 75-11031.

Key words: accident research; consumer products; injury data; opinion survey; portable circular saws; power saws; radial arm saws; safety; table saws.

Two activities of an investigation of power saws are described: review of power saw injury data and two surveys of saw manu-acturers' opinions concerning safety aspects of saw use and esign. The injury data reviewed consisted of information from he National Electronic Injury Surveillance System and from ummaries of In-Depth Investigation Reports compiled by the onsumer Product Safety Commission. The two surveys, deal-ng with portable circular saws and table and radial arm saws espectively, were directed toward obtaining the opinions of chnical representatives of power saw manufacturers on five ajor areas of saw use and design, i.e., electrical safety, blade ontact hazards and prevention, accidental starting, the design of arious saw components and the judged adequacy of saw in-ruction manuals. Power saw engineers and designers recognize me problems with present saw designs, especially relating to ickbacks. Overall, however, the survey respondents believe aws to be reasonably free from hazards introduced by product esign. The area in which the saw manufacturers believe the ost hazards to exist is that of the operator's use of power saws. his human element in saw accidents is recognized as a major ntributor to saw related injuries, but little is known about how assure that safe practices will be followed. Areas for further udy are suggested.

NBSIR 75-750. **The calibration of indexing tables by subdivision,** C. P. Reeve, 38 pages (July 1975). Order from NTIS as PB249934.

Key words: angle standard; autocollimator; calibration; complete closure design; indexing table; least squares estimation; partial closure design; standard deviation; subdivision; variance-covariance matrix.

The indexing table plays a vital role in the calibration of angle standards at the National Bureau of Standards. It is often useful to know the values of several different intervals on the table as precisely as possible. The usual measurement designs call for a complete intercomparison of two tables which are being calibrated simultaneously. Two new types of measurement designs have been developed which call for only a fraction of this effort. One type of design subdivides the entire circle on each table into equal segments, and the other design subdivides these into smaller segments. Together the designs form a flexible system for calibrating any desired intervals on the two tables. Formulae are given for the propagation of random errors through all levels of subdivision. An example is included.

NBSIR 75-751. **Thermodynamics of chemical laser and high temperature species,** C. W. Beckett, 37 pages (Oct. 1975). Order from NTIS as ADA017626.

Key words: chemiluminescent; diatomic molecules; dissociation energies; high temperature; PbO; thermophysical measurements.

This report (covering July 1974 through June 1975) gives summaries (a) for high-speed thermophysical measurements on hafnium, iron, tantalum, and molybdenum and (b) for an interpretation of the Raman spectra of PF_5, AsF_5, and VF_5. Details of these activities have been or are in the publishing process. In addition, this report includes two articles which are current and have not started the publication process. One is a study on the chemiluminescence of the $Pb(g)+O_3(g)$ reaction, and the other is a review of the literature for dissociation energies of diatomic oxides and fluorides relevant to chemical lasers in the visible region. Finally, some related bibliographies on chemical kinetics are indicated.

NBSIR 75-755. **The CPSC road test of bicycle braking performance—Experimental evaluation,** D. E. Marlowe, 32 pages (Aug. 1975). Order from NTIS as PB248642.

Key words: bicycles; braking; consumer safety; handbrake; safety; testing.

The brake performance criteria to be published as part of a mandatory regulation on bicycle safety requirements has been evaluated. Fifteen bicycles were tested in accordance with the regulation. A mathematical adjustment of the actual test speed of the bicycle to 24 km/hr (15 mph) is necessary before the weight allowance can be made to the stopping distance in the evaluation of these tests. A danger of injury to the test rider exists during the tests and future efforts should be made toward replacement of these tests with a simpler laboratory procedure.

NBSIR 75-757. **A technique for the measurement of flash fire potential of polymeric materials,** J. E. Brown and J. J. Comeford, 33 pages (Dec. 1975). Order from NTIS as PB248914.

Key words: aircraft fires; fire hazard; flash fire; polyurethane; pyrolysis.

This report summarizes work for the period February-August 1974 on a continuing program to characterize the chemical and physical parameters of importance in a flash fire and to develop

laboratory scale methods for measuring the flash fire potential of materials.

Significant modifications have been made to a flash-fire cell developed earlier to measure the flash fire potential of materials by characterizing the condition required to produce an ignitable pyrolyzate-air mixture by thermally degrading a polymer. The furnace temperature, cell geometry and orientation, and sample size are specified. These modifications have resulted in an improved technique, especially in terms of reproducibility, for evaluation of flash fire potential of materials.

Experiments have been conducted on rates of combustible gas formation from flexible polyurethanes to assist in the optimization of the flash-fire cell operating conditions.

In the rate study, two successive major stages of degradation were found for polyurethane as the temperature approached 500° at a rate of about 60 °C/min. It was also found that the products of the second stage appear to be responsible for flash fires in the flash-fire cell. A minimum polyurethane weight to enclosure volume ratio greater than 0.2 g/l and a sample pyrolysis temperature greater than 380 °C were required to produce a flash fire in this apparatus.

NBSIR 75-760. **Proceedings of piezoelectric and pyroelectric symposium-workshop,** M. G. Broadhurst, 222 pages (Sept. 1975). Order from NTIS as COM 75-11436.

Key words: electrets; hydrophone; piezoelectric; polymers; polyvinylidene fluoride; pyroelectric; radiometer; transducers.

The purpose of this Symposium-Workshop was to bring together scientists and program managers from federal (primarily DoD), industrial, university, and foreign laboratories who are involved in the research on and manufacture of piezoelectric and pyroelectric polymer materials and devices, in order to exchange information about and stimulate further work on the new and rapidly developing measurement technology involving polymer transducers. This meeting is particularly important at this time because highly active polymer films are not yet available to device manufacturers in the U.S. or to potential users such as DoD.

NBSIR 75-761. **The demonstration of experimental lead paint hazard abatement methods in Washington, D.C.,** T. H. Boone, H. W. Berger, A. P. Cramp, and H. A. Jackson, 105 pages (June 1975). Order from NTIS as COM 75-11377.

Key words: abatement; barrier materials; building materials; housing; lead-based paint; lead poisoning; paint removal.

This report describes the first stage of an experimental lead paint hazard abatement program carried out in 30 dwelling units in Washington, D.C. The entire program will ultimately involve the abatement of lead paint hazards in a total of approximately 250 dwelling units located in three or more cities.

The procedures, demonstrated in Washington, included: paint removal methods using chemical solvents and a heat producing device; the replacement of components such as windows, doors and wood trim; and the installation of flexible sheet and rigid board barrier materials over existing lead paint on wall.

The report presents procedures and the forms used in inspecting and selecting dwellings for lead paint hazard abatement, evaluations of the suitability and implementation characteristics of the abatement methods and recommendations for their use.

Subsequent reports will present the results of comparable programs in additional cities and a final report will compare the cost-effectiveness of the alternative abatement methods.

NBSIR 75-763. **Thermodynamic and transport properties of ethylene and propylene,** I. A. Neduzhii (Principal Author), 210 pages (June 1972). Order from NTIS as COM 75-11276.

Key words: critically evaluated data; ethylene; propylene; thermodynamic properties data; transport properties data.

A comprehensive review of the data on the thermodynamic and transport properties of ethylene and propylene is given. Subjects covered include equation of state for liquid and vapor, second virial coefficient, enthalpy, etc., heat capacity, speed of sound, viscosity, and thermal conductivity. New experimental measurements are given for several properties, especially speed of sound, densities of the liquid and transport properties. Tables of properties covering the temperature range from 160 K to 500 K are given. The book has been translated into English from the original Russian.

NBSIR 75-766. **Properties and interactions of oral structures and restorative materials,** J. M. Cassel, 51 pages (July 1975). Order from NTIS as COM 75-11376.

Key words: adhesive materials; composites; dental materials; polymer grafting; resins; restorative materials; sealants; wear resistance.

A diversity of experimental approaches is being investigated to develop techniques which can be applied in formulation of adhesive restorative and caries-preventive dental materials. A newly developed testing procedure, still in the evaluation stage, has demonstrated expected ranking of adhesive bond strengths within a group of selected coating agents, both coupling and release types. Deterioration on exposure to water of cohesive bond strength in the Bis-GMA matrix has been indicated without concurrent deterioration of the coupling agent. A monomer system with potential as a composite or pit and fissure sealant resin and giving a polymerizable liquid of desired viscosity at room temperature was derived from three low-melting, crystalline isomers of ether-ester linked aromatic dimethacrylates. A series of monomers of varying chemical structure was evaluated for possible application in photopolymerization experiments designed to investigate modification of hard tissue by grafting. Modifications to extend the running time of a dental restorative wear-generating experiment three-fold and which allow the computerized recording of ten, instead of two, depth of wear measurements around the circular wear track have significantly reduced the standard error of measurement. Surface coating techniques being developed to strengthen interfacial bonding in dental cements and other dental materials show more promise with titanate than with carbon reinforcing fibers.

NBSIR 75-767. **A methodology for establishing conditioning requirements for building materials and composites,** L. W. Masters and M. Tryon, 35 pages (Oct. 1975). Order from NTIS as PB246879.

Key words: building composite; building material; conditioning; equilibration; gypsum wallboard; methodology; relative humidity; structural sandwich panel; temperature; testing.

The measured properties of building materials and their composites sometimes reflect the conditions to which they have been exposed while being prepared for test. Conditioning these materials to some standard reference state is sometimes used to minimize this effect.

A methodology for establishing conditioning requirements for building composites and materials is presented and its use illustrated by applying it to two building composites.

NBSIR 75-768. **Reevaluation of the densities of the four NBS silicon crystal standards,** H. A. Bowman, R. M. Schoonover, and

C. L. Carroll, 36 pages (Aug. 1975). Order from NTIS as PB247943.

Key words: density standard; phase shift; silicon.

There were a few features of our recently completed density standard experiment which were based upon ideas which, we believe, should be changed. This report lists these changes and their justification. The result is to increase the assumed values of the densities of the crystals by about 1.7 ppm. The new assumed values are: X2 = 2.329 1289 g/cm^3; X3 = 2.329 1253 g/cm^3; X4 = 2.329 1228 g/cm^3; X5 = 2.329 1226 g/cm^3.

Additionally, we now believe that the densities of the crystals are stable, and not appreciably changing due to oxidation – a point left unresolved in our published report.

NBSIR 75-769. **Report on an NBS/AID/OAS Workshop on standardization and measurement services in industrializing economies,** H. S. Peiser, R. S. Marvin, M. McNeil, and J. Mejeur, Eds., 227 pages (Sept. 1975). Order from NTIS as PB247978.

Key words: AID; assistance; economics; foreign relations; industrializing nations; LDC's; measurement services; OAS; standardization.

On November 3-16, 1974, a Workshop was held at the National Bureau of Standards, Gaithersburg, under the sponsorship of AID and the Organization of American States, the object of which was to give standards officials of industrializing nations insight into the standards and measurement systems in the United States and the role of the National Bureau of Standards, so that these officials might consider what parts of the U.S. system might usefully be adapted to conditions in their home countries. The report contains copies of speeches and presentations by the U.S. hosts and the participants from the other nations. In addition, information is given on the general agenda of discussions, presentations, and tours of laboratories at NBS and other U.S. organizations.

NBSIR 75-770. **The equation of state for ammonia,** L. Haar and J. Gallagher, 27 pages (Sept. 1975). Order from NTIS as COM 75-11370.

Key words: ammonia; correlation; gas; liquid; thermodynamic properties; thermodynamic surface.

An outline is presented of the basic results of the extensive correlation for the thermodynamic properties of ammonia recently completed at this laboratory. Computer programs are presented for the calculation of thermodynamic properties in the range including the triple point temperature to 5/3 the critical temperature and pressures from the dilute gas to 8000 bar.

NBSIR 75-772. **The dynamic response of helicoid anemometers,** J. M. McMichael and P. S. Klebanoff, 54 pages (Nov. 1975). Order from NTIS as PB246861.

Key words: air; analytical; anemometer; dynamic response; experimental; lag; unsteady flow.

The results of an analytical and experimental investigation of the dynamic response of a helicoid anemometer are presented. The experimental investigation was conducted using the NBS Unsteady Flow Facility and data are presented which illustrate the dynamic behavior in a spatially uniform, fluctuating flow with varying amplitudes, frequencies, and mean velocities. An analytical model governing the dynamic response is also presented and compared with the experimental results.

NBSIR 75-774. **Calibration of Kerr systems used to measure high voltage pulses,** R. E. Hebner, Jr., 51 pages (Aug. 7, 1975). Order from NTIS as COM 75-11364.

Key words: automated measurements; dielectrics; dividers; electrical measurement; electric fields; electro-optics; high voltage measurements; insulating fluids; Kerr effect; nitrobenzene; pulse measurements; space charge.

The purpose of this work is to define, develop and refine techniques for calibrating pulse voltage measurement systems, particularly those based on the electro-optic Kerr effect. The approach used exploits the assumed frequency independence of the Kerr coefficient of nitrobenzene. Theoretically, the Kerr coefficient should exhibit the same frequency dependence as the relative permittivity. Measurements have shown the relative permittivity to be approximately frequency independent over the frequency range from direct voltage to 10^9 Hz. The realization of this calibration approach has been hampered by the fact that the electric field distribution, in the liquid exhibiting the electro-optic Kerr effect, is itself frequency dependent.

This report describes the present best comparison of cell calibration under direct voltage with calibration under low frequency alternating voltage and calibration under pulsed high voltage. The results under all three types of waveforms agree to within ± 0.5 percent. From these results it can be inferred that it is feasible to use an electro-optic Kerr system as an independent, and possibly more accurate, device against which to calibrate other pulse voltage measurement systems.

In addition to this discussion of Kerr system calibration, the report contains two appendices. One presents an improved technique for analysis of data obtained from a Kerr system and the other discusses space charge in a nitrobenzene-filled Kerr cell.

NBSIR 75-775. **Electrical measurement of high voltage pulses in diagnostic x-ray units,** R. E. Hebner, Jr., 62 pages (Nov. 1, 1975). Order from NTIS as PB248684.

Key words: calibration; electrical measurements; electro-optics; frequency response; high voltage; Kerr effect; operational amplifier; pulses; radiation; safety; x-ray generators; x rays.

The report describes a method of calibrating dividers used to measure high voltage pulses in diagnostic x-ray units. The experimental development emphasized four areas. These were the divider ratio under direct voltage, the frequency dependence of the ratio, the voltage dependence of the ratio and the effect of self-heating on the device. The results of measurements on approximately fifteen different dividers are summarized.

In addition, this report contains two appendices. The first discusses conventional and electro-optical methods of measuring the high voltage pulses, while the second presents a more detailed analysis of the feasibility of electro-optical measurement of these pulses.

NBSIR 75-778. **ETIP: THE FIRST 18 MONTHS. A progress report of the experimental technology incentives program, National Bureau of Standards,** J. D. Lewis, 74 pages (Aug. 1975). Order from NTIS as PB246435.

Key words: civilian R&D policy; ETIP; incentives; innovation; procurement policy; regulatory policy; small business policy; technology.

This internally prepared report describes the overall accomplishments of the experimental Technology Incentives Program in carrying out its mission. Progress is compared with the plans that were established in a program plan approved by the Secretary of Commerce in February of 1974. An appendix to the report describes the purpose and shows progress of each of the individual projects that ETIP has launched.

NBSIR 75-779. **The development of an improved compression test method for wall panels,** C. W. C. Yancey and L. E. Cattaneo, 107 pages (Dec. 1975). Order from NTIS as PB249935.

Key words: compression; eccentric loading; flat-end; kern; loading rate; pin-end; test method; wall panels; walls.

An experimental and analytical investigation of the primary factors involved in the testing of prototype wall panels under axial compression loading is reported. The objective of the investigation was to develop a method of testing wall specimens that incorporates the best features of ASTM Standard Method E72 while at the same time incorporating improvements in the areas of deficiency in the Standard. Twenty-five laboratory tests were conducted on samples composed of five types of wall panel construction. The panels were tested to failure under either of two different eccentricities of load, while being supported with one of two types of idealized end conditions. Selected test results and detailed descriptions of the laboratory procedures used are presented. A computer-aided analytical study of the variables affecting the degree of uniformity of loading was conducted. Equations based on the analogy of beams supported on elastic foundations were used in the analysis. A study of the statistical parameters commonly used to interpret test results was conducted to establish useful guidelines for predicting structural performance on the basis of small sample test results. A compression test method applicable to traditional and innovative wall constructions is presented. The principal additions in the revised test method are as follows: (a) a provision for variable eccentricity, (b) a procedure for selecting a load distribution assembly which will be compatible with the test panel.

NBSIR 75-781. **Optical materials characterization,** A. Feldman, D. Horowitz, R. M. Waxler, I. H. Malitson, and M. J. Dodge, 24 pages (Aug. 1975). Order from NTIS as COM 75-11375.

Key words: birefringence; elastic constants; infrared-laser window materials; interferometry; KCl; photoelasticity; polycrystalline ZnSe; refractive index; stress-optical constants; thermal coefficient of refractive index; ZnSe.

The refractive index of each of two prismatic samples of chemical vapor deposited (CVD) ZnSe was measured from 0.5086 μm to 18.2 μm by means of the minimum-deviation method on a precision spectrometer. Data were obtained at temperatures near 20 and 34 °C and each set of data was fitted to a three-term Sellmeier-type dispersion equation, which permits refractive index interpolation within several parts in 10^{-5}. From the data obtained at the two temperatures, dn/dT was calculated for both samples. A comparison of refractive index and dn/dT is made with other types of ZnSe. Preliminary photoelastic data are presented for single crystal specimens of Ge, reactive atmosphere processed (RAP) KCl, and KCl doped with KI. The Ge data, which were obtained at 10.6 μm differ from previously reported data. Data on the two types of KCl were obtained at 10.6 μm, 0.633 μm and 0.644 μm. These data are compared with values from the literature. Also presented are revised photoelasticity data for CVD ZnSe. The design of an improved stressing apparatus that was developed for the measurement of photoelastic constants is discussed.

NBSIR 75-782. **Full-scale corridor fire experiment using a glass fiber carpet,** L. H. Breden, 33 pages (Dec. 1975). Order from NTIS as PB248643.

Key words: carpet; corridor test; fire testing; flammability; glass fiber.

A corridor fire experiment was carried out using a glass fiber carpet. It was observed that with a fuel loading of 2.7 pounds per square foot of wood in an adjacent fire room, no propagation of the fire occurred down the corridor. The glass fiber carpet in the burn-room became discolored and there was a significant weight loss of the carpet directly in contact with the fire. The carpet did not produce significant levels of smoke and did not spread the fire into the corridor.

NBSIR 75-783. **Validation of the DELCAP airport simulation model,** J. F. Gilsinn, 167 pages (July 1975). Available from the author at the National Bureau of Standards, Washington, D.C. 20234.

Key words: airport; airport capacity; airport simulation; models; model validation; runway capacity; simulation; validation.

This report documents exercises of the DELCAP airport simulation model performed to validate the outputs of that model. Airport throughput levels were calculated by DELCAP for five runway configurations, with three or four appropriate operating policies chosen for each, and for three different mixes of aircraft types. These estimates from DELCAP agreed well, generally within 6 to 8 percent, with current values provided by the FAA. An attempt at validating DELCAP's delay-figure output, using existing data on scheduled and actual times of aircraft departures and arrivals, is also reported. It proved unsuccessful, because available data are not sufficient to isolate that portion of total delay which DELCAP is designed to measure, i.e., terminal area ATC delay. A collection effort to accumulate the necessary data is formulated. Appendices to the report contain program listing, flowcharts, descriptions of program changes from earlier versions, and user instructions for the model's operation.

NBSIR 75-784. **Fire incidents involving flammable liquids, gas and dry explosives,** E. A. Tyrrell, 58 pages (Oct. 1975). Orde from NTIS as PB246862.

Key words: accidents; burn injuries; burn severity; explosives; fabric fires; FFACTS; flammable liquids; gas gasoline; ignition-causing activities; ignition sources; injur disposition.

From the NBS Flammable Fabrics Accident Case and Testin System as of December 1973, flammable liquids, gas, and dr explosives were found to be involved in 832 incidents, injurin 863 victims. Volatile flammable liquids represented 77 percen of the incidents; 72 percent of these liquids were gasoline. Mal victims outnumbered females more than 3 to 1. Young adults ages 21-45, and youth, ages 13-20, were injured most frequently Children and youth were injured primarily through what wa considered as play activities. Adults generally were injured whil engaged in activities traditionally considered as being oriented t the particular sex involved. Streetwear, particularl shirts/blouses, was reported most frequently as igniting firs Thirty-six percent of the fabrics represented in these incident were contaminated with a flammable liquid. Most of the victim sustained burn injuries covering 1-10 percent of their bodie only 6 percent sustained burn injuries covering 61 percent o more of their bodies. Most of the victims were hospitalized fo treatment of their injuries. Although the very young and the e derly were involved in these incidents less frequently than othe age groups, they generally were burned more severely an represented 46 percent of the victims who died in the hospital c were dead on arrival.

NBSIR 75-785. **The review of standardization and measuremen services at the Ecuadorian Institute for Standardization,** R. E trada and H. S. Peiser, 17 pages (June 27-29, 1974). Orde from NTIS as PB246345.

Key words: AID; development assistance; economic Ecuador; less developed countries; measurement service review; standardization; survey.

An international team of standards and measurement specialists visited the Ecuadorian Institute for Standardization on June 27-29, 1974, to review the operations of that organization in light of the recommendations made two years earlier by a Survey of Standardization and Measurement Services in Ecuador conducted by a team which was organized and sponsored by the U.S. National Bureau of Standards and the U.S. Agency for International Development. The review consists of the historical background of the Institute, results of the 1972 Survey, and recommendations for future planning.

NBSIR 75-786. **The CPSC road test of bicycle braking performance—Kinetic and error analyses,** L. Mordfin, 75 pages (Oct. 1975). Order from NTIS as PB251411.

Key words: bicycle brakes; brakes, bicycle; dynamics, bicycle; error analysis; friction, tire/pavement; kinetics, bicycle; measurements, bicycle braking; pitchover; standards, bicycle safety; test method, bicycle.

The Consumer Product Safety Commission has promulgated a safety standard for bicycle braking systems based on the stopping distances achieved in road tests under specified conditions. This report presents an error analysis of the test method, for the Commission's use in justifying or modifying the test criteria. The error analysis is based on experimental data, for the most part, and on theoretical principles where sufficient data are lacking. The theory, a kinetic analysis of the bicycle braking process, is included in the report together with proposed definitions of terms intended to quantify important aspects of bicycle braking performance.

The error analysis produced estimates of rather large lab-to-lab and test-to-test variabilities to be expected from the test method. These, in turn, were found to be principally dominated by errors resulting from an incorrect overweight-rider allowance specified by the Commission, and by variations in rider reaction times, respectively. Suggestions are made for more accurate methods of accommodating variations in rider mass, for reducing the effects of the test-to-test variability, and for reducing the danger of pitchover in the performance of the road test.

NBSIR 75-787. **Piezo- and pyroelectric properties of electrets,** M. G. Broadhurst and G. T. Davis, 55 pages (Oct. 1975). Order from NTIS as COM 75-11471.

Key words: electrets; piezoelectricity; polarization; polymers; polyvinylchloride; polyvinylfluoride; polyvinylidenefluoride.

A model for piezo- and pyroelectricity in polymers is presented. These effects are true piezo- and pyroelectricity rather than electrostriction, conduction, electromechanical effects or the motion of conductors in the field of space charges. Two distinct types of polymers can be piezoelectric. Amorphous polymers are piezo- and pyroelectric by virtue of a nonequilibrium but kinetically stable net dipole orientation. The semicrystalline polymers are piezoelectric due to alignment of polar, ferroelectric crystals dispersed in the amorphous phase. In both types the magnitudes of the piezo- and pyroelectric effects are in accord with the expected temperature and pressure dependence of the dipolar polarization. Space charges embedded in the polymer normally will not produce a piezo- or pyroelectric current. Those embedded near the crystal-liquid interfaces tend to reduce the piezo- and pyroelectricity. Improved orientation of dipoles and reduction of ionic impurities should increase p and d for PVF_2 by a factor of three above typical values presently reported. The sensitivity of amorphous polymers is limited mainly by dipole moment per unit volume and breakdown strength.

NBSIR 75-788. **Evaluation of the fire hazard in a mobile home resulting from an ignition on the kitchen range,** E. K. Budnick and D. P. Klein, 28 pages (Feb. 1976). Order from NTIS as PB250843.

Key words: fire test; flame spread; kitchen cabinets; kitchen range; kitchen range hood; limited combustibility; mobile home.

A series of fire tests was conducted in a typical mobile home to evaluate the potential fire hazard resulting from an accidental ignition from cooking on the kitchen range. Specific attention was directed to (a) ease of ignition of the kitchen cabinets as a function of the clearance between the range and the underside of the cabinets with and without the presence of a metal hood and (b) flame spread following the ignition.

The tests, which used a preheated pan of cooking oil as an ignition source, were conducted in a mobile home kitchen area. The materials tested were printed lauan plywood, printed particle board, and molded polystyrene, representative of materials used in kitchen cabinet construction in mobile homes.

Under the test conditions employed, it was found that ignition of the kitchen cabinets occurred in all cases in which a metal hood was not used. The time to ignition of the materials was only slightly affected by the clearance between the specimen (cabinet bottom) and the range. A significant time delay or no ignition resulted from the installation of a metal range hood.

An additional problem area revealed by the tests was the ignition and burn-through of the partition directly behind the range.

Specific design recommendations based on test results are presented along with suggestions for further investigation.

NBSIR 75-790. **FY75 progress report on design criteria and methodology for construction of low-rise buildings to better resist typhoons and hurricanes,** R. D. Marshall and N. J. Raufaste, Jr., 362 pages (Nov. 1975). Order from NTIS as PB250848.

Key words: buildings; codes and standards; housing; hurricanes; low-rise buildings; natural disaster; structural connections; typhoons; wind loads.

This report represents the major accomplishments conducted during the third phase (FY75) of a three year project to develop improved design criteria for low-rise buildings in developing countries to better resist extreme winds. The research study sponsored by the Agency for International Development commenced in March 1973. Two other reports were prepared: NBSIR 74-582 FY73 Progress Report (first phase of the research—4 months) and NBSIR 74-567 FY74 Progress Report (second phase of the research—12 months). During FY75, 6 major tasks were completed (instrumentation of fifth and sixth of six test houses to collect full scale field wind data, continuation of technician training at the field sites and at the wind tunnel facility, analyzed of extreme wind data, development of draft improved design criteria reports, participation in regional conferences in Manila and scheduling of regional dissemination of project results conference in Jamaica for November 1975). Research activities will be completed in December 1975. A final report will be published by the end of FY76.

NBSIR 75-791. **Procedural options for modification of architectural glass in residences to improve occupant safety,** S. W. Stiefel, 57 pages (Dec. 1975). Order from NTIS as PB253229.

Key words: architectural glass products; Consumer Product Safety Act; residence-related products; residential safety modification; safety implementation approaches.

The U.S. Consumer Product Safety Commission has the responsibility for developing and promulgating mandatory safety standards for products which pose unreasonable risks of injury for consumers. One of the first products selected for development of a safety standard under the Consumer Product Safety Act of 1972 was architectural glass. The prospects for regulation of many other residential unit component parts are wide open. Nevertheless, the initial impact of the adoption of a mandatory standard for architectural glass would be rather limited. The limited impact is largely due to the fact that people will continue to occupy existing housing that will not be immediately subject to the new rule.

This report documents the second and final phase of a project which considered the possible modifications for architectural glass products and the means for encouraging their implementation. The report evaluates available injury data, defines the population of hazardous architectural glass products and compares the relative level of hazard among the products. A set of possible retrofit options is presented, suggested by accident pattern review, and criteria are developed, which are useful in assessing their effectiveness. A model has been developed and exercised to calculate benefit-cost ratios for retrofit modification based upon averted injury medical costs attributable to injuries prevented by product modification. A set of implementation approaches has been postulated for consideration by the CPSC, for encouraging safety modification of component parts of residential units.

NBSIR 75-793. **Microsecond-resolution pulse calorimetry for semiconducting materials at high temperatures (a feasibility study)**, A. Cezairliyan and C. W. Beckett, 51 pages (Oct. 1975). Order from NTIS as PB247538.

Key words: capacitor discharges; heat capacity; high-speed measurements; high temperature; thermodynamics; uranium dioxide.

A feasibility study is conducted for the applicability of microsecond-resolution pulse heating techniques to the measurement of selected thermodynamic properties of semiconducting substances at high temperatures. The method of pulse heating of the specimen using capacitor discharges is described and general design considerations, including electrical circuitry and various physical, electrical and chemical phenomena, are presented. Measurements of experimental quantities, such as current, voltage, temperature, and pressure are described. The special problems in relation to measurements of heat capacity and vapor pressure of uranium dioxide in the temperature range 2000 to 6000 K are discussed. It is concluded that the capacitor discharge circuitry and the measurement of the experimental quantities, although difficult, are not likely to present major problems. However, problems are likely to stem from the experiment chamber and the specimen. The nature of these problems is discussed, and the performance of some preliminary experiments is suggested.

NBSIR 75-794. **Heat transfer in furnaces for CIB cooperative program and heat balance analysis of wall furnace**, J. B. Fang and J. T. Scott, 48 pages (Nov. 1975). Order from NTIS as PB247203.

Key words: fire resistance ratings; fire test furnace; heat balance; heat transfer; temperature-time curve.

Tests were conducted in the NBS wall panel furnace as part of a CIB international cooperative program to measure and compare heat transfer in fire endurance furnaces. Additionally, a heat balance analysis showed that a cellular concrete block wall specimen absorbed more heat by convection than by radiation. The rate of radiant heat transfer was found to decrease slowly, while the furnace exhaust heat loss increased during the test from 42 to 58 percent of the heat output. The calculated radiant heat fluxes incident at furnace walls was found to be somewhat lower than the experimental values measured at the test wall.

NBSIR 75-795. **Recommended criteria for retrofit materials and products eligible for tax credit**, W. J. Rossiter, Jr. and R. G. Mathey, Eds., 44 pages (Nov. 1975). Order from NTIS as PB246866.

Key words: caulks and sealants; clock thermostats; energy conservation; insulation; retrofitting; storm doors; storm windows; tax credit; vapor barriers; weatherstripping.

The Federal Energy Administration requested the National Bureau of Standards to develop criteria for retrofitting for possible use by the Internal Revenue Service in implementing the Presidential initiative authorizing tax credit to homeowners. Criteria are recommended for materials and products considered eligible for proposed tax credit for retrofitting one and two family residences to conserve energy. The materials considered include insulation and vapor barriers, storm windows and doors, caulking and weatherstripping, and clock thermostats. A list of these retrofit materials was compiled by generic type and recommendations made on their installation.

In addition to recommended criteria for materials and products eligible for tax credit, desired levels of performance for the retrofit materials are presented as a guide to homeowners to achieve maximum benefits in energy conservation through retrofitting.

NBSIR 75-796. **An analysis of the Salmon Statistical Information System**, F. C. Johnson, 20 pages (Sept. 29, 1975). Order from NTIS as PB247656.

Key words: Anadromous Fish Catch Record System; catch record system; fisheries statistics; fish record system; fishery management model; fishery modeling; modeling; salmon; salmon fishery; salmon information system; Washington State Fisheries.

This report contains an analysis of the official salmon statistical information system of the Washington State Department of Fisheries relative to the changing data requirements of the Department. Recommendations are given for revising the current system in order to assure the availability of complete, accurate statistics on a timely basis. In addition, the principal requirements are identified for the development of improved procedures for generating input to the hatchery and fishery management models in use by the Department. This project was sponsored by the Washington State Department of Fisheries under Service Contract No. 626.

NBSIR 75-797. **An evaluation of a range-top warning light system**, M. E. Stefl and J. J. Persensky, 22 pages (July 1975). Order from NTIS as COM 75-11465.

Key words: consumer products; human factors; kitchen ranges; reaction time; safety; warning lights.

A descriptive analysis of In-Depth Injury Investigations of range-related accidents revealed a series of incidents where range-users were unaware that surface elements were energized. One proposed solution to this problem involved a system of four warning lights to indicate individual surface unit activation. A laboratory study using human subjects evaluated the effectiveness of such a system. The backgrounds against which the warning lights were fitted and the intensity of the lights were not shown to influence subjects' responses in a reaction time task; however, the position of the lights and the type of ancilliary task

veing performed by the subject did. These results are discussed n terms of product design and safety, and implications of the tudy for methodological development are considered.

NBSIR 75-801. **A bibliography on automated measurements (July 1, 1969, to July 1, 1974),** G. A. Teamer and A. Y. Rumfelt, 158 pages (Apr. 1976). Order from NTIS as PB252044.

Key words: automated measurements; computer-aided measurements; computer-controlled instruments.

This bibliography lists approximately 1000 citations pertinent o the field of automated measurement of electrical/electronic uantities and characteristics. In addition, approximately 400 itations are included that should be helpful in applying compuers to the automation of measurements. Only references appearng in the open literature between July 1, 1969, and July 1, 1974, re listed.

NBSIR 75-804. **Generation of standard EM fields for calibration of power density meters 20 kHz to 1000 MHz,** M. L. Crawford, 44 pages (Jan. 1975). Order from NTIS as COM 75-10395.

Key words: hazard level fields; power density meter calibration; TEM transmission cells.

This report describes techniques for calibrating power density neters used by the Department of Defense in measuring high inensity (hazard level) RF fields in the frequency range 20 kHz to 000 MHz. It reports on part of the work sponsored by the Calibration Coordination Group (CCG), of the Department of Defense covering the frequency range 20 kHz to 20 GHz.

Several techniques were considered for producing a standard ield including parallel plate and parallel wire transmission lines, ransverse electromagnetic mode (TEM) transmission cells, varius directive antennas and open ended waveguide (OEG). The najor emphasis in this report is on the TEM cells, which are ecommended for the frequency range 20 kHz to 500 MHz. Design and evaluation details and an error analysis associated vith the TEM cell measurement system are given. Power densiy levels can be established in the cells from a few $\mu W/cm^2$ to 00 mW/cm^2 with uncertainties less than $\pm$ dB.

Limited information is also given describing the use of OEG, he recommended technique for the frequency range 500 MHz o 2.6 GHz, and giving the results of intercomparisons among arallel plate lines, TEM cells, OEG, and standard gain horns.

NBSIR 75-805. **Calibration techniques for electromagnetic hazard meters: 500 MHz to 20 GHz,** R. R. Bowman, 38 pages (Apr. 1976). Order from NTIS as PB252971.

Key words: calibrations; electromagnetic hazards; field meters; gain; microwave; near-field.

The calibration techniques discussed are suitable for producng fields for calibrating most electromagnetic (EM) hazard meers to within $\pm$1.0 dB using a minimum of laboratory space and scillator power. Above about 2.6 GHz, adequate equipment nd standards have been available for these calibrations. Below his frequency the large apertures of the usual horn radiators equire more power than is available from medium power oscillaors. Further, calibrations in closed systems are difficult except t frequencies well below 1 GHz. Thus there is a need for smallperture gain standards from about 500 MHz to 2.6 GHz. The nain portion of the work reported here consists of accurate gain neasurements for open-ended hollow waveguide radiators OEG) for use from 500 MHz to 2.6 GHz. Other characteristics f this type of radiator important for EM hazard meter calibraions were also determined: near-field corrections, reflection oefficients, and aperture scattering. The suitability of the alibration scheme was tested by performing calibrations at 2 GHz on an EM hazard meter with both a horn radiator and an OEG radiator.

NBSIR 75-806. **Phase equilibrium and flow-induced desorption data for He-CO, He-N_2O, and He-N_2 systems,** W. G. Steward, R. O. Voth, J. Hord, W. R. Parrish, C. F. Sindt, and J. M. Arvidson, 62 pages (Mar. 1975). Order from NTIS as COM 75-10368.

Key words: binary mixture; cavitating venturi; enhancement factors; experimental vapor-liquid equilibria; flow induced desorption; helium-carbon monoxide system; helium-nitrous oxide system; Henry's law constants; two phase choking; two phase flow.

Liquid-vapor equilibrium data were obtained for the helium-carbon monoxide and helium-nitrous oxide systems at pressures to 138 bars. Liquid and vapor phase compositions were measured at nominal temperatures of 80, 85, 90, 100, and 120 K (144, 153, 162, 180, and 216 °R) for the helium-carbon monoxide system, and at 235, 245, 265, and 285 K (423, 441, 477, and 513 °R) for the helium-nitrous oxide system. Internal consistency of the data was checked by using pseudo-Henry's law constants and enhancement factors.

The effects on flow of helium absorption and subsequent flow-induced desorption were investigated by means of reduced scale model experiments. Friction losses attributable to helium desorption in the long channels proved to be negligible both in experimental measurements and in calculations based on assumed equilibrium of liquid and gas. Contrarily, the assumption of phase equilibrium leads to gross miscalculations of flow rates in cavitating or near cavitating nozzles or venturis. Actual venturi mass flow rates reached in the experiments were fifty times the theoretical choking flow rates; however, definite mass flow rate reductions due to helium desorption were measured, ranging from four percent for nitrogen to twelve percent for nitrous oxide. Pertinent experiences in handling these fluids and operating the test equipment are also discussed.

NBSIR 75-807. **Turbulent natural convection of liquid deuterium, hydrogen, and nitrogen within enclosed vessels,** D. E. Daney, 82 pages (Feb. 1975). Order from NTIS as COM 75-10396.

Key words: cryogenic; heat transfer; hemisphere; horizontal cylinder; liquid deuterium, liquid hydrogen, liquid nitrogen; natural convection; sphere; vertical cylinder.

Quasi-steady natural convection of liquid deuterium, hydrogen, and nitrogen within a sphere, hemisphere, horizontal cylinder, and vertical cylinder has been studied experimentally for the case of a nearly isothermal wall. A single expression relating the Nusselt and Rayleigh numbers,

$$Nu = 0.104\ Ra^{0.352},$$

fits the deuterium and nitrogen data over the range $7 \times 10^8 < Ra < 6 \times 10^{11}$, while the hydrogen Nusselt numbers are 8 percent lower. The temperature field within the vessels is virtually free of horizontal temperature gradients. A single dimensionless temperature profile characterizes the vertical temperature distribution for each vessel shape, with the profiles for the sphere, hemisphere, and horizontal cylinder being nearly identical.

NBSIR 75-809. **Non-planar near-field measurements: Spherical scanning,** P. F. Wacker, 67 pages (June 1975). Order from NTIS as COM 75-10989.

Key words: antennas; arrays; coordinate transformations; data processing; group representations; measurements; near field; non-planar; patterns; scanning; spherical; symmetry.

The advantages and limitations of near-field antenna measurements are compared with those of conventional far-field measurements. Further, the advantages and limitations of planar, circular cylindrical, and spherical scanning are compared.

Spherical scanning is advantageous for arrays steered well off-axis and for antennas with wide angle side lobes, but the data processing has been quite impractical except for very simple antennas and probes. A new highly efficient data processing scheme is given for spherical scanning with and without probe pattern correction. The translation-of-centers transformation of the probe pattern coefficients (required only with the probe pattern correction) is carried out once and for all for a given probe, scanning radius, and frequency. The routine computations involve Fast Fourier "Transforms" and multiplication by matrices with constant elements, matrices which are independent of the detailed nature of the probe, the radius of the scanning sphere, the points at which measurements are made, and the nature of the test antenna. The FFT's and matrix multiplications supplant matrix inversion, ordinary solution of simultaneous equations in more than two unknowns, ordinary numerical integration, and (in routine processing) ordinary evaluation of functions, even for computation of the far field. Except for the truncation of the infinite series of spherical modes, no analytical or data processing approximations are made, even in the use of the FFT.

So that readers may draw from their understanding of planar and cylindrical scanning, a unified theory of near-field data processing is given, treating planar, cylindrical, and spherical scanning as mere special cases.

NBSIR 75-810. **Semi-annual report on materials research in support of superconducting machinery,** R. P. Reed, J. G. Hust, M. B. Kasen, H. M. Ledbetter, R. P. Mikesell, R. E. Schramm, L. L. Sparks, R. L. Tobler, and W. F. Weston, 201 pages (Apr. 1975). Order from NTIS as COM 75-10919.

Key words: composites; elastic properties; fracture; liquid helium; mechanical properties; structural materials; superconducting machinery; thermal conductivity.

Results of six months of study on materials in support of superconducting machinery (October 1974 through March 1975) are reported to the sponsor, the Advanced Research Projects Agency of the U.S. Department of Defense. The report is divided into five sections: thermal conductivity, magnetothermal conductivity, fatigue and fracture-toughness properties, properties of advanced composites, and elastic properties. The temperature range 4 to 300 K is covered by the study. Materials studied are either being used or are candidates for use in superconducting machinery and include: aluminum alloys, composites, copper, age-hardened, nickel-base superalloys, stainless steels, and titanium alloys.

Special results of the study include: thermal conductivity data for comparison of the effects of heat treatment on age-hardenable alloys, the first determination of a complete set of elastic constants for a composite at liquid helium temperature, boron-aluminum composite tensile data at 4 K, and a summary of fatigue crack-growth rate behavior at 4 K for a number of different structural alloys. These data provide considerable insight into material characteristics at extremely low temperatures, assisting in material selection and efficient design.

NBSIR 75-812. **The Kapitza conductance of the (100) surface of copper and polycrystalline indium and niobium,** N. S. Snyder, 51 pages (June 1975). Order from NTIS as COM ADA012889.

Key words: heat transfer to helium II; interfacial thermal resistance; Kapitza conductance of copper; Kapitza conductance of indium; Kapitza conductance of niobium; x-ray diffraction examination of single crystal lattice damage; (100) surface of copper.

Measurements of the Kapitza conductance to liquid helium II across the (100) surface of single crystals of copper are presented. The temperature range of these measurements was 1.6 to 2.1 K.

The sample surfaces were subjected to several different treatments. Some surfaces were cleaned by low energy argon ion bombardment, annealed in an ultrahigh vacuum system, and preserved under vacuum until purified liquid helium was admitted. Other surfaces were intentionally damaged by machining and/or exposure to the atmosphere. The conductance after these latter treatments was found to be about a factor of three higher than that of the more ideally cleaned and annealed surfaces, and a significant increase in the temperature dependence of the conductance was also observed. Indications are that these effects on the conductance are produced primarily by the last few atomic layers of the solid, so extensive cold-working, which impairs the thermal conductivity of the bulk, need not be undertaken to improve surface heat transfer. This finding has important implications for the design of practical heat transfer surfaces. Good reproducibility was found for the conductances of similarly treated surfaces and good correlation with studies of damage carried out by x-ray diffraction. The relationship of these results to the numerous current theories of the Kapitza conductance is discussed. Conductance measurements of polycrystalline niobium and indium are presented in the appendices.

NBSIR 75-814. **A modified Benedict-Webb-Rubin equation of state for parahydrogen-II,** H. M. Roder and R. D. McCarty, 54 pages (June 1975). Order from NTIS as COM 75-11132.

Key words: critical point; density; enthalpy; equation of state; hydrogen; index of refraction PVT; saturation properties; scaling laws; specific heat.

A 32 term modified Benedict-Webb-Rubin equation of state has been applied to data for parahydrogen. The adjustable parameters in the equation of state were determined using 266 points including very recent measurements at low temperatures and high pressures. The new values extend the range of the PVT data sufficiently to warrant a refitting of the equation of state. Temperatures for the data range from the triple point to about 700 K with pressures reaching 3000 atmospheres near ambient temperatures. The PVT data were adjusted to the T_{68} scale. In addition, extensive modifications have been made to the previously accepted PVT surface in the region near the critical point. These adjustments have been made on the basis of more recent refractive index data and the application of scaling law equations. Detailed comparisons between experimental and calculated values are given for density. Corresponding comparisons are made for enthalpy and the specific heat at constant pressure.

NBSIR 75-816. **Performance characteristics of a liquid helium pump,** P. R. Ludtke, 55 pages (July 1975). Order from NTIS as COM 75-11133.

Key words: cavitation; cryogenic motors; induction motors; liquid helium pumps; motor efficiency; net positive suction head; pump efficiency; pump performance.

Part A of this report presents performance data for a simple preinduced, single stage, centrifugal liquid helium pump powered by a close-coupled submersible cryogenic induction motor. Data on pump efficiency and the motor efficiency are given, and the effects of decreasing the pump leakage loss and removing the pre-inducer were also investigated.

Part B describes a study of the cavitation characteristics of the pump in liquid helium I. The net positive suction head at cavita

tion of the pump was extensively investigated, and found to be near zero; the effects of removing the inducer, changing the pump inlet geometry, and varying the helium temperature were determined.

NBSIR 75-818. **Bibliography of the Electromagnetics Division June 30, 1974 to June 30, 1975,** M. L. Woolley, 27 pages (Sept. 1975). Order from NTIS as PB246439.

Key words: antenna parameters; attenuation; automated measurements; EM metrology; field strength; impedance; laser parameters noise; optical electronics; phase; power; pulsed quantities; squids; transmission lines; waveform analysis; waveguides.

This bibliography lists the publications of the NBS Electromagnetics Division between June 30, 1974 and June 30, 1975.

NBSIR 75-819. **Sensitive isotropic antenna with fiber-optic link to a conventional receiver,** E. B. Larsen, J. R. Andrews, and E. E. Baldwin, 108 pages (Sept. 1976). Order from NTIS as PB258554.

Key words: electromagnetic compatibility; fiber optics; field strength measurement; isolated EMC antenna; sensitive isotropic probe.

A broadband, active, isotropic receiving antenna was developed at NBS for the frequency range 15 kHz to 150 MHz. It was designed for use with a conventional receiver to measure weak, near-zone electric fields of unknown polarization, such as leakage emanations from electronic equipment placed within a shielded enclosure. The antenna system consists of three mutually-orthogonal active dipoles, each 31 cm long by 3.5 cm diameter. The entire frequency range of each of the three field components is amplified and used to modulate a high-speed light emitting diode (LED) located inside the dipole. The modulated infrared (IR) signals are guided through glass fibers 10 meters long which connect the "isolated" dipoles to avalanche photodiodes at the far end of the fiber guides. These photodetectors recover the rf modulation from the IR carrier for input to the receiver.

The fiber-optic antenna system described in this paper has high sensitivity (down to 10 μV/m) and fast response time (rf modulations up to 150 MHz). The readout indication at each receiver frequency is proportional to the Hermitian magnitude of E, which is the root-sum-square value of three orthogonal E field components at the measurement point. The linear dynamic range of the antenna system depends on the receiver bandwidth and signal frequency. It is 70 to 75 dB at frequencies between 0.02 and 2 MHz (for 0.5 kHz receiver bandwith), 60 to 70 dB between 2 and 25 MHz (for 5 kHz receiver bandwidth) and 40 to 55 dB between 25 and 200 MHz (for 50 kHz bandwidth).

NBSIR 75-820. **Study of cryogenic propellant systems for loading the space shuttle—Part II, Hydrogen systems,** W. G. Steward, 63 pages (Oct. 1975). Order from NTIS as PB246658.

Key words: computer modeling; cooldown; cryogenic flow; stresses; two phase flow.

This report covers computer simulation studies of liquid hydrogen fill and vent systems for the space shuttle. The computer programs calculate maximum and minimum permissible flow rates during cooldown as limited by thermal stress considerations, fill line cooldown time, pressure drop, flow rates, vapor content, vent line pressure drop and vent line discharge temperature. The input data for these programs are selected through graphic displays which schematically depict the part of the system being analyzed. The computed output is also displayed in the form of printed messages and graphs. Digital readouts of graph coordinates may also be obtained.

Procedures are given for operation of the graphic display unit and the associated minicomputer and timesharing computer.

NBSIR 75-822. **Study of errors in absolute flux density measurements of Cassiopeia A,** M. Kanda, 34 pages (Oct. 1975). Order from NTIS as PB246933.

Key words: accuracy; antenna; calibration; Cassiopeia A; error analysis; flux density; ground station; G/T (system gain/system noise temperature); radio star.

An error analysis for absolute flux density measurements of Cassiopeia A is discussed. The lower-bound quadrature-accumulation error for state-of-the-art measurements of the absolute flux density of Cas A around 7 GHz is estimated to be 1.71 percent for 3σ limits. The corresponding practicable error for the careful but not state-of-the-art measurement is estimated to be 4.46 percent for 3σ limits.

NBSIR 75-823. **Helium research in support of superconducting power transmission,** V. D. Arp, D. E. Daney, N. V. Frederick, M. C. Jones, P. R. Ludtke, W. R. Parrish, and R. L. Powell, 79 pages (Oct. 1975). Order from NTIS as PB246436.

Key words: cooling system; cryogenics; helium-cooled electrical leads; helium impurities; microwave cavities; negative differential flow resistance; pressure measurement; system dynamics; thermometers.

This is the first annual report on a program of helium-related research in support of superconducting power transmission. Program areas reported on are concerned with the dynamics of helium cooling systems—theoretical aspects of oscillatory behavior and experiments—and helium related measurements. The latter include pressure measurement, temperature measurement and the problem of impurity levels in the helium refrigerant.

NBSIR 75-825. **The National Measurement System for cryogenics,** T. M. Flynn, 76 pages (Oct. 1975). Order from NTIS as PB258913.

Key words: cryogenics; data; flowmeter; instrumentation; measurements; National Measurement System.

The Cryogenics Division of NBS has evolved as the nation's central laboratory for cryogenics, much as NBS itself has evolved as the nation's central laboratory with both broad and specific responsibilities. Cryogenic measurement and data outputs provide the common foundation for all the institutions and agencies throughout the nation employing cryogenics to solve their problems.

This Study of the National Measurement System showed that the Cryogenics Division of NBS provides almost every category of measurement and data service that NBS itself provides: not just an instrumentation system (including, for example, pressure, temperature, density, liquid level, flow rate, etc.), but also properties of fluids (both thermodynamic and transport properties); properties of solids (thermal, mechanical and electrical); an interface with the users through systems integration and advisory and consulting services; and a dissemination network through the Cryogenic Data Center.

This study documents the impact, status and trends of the cryogenic measurement system and specifically illustrates these characteristics wherever possible with a specific case study, a recently completed measurements and data program for the flow-metering of liquid nitrogen.

NBSIR 75-827. **Report on NBS dual mixer time difference system (DMTD) built for time-domain measurements associated with Phase 1 of GPS,** D. W. Allan, 21 pages (Jan. 1976). Order from NTIS as PB247938.

Key words: frequency measurement; frequency mixing; global positioning system; isolation amplifiers; low-noise amplifiers; precision frequency measurements; precision time measurements; time difference measurements; time-domain frequency stability; time interval.

Based on a previous work reported at the 1975 Frequency Control Symposium, the National Bureau of Standards was asked to build a Dual Mixer Time Difference (DMTD) measuring system. This report includes the design, construction, and testing of this DMTD system in fulfillment of this request. The precision of time difference measurement with this system was shown to be about 0.1 picosecond and the accuracy about 10 ps; similarly, the frequency stability precision was shown to be described by $\sigma_y(\tau) \simeq 10^{-13}\,\tau^{-1}$, $0.1\text{s} < \tau < 10^3\text{s}$ and equal to 10^{-16} at τ equal about half a day.

The request for this DMTD system was for measuring the clocks that will go on board the satellites for Phase 1 of the Global Positioning System (GPS) program. The DMTD system described in this report is the only system that can easily meet all of the time-domain measurement requirements for this program.

NBSIR 75-828. **Semi-annual report on materials research in support of superconducting machinery,** R. P. Reed, J. G. Hust, M. B. Kasen, H. M. Ledbetter, D. T. Read, E. R. Naimon, R. E. Schramm, L. L. Sparks, R. L. Tobler, and W. F. Weston, 193 pages (Jan. 1976). Order from NTIS as PB249041.

Key words: composites; copper alloys; cryogenic temperatures; elastic properties; engineering materials; fatigue; fracture; iron alloys; mechanical properties; nickel alloys; superconducting machinery; thermal conductivity.

Results are reported of a six-month study, March through August 1975, on candidate materials for superconducting machinery. The results cover five areas—advanced composites, elastic properties, fatigue resistance and fracture toughness, magnetothermal conductivity, and thermal conductivity. Material properties were studied over the temperature range 4 to 300 K. Materials studied include: oxygen-free copper; copper-nickel alloys; a precipitation-hardening copper alloy; invar; nickel-chromium-iron alloys; stainless steels; and the composite materials boron/aluminum, boron/epoxy, S-glass/epoxy, graphite/epoxy, and an organic-fiber/epoxy. Some notable results of the study are: the first 4 K fatigue data on a composite material; a ten-fold increase in the fatigue life of a uniaxial glass/epoxy composite between room temperature and liquid-helium temperature; the first 4 K fatigue fracture toughness studies on a nitrogen-strengthened chromium-nickel-manganese steel, which show this material has higher yield strength and adequate toughness compared to conventional stainless steels; room-temperature elastic properties of a copper-cadmium-chromium precipitation-hardening alloy, which are quite different from those of unalloyed copper and show a nonparallel behavior of the shear modulus and the bulk modulus; the thermal conductivity of 304 stainless steel may be reduced one third at 4 K by a 6 MA/m (80 k0e) magnetic field; the first systematic study of the tensile properties of fiber-reinforced composite materials between room temperature and liquid-helium temperature.

This work was supported by the Advanced Research Projects Agency of the U.S. Department of Defense.

NBSIR 75-829. **Radiation characteristics of dipole sources located inside a rectangular, coaxial transmission line,** J. C. Tippet and D. C. Chang, 35 pages (Jan. 1976). Order from NTIS as PB248855.

Key words: EMC measurements; radiation resistance; rectangular coax; shielded strip line; TEM cell.

When making EMC measurements inside a shielded enclosure, the radiation characteristics of the device being tested changes. In this report the change in radiation resistance of dipole sources located inside a National Bureau of Standards TEM transmission cell is determined. In many cases a practical device can be modeled by dipole sources. In these cases, the analysis allows one to predict the device's radiation characteristics in other environments, e.g., free space.

NBSIR 75-900. **Liquid level instrumentation in volume calibration,** R. M. Schoonover, H. H. Ku, J. R. Whetstone, and J. F. Houser, 37 pages (Oct. 1975). Order from NTIS as PB250859.

Key words: density measurement; electromanometer; large volume calibration.

The technique of pressure head measurement for determining liquid levels in tanks has been used for the intercomparison of commercially available electromanometers with themselves and a sight glass. In addition to obtaining intercomparison information, the high precision of these devices coupled with that of volumetric transfer techniques demonstrates the applicability of the calibration method in determining departures of the actual tank geometry from that of a model straight-walled geometry. It is shown that the calibration of the volume-to-height relationship of a 3300 liter tank may be accomplished with an uncertainty in this relationship of ~4 parts in 10,000.

NBSIR 75-901. **Smoke and carbon monoxide formation from materials tested in the smoke density chamber,** T. Y. King, 40 pages (Oct. 1975). Order from NTIS as PB246860.

Key words: carbon monoxide; electrostatic precipitation; heat flux; oxygen depletion; particulate mass; scanning electron microscope; smoke.

The effects of physical and chemical factors on the smoke and carbon monoxide generated by burning polymers and red oak in the NBS Smoke Density Chamber are reported.

NBSIR 75-902. **A survey of fire accidents involving curtains and draperies—deaths, injuries and financial loss,** L. D. Moore and A. K. Vickers, 35 pages (Dec. 1975). Order from NTIS as PB249539.

Key words: curtains; draperies; FFACTS system; fire; flammable fabrics; NFPA.

A case history survey of 286 fire accidents was conducted. This survey was composed of three groups of case histories in which curtains or draperies (C/Ds) were involved. The cases were analyzed in detail, attempting to ascertain the extent to which these products represented fire hazards.

As none of the three files were chosen on a statistical basis, projection of the data to the overall fire hazard situation is not technically feasible.

To learn more of the physical nature of burning C/Ds, and to supply information that may be utilized to judge the extent of hazard, it is recommended that full-scale experiments be conducted.

Smoke and carbon monoxide formation was found to depend on irradiance level and oxygen concentration in the chamber. Smoke optical density correlations with particulate mass density showed that the ratio of these two varied with material composition and burning conditions.

NBSIR 75-903. **San Antonio Veterans Administration Hospital smoke movement study,** F. C. W. Fung and R. H. Zile, 37 pages (Nov. 1975). Order from NTIS as PB246859.

Key words: experiments; full-scale; gas tracer; interstitial space; penetration through ceiling; smoke movement; smoke simulation; sulfur hexa-fluoride (SF_6); Veterans Administration Hospital.

A series of full-scale smoke movement experiments was conducted using a sulfur hexa-fluoride (SF_6) gas tracer, smoke simulation system. The experiments were designed to study smoke movement in a hospital building with an interstitial space between floors. The penetration of smoke through ceiling and interstitial space and the vertical smoke movement in such a building were investigated.

NBSIR 75-908. **Characterization of sharp points and edges by electrical breakdown,** J. Cohen, 21 pages (Aug. 1975). Order from NTIS as PB247270.

Key words: consumer products; electrical breakdown; gases; hazard; high voltage; sharp edges; sharp points; threshold.

Experiments were made to determine the feasibility of using the phenomenon of electrical breakdown in air to characterize sharp metallic edges and points. A fixed voltage was applied between a sample edge or point and a parallel plane, and threshold gap length for breakdown observed. Results were quite favorable for edges, but not for points, and the polarity on the sample was required to be negative.

NBSIR 75-909. **Index of automated system design requirements as derived from the OMB Privacy Act implementation guidelines,** D. K. Branstad and R. A. Krell, Standards Coordinators, 14 pages (Oct. 1975). Order from NTIS as PB246863.

Key words: computer; data processing; index; information processing; privacy; requirements definition; security; systems design.

This index is a list of certain requirements which must be considered by Federal technical and administrative personnel in order to comply with those provisions of the Privacy Act of 1974 relating to automated systems design and development. This index has been derived from the Office of Management and Budget (OMB) guidelines for implementing those provisions. Each requirement listed contains a reference to an applicable part of the Privacy Act and to a page and column number of the OMB guidelines as they appear in the *Federal Register*. Therefore, these documents must be used in conjunction with this index. Furthermore, a familiarity with these documents will increase the utility of this index.

NBSIR 75-910. **The role of chemical kinetics in energy conservation,** H. M. Rosenstock, D. Garvin, J. T. Herron, and W. Tsang, 123 pages (Oct. 1975). Order from NTIS as PB248646.

Key words: combustion; data base; energy conservation; estimation schemes; kinetics; modeling; oxidation; pyrolysis.

Many of the technological areas of pertinence to energy independence involve chemical transformation of gas phase materials at high temperatures. The design, control and optimization of such devices and processes have come to depend increasingly on mathematical modeling. Among the most important input data required for these models are information on the detailed chemical mechanisms and the rates of the individual processes. It is concluded that although many resources are available there does not exist at present an adequate, publicly available data base for the modeling of high temperature systems. A detailed program involving a combination of experimentation and compilation, evaluation and dissemination of gas kinetic data is proposed.

NBSIR 75-913. **Structural test procedures for bicycles,** D. E. Marlowe, 50 pages (Oct. 1975). Order from NTIS as PB248911.

Key words: bicycle; consumer safety; regulations; safety; structural testing.

Tests for several structural performance criteria have been included in a mandatory regulation on bicycle safety which has been proposed by Consumer Product Safety Commission. The apparatus and procedures developed to conduct these tests and results from 15 representative bicycles are described. Several of the bicycles tested failed to meet the requirements for the seat and handlebar stem friction clamp strength.

NBSIR 75-915. **A source of error in paper extract pH determinations: Contact between paper and reference electrodes,** E. J. Parks and R. L. Hebert, 17 pages (Jan. 31, 1975). Order from NTIS as PB249775.

Key words: acidity; contact; decantate; electrode; error; extract; paper; pH; suspension.

If the reference electrode of a pH meter is permitted to contact paper suspended in an aqueous medium, the pH observed is lower than that observed with no contact. The effect has been observed with papers of widely different pH, and varies in magnitude with the proximity of contact and with different papers. The problem can be avoided by taking measurements on decanted equilibrium solutions instead of suspensions of paper.

The cause of this effect may be analogous to the suspension effect in colloidal systems.

NBSIR 75-916. **The role of passive film growth kinetics and properties in stress corrosion and crevice corrosion susceptibility,** J. Kruger, J. R. Ambrose, and T. Kodama, 85 pages (Oct. 1975). Order from NTIS as ADA019648.

Key words: chemical breakdown of passivity; chloride; crevice corrosion; ellipsometry; iron; molybdenum; repassivation kinetics; stress corrosion.

This report consists of four parts as follows: Part I – A study of the influence of molybdate ions on the repassivation kinetics of iron in chloride solutions. Results indicate that molybdate ions precipitated as ferrous molybdate in pits inhibit propagation but not initiation. Part II – Using a technique that allows ellipsometric studies to be made in a crevice, this work has found significantly lower film growth rates in a crevice on iron as compared to the rates observed outside the crevice. Part III – A review of the current state of our understanding of chemical breakdown of passivity is given with a listing of critical questions that remain to be resolved. A short bibliography on the subject is included. Part IV – A review of the qualitative applications of ellipsometry to study localized corrosion that have been developed at NBS is given.

NBSIR 75-917. **A multiple-chamber humidity apparatus,** L. Greenspan, 22 pages (Dec. 1975). Order from NTIS as PB247655.

Key words: humidity; humdity chamber; microbiological growth; relative humidity; salt solutions; saturated salt.

An apparatus has been developed for studying the growth of microbiological organisms on food under controlled conditions of humidity and temperature. This apparatus contains twenty-eight individual humidity chambers within a temperature controlled bath. A wide range of humidities can be provided within the individual chambers by means of saturated salt solutions. These chambers can be maintained at stable temperatures from 5 to 50 °C with a constancy and uniformity within ± 0.02 °C. In-

dividual chambers may be conveniently removed or changed without affecting the other chambers.

NBSIR 75-918. **Machine-readable mapping from National Network Simulation (NNS) zones to Bureau of Economic Analysis (BEA) areas,** D. W. Lozier and J. R. Stiehler, 77 pages (Sept. 1975). Order from NTIS as PB251412.

Key words: commodity flow analysis; economic analysis; National Network Simulation system.

This report describes the allocation of freight flow data from the National Network Simulation (NNS) zone system to the Bureau of Economic Analysis (BEA) area system. The NNS zone system was developed for use in the analysis of national modal freight flows. The BEA area system was primarily developed for the allocation of national economic data to regions of the United States. The BEA area system contains approximately 175 distinct areas and the NNS zone system, approximately 500. Assuming flows of commodities are known among the NNS zones, the NNS zone to BEA area mapping enables the determination of flows among the BEA areas. When an NNS zone is completely contained in one BEA area, flows entering and leaving the NNS zone accrue entirely to that BEA area. When an NNS zone overlaps more than one BEA area, the mapping specifies the allocation of incoming and outgoing flows among the affected BEA areas. This report presents the NNS zone to BEA area mapping which utilizes 1970 economic data as the basis for allocating flows when an NNS zone overlaps more than one BEA area. It also presents computer programs that could be used to generate a mapping using economic data from some other year. Closely related reports are R. Schofer, "Final Report on the National Network Simulation," NBS Internal Report 75-912 and R.H.F. Jackson, "A National Network Data Base System," NBS Internal Report 75-911.

NBS1R 75-920. **Distribution of water through a vertical plane from automatic sprinkler heads,** R. L. P. Custer and K. Wahle, 48 pages (Dec. 1975). Order from NTIS as PB248913.

Key words: automatic sprinkler; corridor sprinkler systems; discharge patterns; spray distribution; water distribution; water spray.

An investigation was conducted to evaluate the distribution of water through a vertical plane from automatic sprinkler heads as a function of water discharge rate and sprinkler spacing. Tests were conducted to simulate discharging an automatic sprinkler head in a corridor to determine the effectiveness of the sprinkler head in covering a doorway with water spray when positioned at various locations. Major differences in distribution characteristics between sprinkler heads produced by different manufacturers were observed. It was determined that only sprinklers installed on the centerline of the doorway and discharging water at a flow rate of 20 gallons-per-minute or more would cover the top of the doorway.

NBSIR 75-923. **Corrosion of metallic piping on military bases—A survey,** P. W. Brown and J. R. Clifton, 21 pages (Nov. 1975). Order from NTIS as PB250767.

Key words: corrosion; corrosion control; metallic piping; nondestructive evaluation; survey; water hardness.

The results of surveys of the extent of corrosion of metallic piping systems at selected military installations have been analyzed. Potable water, fire protection, heat distribution, cooling, and natural gas distribution systems are included in these surveys. The corrosion evaluation techniques used in these surveys and the types of protection applied are discussed. General recommendations regarding continuation and extension of these surveys are given.

NBSIR 75-924. **Evaluation, revision and application of the NBS stylus/computer system for surface roughness measurement: Minicomputer software,** E. C. Teague, 79 pages (Apr. 1975). Order from NTIS as PB248686.

Key words: amplitude density function; arithmetic average; autocorrelation function; linear least-squares fit; machine language; minicomputer software; surface texture measurement.

A thorough description of all the software used at NBS for characterizing surface texture is given in this report. The description includes flow diagrams and detailed, annotated listings of machine language programs for step-calibrating the system, for acquiring digitized surface profiles and for calculating from these profiles important parameters and statistical functions. Parameters and functions included are the arithmetic average value, mean square value, average wavelength, average slope, amplitude density function and autocorrelation function.

NBSIR 75-926. **The National Measurement System for length and related dimensional measurements, Part I,** J. W. Lazar and R. L. Bach, 115 pages (Aug. 1976). Order from NTIS as PB257467.

Key words: dimensional; gage; instrument; laser; length; machine; measurements; standard.

The determination of length and related dimensional measurements constitute the largest group of measurements made in science, manufacturing and technology. We have shown that length and related dimensional measurements have impact upon many areas of the economy. We have also shown that the National Measurement System is viable and is adaptable in conforming to the changing requirements of industry. The greater accuracy requirements of some industries brought new measurement techniques into use, e.g., the fringe counting laser interferometer systems now used in many tool rooms and metrology laboratories. We have found no deficiencies in the system but only in individuals or the measurement technique that they use as shown in the comparison measurement on audit packages that were made by the various standards laboratories.

NBSIR 75-927. **The national measurement system for surface finish,** R. D. Young, 51 pages (July 1976). Order from NTIS as PB255809.

Key words: economic factors; measurement; surface; surface finish; surface roughness; technology assessment.

NBS has conducted a study of the National Measurement System for Surface Finish. The proposed system model is discussed including the role of standards committees, instrument manufacturers and measurement users. The economic dimensions of the measurements impact areas and the technological base from which new measurement technology springs is described.

NBSIR 75-929. **A study of the National Force Measurement System,** D. E. Marlowe, 40 pages (June 1975). Order from NTIS as PB261498.

Key words: dynamic force; economic; force; metrication; national measurement system; standards.

A study of the National Force Measurement System has been conducted. The overall structure of the system has been defined, and the size of several of its component elements has been measured. The interactions of many of these components within the system have been assessed. The position which NBS has and the role it plays in the system are better understood as a result of this study.

The best assessment of the condition of the National Force easurement System is that areas such as static force measure-nt are fully adequate with the levels of accuracy now provided ile other areas such as dynamic force measurements and in-rmation transfer, are very inadequate to serve even our present eds.

BSIR 75-930. **The national measurement system for fluid flow,** W. C. Haight, P. S. Klebanoff, F. W. Ruegg, and G. Kulin, 66 pages (Aug. 1976). Order from NTIS as PB258250.

Key words: aerodynamics; air flow; flow measurement; fluid flow; fluid metering; hydraulics.

Fluid flow is a diverse field concerned with the motion of a de variety of fluids encountered both in daily life and in scien-c applications. It encompasses movement of weather systems atmospheric winds, travel and dispersion of air pollutants, w around aircraft and spacecraft bodies, oil and gas pipeline w, irrigation and waste water flow, and many others. The pes of fluid motions encountered in descriptions of these enomena include closed-conduit, open channel, supersonic, bsonic, steady, unsteady, laminar, and turbulent flow. Mea-rements of the properties of these flows are instrumental in the nctioning of the nation's industries and the advancement of ientific technology, and impact the lives of every consumer.

This report presents the concept of the National Measurement stem for Fluid Flow as it exists today and the activities and echanisms employed within it to generate and implement mea-rement data. The system structure is presented, and data and formation gathered on the interrelationships between the entifiable parts are reported. To further the study, more than 40 contacts were made with trade associations, government encies, private companies, universities and laboratories.

This study was conducted over the time span June 1973 to ecember 1975.

BSIR 75-931. **The National Measurement System for pressure,** P. L. M. Heydemann, 42 pages (Sept. 1976). Order from NTIS as PB261030.

Key words: calibration; calibration chain; pressure; pressure measurement.

The state of the national measurement system for pressure in e range where NBS presently provides calibrations and related rvices is in a satisfactory state. Needs for expansion of the nge have been identified and most of these needs will be tisfied in the near future.

Rapid changes in the needs of the system are generated by the creased use of transducers to transfer measurements and plans e being implemented at NBS to provide all necessary services.

BSIR 75-932. **The National Measurement System for temperature,** J. F. Schooley, 61 pages (Aug. 1976). Order from NTIS as PB257425.

Key words: data; International Practical Temperature Scale; measurements; National Measurement System; standards; thermometry.

The National Temperature Measurement System reaches uite literally into all phases of American life. Comfort control in ome, school, office and factory, health care, manufacturing, ood preparation and storage, and all forms of powered transpor-tion are just a few of the many facets of America's human ac-vities that depend for their trouble-free operation on the ex-tence of reliable thermometry.

The Heat Division of the National Bureau of Standards col-borates with the national laboratories of other nations in establishing an International Practical Temperature Scale which represents thermodynamic accuracy insofar as current scientific practice permits. The NBS is the only U.S. agency bearing this responsibility; in addition, only the NBS is responsible for disseminating the International Scale to U.S. scientific and technical activities.

The Study of the National Temperature Measurement System shows that the NBS continues to contribute energetically to the quality of the International Scale. It further indicates that NBS maintains a consistent and deliberate effort not only to provide access to the Scale at the several levels required by U.S. science and technology, but also to participate in solving special problems in thermometry. These are problems for which the nature of NBS as an objective, expert resource in thermometry uniquely qualifies it to furnish effective, practical solutions.

In briefly describing the many aspects of the National Temperature Measurement System, this Study attempts to portray its great diversity of products, services, and people. The System is largely organized, as might be expected, for the purpose of economic gain; the NBS enters the picture only in those areas where highly accurate or intricate thermometry is essential.

NBSIR 75-933. **A study of the national humidity and moisture measurement system,** A. Wexler, 52 pages (Aug. 1975). Order from NTIS as PB248983.

Key words: humidity; humidity measurement system; measurement of humidity; measurement of moisture; moisture; moisture measurement system; water vapor.

This study analyzes and assesses the status of the National Measurement System for humidity and moisture. It focuses on the physical process of measuring and controlling water vapor and moisture. It describes the nature, extent and economic dimensions of the system. It indicates impacts and trends, identifies deficiencies and shortcomings and shows the role NBS plays in the system. The study presents an overview of the complex structure of interrelated scientific, technological, social and economic components that form the basis of this system.

NBSIR 75-937. **The national measurement system for medical ultrasonics,** P. A. Hudson, 20 pages (Feb. 1976). Order from NTIS as PB265614.

Key words: electroacoustics; medical diagnostics; radiation safety; radiation therapy (ultrasonic); ultrasonics.

The rapid increase in the use of ultrasonics in medical diagnostics has been brought about by recent advances in imaging techniques employing sophisticated electronic systems. Along with the proliferation of this equipment in the medical community has come concern about possible tissue damage due to this type of radiation. Research on damage thresholds is being carried out in laboratories across this country and overseas. Agreement between various researchers is hampered by lack of accurate standards for measurement of transducer beam power and intensity.

The National Measurement System for medical ultrasonics is, at this time, inadequate, fragmented and largely uncoordinated. The Electromagnetics Division is in process of developing standards for measurement of transducer beam power, intensity, and beam pattern. These standards will be disseminated widely throughout the country to provide the needed accuracy and measurement agreement among biomedical researchers and ultimate users (hospitals, physicians, clinics, etc.). Interim standards for beam power were developed 1 1/2 years ago and are already in use by standards laboratories of manufacturers and universities. It is estimated that another 5 years will be required to bring the measurement system under some form of control.

NBSIR 75-942. **The national measurement system for optics,** D. A. Swyt, 63 pages (Aug. 1976). Order from NTIS as PB256644.

Key words: imaging optics; lens testing; microcopy resolution charts; National Measurement System; photographic density; technology assessment.

NBS has conducted a study of the National Measurement System for Optics. The proposed system model is discussed including the role of standards committees, instrument manufacturers and measurement users. The economic dimensions of the measurements impact areas and the technological base from which new measurement technology springs are described.

NBSIR 75-943. **Transactions matrix description of the National System of Physical Measurements,** R. C. Sangster, 91 pages (Aug. 1976). Order from NTIS as PB258914.

Key words: acoustic quantities; electrical quantities; electromagnetic quantities; end-use measurements; ionizing radiation; measurement activities; measurement institutions; mechanical quantities; National Measurement System; optical quantities; thermal quantities; time and frequency.

The interactions among the various elements of the National Measurement System are described in a series of transactions matrices. The National Measurement System consists of all of the activities and mechanisms used by this country to produce measurement data. The transactions matrices describe both the flow of measurement knowledge, goods, and services from suppliers to users in this System, and the activities within a given supplier-user sector. Semiquantitative estimates are made for the magnitude of the transactions, the rate of change of that magnitude, the relative importance or criticality of the transactions, and their adequacy. Basic supplier-user matrices have been developed for the system as a whole and for some 24 different measurement sectors (time and frequency; length and related dimensional measurements; vibration and shock; surface finish; mass, volume and density; force; fluid flow; pressure; temperature; humidity and moisture; thermodynamic properties of fluids; cryogenics; electricity; electromagnetics; medical ultrasonics; acoustics; radiometry and photometry; spectrophotometry; far ultraviolet radiometry; optics; lasers; physical properties of atoms and molecules; surface properties; and ionizing radiation). Some 25 supplier-user sectors have been defined, ranging from technical infrastructural institutions through governmental agencies to a series of commercial-industrial sectors defined by Standard Industrial Classification codes, to the "general public." Combination of like rows or columns from the basic supplier-user matrices for the different measurement sectors has allowed the generation of total input and output matrices for each supplier-user sector.

NBSIR 75-944. **National measurement system for the physical properties of atoms and molecules,** J. W. Cooper, A. V. Phelps, and S. J. Smith, 39 pages (Sept. 1976). Order from NTIS as PB258372.

Key words: atom; energy generation; industrial technology; molecule; primary standards; properties.

National activity in measurement, compilation, evaluation, and dissemination of atomic and molecular data, estimated at 20-25 million dollars annually, impacts directly upon applied research and development projects costing over one-third billion dollars annually. NBS atomic and molecular programs, costing about 3 million dollars annually, provide the basis for the accepted standards for length, time and frequency; provide advanced measurement techniques; set rigorous performance standards for generation of atomic and molecular data, and provide for the construction of a sound data base for the user community. The largest users are programs aimed at energy generation and conversion. Basic sciences of aerodynamics, astrophysics, atmospheric physics and plasma physics are important users. Benefits for a broad range of industrial research activities are potentially large. It is recommended that NBS undertake to ensure the reliability and adequacy of the data base needed for important national programs, expand its contacts with private industry, develop increased awareness of the methodology for applying atomic and molecular data to technological development, and encourage effective utilization of this sector of the measurement system for the benefit of the economy.

NBSIR 75-947. **Collected executive summaries. Studies of the National Measurement System 1972-75,** R. C. Sangster, 56 pages (Aug. 1976). Order from NTIS as PB258323.

Key words: acoustics; atomic properties; economics; electrical quantities; ionizing radiation; mechanical quantities; national measurement system; optical quantities; surface properties; thermal quantities; time and frequency.

This report contains the Executive Summaries of the reports of the 1972-75 study by the NBS Institute for Basic Standards of the U.S. National Measurement System, which consists of all of the activities and mechanisms which provide physical measurement data required by our society. A series of microstudies focused on specific technical measurement sectors. A macroeconomic study looked at costs of instrumentation and labor for measurement-related activity in our economy. University economists were retained to assist the microstudy authors and to prepare an overall economics report. A central coordinator set a basic pattern for the microstudies, prepared an overall summary report, and generated several documents relating to the system as a whole. Abbreviated titles of the executive summaries are: Final summary report. Direct measurements transactions matrices. Economic analysis. Structure and functions of measurement system. Time and frequency. Length and related dimensional measurements; vibration and shock. Surface finish. Mass, volume and density. Force. Fluid flow. Pressure. Temperature. Humidity and moisture. Thermodynamic properties of fluids. Cryogenics. Electricity. Electromagnetics. Medical ultrasonics. Acoustics. Radiometry and photometry. Spectrophotometry. Far ultraviolet radiometry. Optics. Physical properties of atoms and molecules. Surface properties. Ionizing radiation.

NBSIR 75-950. **Proposed criteria for use of the critical radiant flux test method,** I. A. Benjamin and C. H. Adams, 49 pages (Dec. 1975). Order from NTIS as PB250664.

Key words: fire hazard; fire safety; flooring test; radiant panel.

The objective of this discussion is to present background and other technical data that will help in suggesting criteria to be used in conjunction with the Flooring Radiant Panel Test to determine the potential contribution to fire growth of floor covering systems for use in corridors and exitways.

NBSIR 75-951. **Correlation of floor vibration to human response,** J. R. Shaver, 32 pages (Dec. 1975). Order from NTIS as PB249094.

Key words: analysis; experimental; floor systems; human response; random process; spectral analysis; vibration.

A new approach to the problem of perceptible floor vibrations is presented predicated on the realization that human activity

nd human response to this activity are random variables. echniques for data reduction are discussed and a detailed escription of one approach is given along with the associated mputer program. Data from floor vibrations is compared with rrent criteria for human response to vibration.

BSIR 75-952. **An error analysis of failure prediction techniques derived from fracture mechanics,** S. M. Wiederhorn, E. R. Fuller, Jr., J. Mandel, and A. G. Evans, 41 pages (Dec. 1975). Order from NTIS as PB248910.

Key words: crack propagation; error analysis; failure prediction; failure prevention; fracture; statistics; strength.

Three principal methods of failure prediction for brittle materis are analyzed statistically. Each method depends on fracture echanics for its predictive value and hence, the variance of the ilure time is found to depend on the scatter in the fracture echanics data and the scatter in the estimate of the initial size the strength limiting crack. The variance is used to calculate nfidence limits for the prediction of failure for two materials, ass and silicon carbide. Procedures for the collection and anal- is of data are discussed, and the implications of the analysis for etime prediction are evaluated.

NBSIR 75-953. **A procedure for determining bicycle braking performance,** D. E. Marlowe, 26 pages (July 1976). Order from NTIS as PB256219.

Key words: bicycles; braking; consumer safety; handbrakes; testing.

A procedure which could be used to determine bicycle braking erformance for compliance with the Federal Bicycle Safety egulation, Requirements for Bicycles, has been developed. The rocedure includes tests for brake system integrity and stopping istance performance. Sample data collection sheets and calcula- ons are given.

NBSIR 75-954. **A survey of manufacturers' views on the ETIP procurement experiment. Volume one: Refrigerator-freezers,** P. C. Goodman, 36 pages (Dec. 1975). Order from NTIS as PB253242.

Key words: energy-efficient products; Experimental Technology Incentives Program; life-cycle costing; procurement experiments; refrigerator-freezers.

This report describes the findings of a survey of six refrigera- r-freezer manufacturers by the Center for Consumer Product echnology. The survey was conducted for the Experimental echnology Incentives Program (ETIP) as part of its evaluation f a Federal Supply Service (FSS) procurement of refrigerator- eezers. Survey questions were designed to obtain manufac- rers' views on the use of Government procurement policies as means of increasing the rate of introduction of new technolo- es into the consumer market place. The questions covered the llowing areas: (1) reasons for participation or nonparticipation f a manufacturer in the ETIP experiment; (2) problems that a anufacturer encountered with existing Federal procurement ractices; (3) acceptability of using life-cycle costing in the idding procedure; and (4) effect of the most recent Govern- ent procurement on present and future company operations, in- luding support for engineering and investment in research, ypes of themes used in advertising campaigns, etc. Results of he survey are reported, and implications are drawn for future TIP involvement in Government procurement activities.

NBSIR 75-955. **Durability and related tests for selected elements and materials used in the exterior envelope of buildings,** L. W. Masters, E. J. Clark, G. A. Sleater, and A. Hockman, 151 pages (Nov. 1975). Order from NTIS as PB248685.

Key words: aging test; building elements and materials; degradation factors; durability; property measurement test; standard test methods.

This report contains a compendium of state-of-the-art methods to aid in the durability testing of selected elements and materials used in the exterior envelope of buildings. The purposes of the report are to identify currently available property measurement tests and aging tests that can be used for durability testing and to identify the degradation factors included in each aging test. The report will form the basis for selecting specific elements and materials for inclusion in subsequent comprehensive durability studies. These additional studies are needed because existing short-term methods are seldom fully adequate for predicting long-term performance.

The sources of the methods include the American Society for Testing and Materials (ASTM), the American National Standards Institute (ANSI), building industry trade associations, Federal Specifications and Federal Standards. Indications are made for each test method to show if the methods described include a property measurement test, an aging test or both. If the method contains an aging test, the degradation factors included in the test are listed.

NBSIR 75-956. **An interference simulator for quantitative determination of the susceptibility of flame detectors to false alarm,** A. Scheidweiler, 16 pages (Nov. 1975). Order from NTIS as PB247654.

Key words: false alarms; false alarm simulator; fire detection; fire detector; flame detection; flame detector.

All fire detectors are susceptible to false alarms, i.e., responding to fire-like conditions when no fire is present. Of all the known fire detectors, flame detectors are probably the most false alarm prone of any of the fire detectors, primarily because these detectors are subjected to more environmental influences resembling the detectors' operating mode than any other fire detector.

In this paper, the author describes an investigation into the susceptibility of flame detectors to false alarms. The author describes a test apparatus, constructed and used by his firm, to evaluate the susceptibility of currently-available flame detectors to false alarms. In addition, the apparatus can be used to evaluate prototype flame detectors.

The data developed indicates the false alarm susceptibility of each type of flame sensor. The data also provides a means of selecting a flame detector having the greatest resistance to known or predictable pseudo-fire sources.

NBSIR 75-957. **Finite element analysis of spotwelded, bonded and weldbonded lap joints,** R. A. Mitchell, R. M. Woolley, and S. M. Baker, 25 pages (Dec. 1975). Order from NTIS as PB250769.

Key words: adhesive-bonded joints; bonded joints; double-lap joint analysis; finite element analysis; joining; joints; single-lap joint analysis; single-lap-joint bending; spotwelded joints; weldbonded joints.

Finite element computer analyses of single-lap and double-lap structural joints are described. A planform analysis articulates the in-plane deformation of the joined sheet material and the lap-shear stresses acting through the spotwelds and/or adhesive. A longitudinal cross-section analysis computes out-of-plane bending effects, particularly important in single-lap joints, and adhesive peel stresses. Numerical results are presented that suggest a reasonable degree of mutual consistency between the planform analysis and the cross section analysis. Although the basic finite element formulation is linear, nonlinear deformation can be simulated by a series of linear solutions. The computer output in-

cludes contour plots of stress and strain fields and exaggerated-scale plots of displacements.

NBSIR 75-958. **Simulated precipitation reference materials,** J. K. Taylor, E. R. Deardorff, R. A. Durst, E. J. Maienthal, T. C. Rains, and E. P. Scheide, 25 pages (Oct. 1975). Order from NTIS as PB248743.

Key words: chemical analysis; rainwater analysis; reference materials.

The preparation of a series of reference materials for chemical analysis of natural precipitation is described. The materials consist of ampoules of concentrates which can be diluted to simulate naturally collected samples of rainwater. The analytical measurements made to verify the composition of the samples are also described.

NBSIR 75-960. **The police patrol car: State of the art,** R. G. Massey, 61 pages (Nov. 1975). Order from NTIS as PB249774.

Key words: functional requirements; patrol cars; performance of patrol cars; police patrol cars; problems with patrol cars; state of the art survey.

This report, entitled "The Police Patrol Car: State of the Art" describes the functional requirements of police agencies for patrol cars, the manner in which these requirements are met, or not met, by vehicles currently in use, and a discussion of new automotive technology which might affect patrol car performance in the future.

NBSIR 75-961. **The police patrol car: Economic efficiency in acquisition, operation, and disposition,** R. T. Ruegg, 225 pages (June 1976). Order from NTIS as PB257466.

Key words: fleet management; life cycle costing; patrol cars; police fleets; vehicle leasing: vehicle management.

This study uses the techniques of life cycle costing to analyze some of the decision problems of police fleet management. It addresses the following questions: (1) What are the cost effects of purchasing different sizes of patrol cars and different optional equipment? (2) What are the advantages and disadvantages of direct ownership of vehicles as compared with leasing vehicles? (3) How do the costs of contracting out maintenance compare with costs of an in-house shop? (4) What are the effects of alternative utilization practices on fleet costs? (5) How often should vehicles be replaced? (6) What method of vehicle disposition is most efficient? The techniques used to compare costs of alternative systems are described in a chapter on life cycle costing methodology. Cost estimates and empirical data are presented in the many tables, exhibits, and charts which support the study. Existing fleet practices are described. Findings of the study are expressed as general guidelines for fleet management. The focus of the study is on police patrol cars, but the methods are applicable to other kinds of vehicles.

NBSIR 75-962. **An outdoor noise monitoring system with automatic calibration and remote digital display,** D. S. Blomquist, J. S. Forrer, and D. M. Corley, 11 pages (Oct. 1975). Order from NTIS as PB247639.

Key words: acoustics (sound); environmental acoustics; instrumentation; noise monitoring; outdoor noise.

An Outdoor Noise Monitoring System is described. This system uses a microprocessor for automatic calibration. The design concepts of the system are applicable to other remote noise monitoring systems.

NBSIR 75-966. **Measurements and observations of the toxicological hazard of fire in a Metrorail interior mock-up,** M. M. Birky, A. W. Coats, S. E. Alderson, J. E. Brown, M. Paabo, and B. Pitt, 20 pages (Feb. 1976). Order from NTIS as PB250768.

Key words: blood; carbon dioxide; carbon monoxide; cyanide; fire; hydrogen chloride; hydrogen cyanide; oxygen; rats.

Oxygen depletion, carbon monoxide, carbon dioxide, hydrogen chloride and hydrogen cyanide were selected for measurement and identification in Metrorail fire tests.

Male rats exposed to the combustion products were examined for changes in blood chemistry, gross pathology and loss of function. Hydrogen cyanide and carbon monoxide levels in blood were elevated and functional changes were noted.

NBSIR 75-967. **Radiative ignition of some typical floor covering materials,** K. D. Braven, 22 pages (Dec. 1975). Order from NTIS as PB251413.

Key words: carpets; floor coverings; horizontal; ignition; ignition time; pilot ignition; radiant heat flux.

The ignition time for some typical floor coverings was measured at varying incident radiant flux levels. A large radiant panel was used as a heat source, with a nonimpinging pilot flame 1.0 cm above the sample as an ignition source. Each material was subjected to flux levels varying from 0.5-2.4 W/cm^2. Samples were 5 cm square, mounted horizontally below the radiant panel. A critical flux level, below which ignition did not occur, was determined for each material. No correlation was observed between the ignition time of flooring samples and the time to flashover in full-scale corridor experiments in which the same flooring materials were used.

NBSIR 75-968. **Selected thermochemical data compatible with the CODATA recommendations,** V. B. Parker, D. D. Wagman, and D. Garvin, 35 pages (Jan. 1976). Order from NTIS as PB250845.

Key words: CODATA compatible values; enthalpies of formation; entropy; Gibbs energy of formation; selected thermodynamic values; thermodynamic properties.

Selected thermochemical properties data at 298.15 K are given for 384 substances. The data are compatible with the current recommendations of the CODATA Task Group on Key Values for Thermodynamics. The set of values provided here is suitable for use as auxiliary data in evaluations of the thermochemical properties of compounds of the actinide elements. Rules used in the conversion of units and the rounding of numbers are stated.

NBSIR 75-971. **A fire hazard evaluation of the interior of WMATA Metrorail cars,** E. Braun, 34 pages (Dec. 1975). Order from NTIS as PB249776.

Key words: flame spread; flammability; full-scale fire tests; laboratory fire tests; Metrorail cars; neoprene; smoke; transportation; urethane.

A series of fire tests was conducted for the Washington Metropolitan Area Transit Authority to assist them in assessing the potential for fire hazard in the new Metrorail subway cars. Results of small-scale laboratory tests were found inadequate for this assessment. Results of full-scale tests on mock-ups of the interior (and on a real car for a smoke penetration test) show that the potential for hazard arises primarily from the seat padding and covering and from the plastic wall lining. The hazard arises both from smoke development and from spread of flame and heat. The times to reach unacceptable conditions has been determined for several test conditions. It is recommended that the authorities review these times in the context of what they consider to be appropriate times for safe escape. Recommendations

e made for increasing the amount of time available for escape. hese would require changes in the seating and wall lining aterials.

BSIR 75-972. **Skid resistance measurement tests at the FHWA eastern field test center,** R. W. Kearns and J. F. Ward, 98 pages (July 1976). Order from NTIS as PB259630.

Key words: accident reduction, skidding; correlation, skid resistance; highway safety; pavement, skid resistance; pavement wetting system, tire-pavement interface forces; wet pavement.

The measurement of the skid resistance of highways, under et weather conditions, is part of the Federal Highway Administation (FHWA) skid accident reduction program. To standardize and to improve the precision of the measurements, the rogram includes national and regional reference systems to hich the highway measuring systems may be systematically reted. This report describes evaluation tests conducted at the HWA Eastern Field Test Center (EFTC) which included the se of the Eastern Area Reference System (EARS) and the Inrim Reference System (IRS) maintained by the National Buau of Standards. The performance characteristics of the ARS, its subsystems and a correlation equation between the ARS and the IRS are presented. A method of quantifying ources of dispersion is applied to the measurements made by ie IRS on the EFTC reference surfaces. Recommendations for odifications to the EARS, the test procedures, and EFTC acilities are made.

BSIR 75-973. **Guide to improving the performance of a manipulator system for nuclear fuel handling through computer controls,** J. M. Evans, Jr., J. S. Albus, A. J. Barbera, R. Rosenthal, and W. B. Truitt, 53 pages (Nov. 1975). Order from NTIS as PB249255.

Key words: computer control of automation systems; computer interface; computer software for robot control; hierarchical control of manipulators; position servos; trajectory control.

The Office of Developmental Automation and Control echnology of the Institute for Computer Sciences and echnology of the National Bureau of Standards provides advisg services, standards and guidelines on interface and computer ontrol systems, and performance specifications for the procureent and use of computer controlled manipulators and other omputer based automation systems. These outputs help other gencies and industry apply this technology to increase productivity and improve work quality by removing men from azardous environments.

In FY 74 personnel from the Oak Ridge National Laboratory isited NBS to discuss the feasibility of using computer control echniques to improve the operation of remote control manipulors in nuclear fuel reprocessing. Subsequent discussions led to n agreement for NBS to develop a conceptual design for such a omputer control system for the PaR Model 3000 manipulator n the Thorium Uranium Recycle Facility (TURF) at ORNL. his report provides the required analysis and conceptual esign. Complete computer programs are included for testing of omputer interfaces and for actual robot control in both point-tooint and continuous path modes.

NBSIR 75-974. **The demonstration of experimental lead paint hazard abatement in Atlanta, Georgia,** T. H. Boone, H. W. Berger, A. P. Cramp, and H. A. Jackson, 121 pages (Dec. 1975). Order from NTIS as PB249777.

Key words: abatement; barrier materials; building materials; children; housing; lead-based paint; lead poisoning; paint removal.

This report describes the second stage of an experimental lead paint hazard abatement program carried out in 80 dwelling units in Atlanta, Georgia. The entire program will ultimately involve the abatement of lead paint hazards in a total of approximately 250 dwelling units distributed over three or more cities.

The procedures demonstrated in this field testing program were: paint removal using chemical solvents; paint removal using three heat producing devices; the replacement of components such as windows, doors, and wood trim and the installation of flexible sheet materials, rigid boards, plaster products and aggregate filled coatings, over existing lead paint on walls. Also evaluated was the covering of deteriorated, lead paint coated floors with plywood.

The report includes procedures for inspecting and selecting dwellings for lead paint hazard abatement, evaluations of the suitability and implementation characteristics of the abatement methods, and recommendations for their use.

Subsequent reports will present the results of comparable programs in additional cities and a final report will compare the cost-effectiveness of the alternative abatement methods.

NBSIR 75-975. **The calibration of an optical flat by interferometric comparison to a master optical flat,** C. P. Reeve, 40 pages (Dec. 1975). Order from NTIS as PB253113.

Key words: calibration; diameter; gravitational bending; interferometry; least squares line; linear model; optical flat; profile; standard deviation; uncertainty.

Optical flats are normally calibrated by one of two methods at the National Bureau of Standards. The most frequently used method involves a direct interferometric comparison of a test flat to a master flat. The purpose of this paper is to present a detailed description of this measurement process. Some of the topics discussed are methods of supporting the flats, effects of gravitational bending, measurement of interference fringes, formulation and solution of the linear least squares model, analysis of errors, choice of profile reference line, and graphical display of profiles. An example is worked out in a step-by-step fashion in order to illustrate the process, and a statistical test is incorporated to check whether the process is in control.

NBSIR 75-976. **Standards and measurement capabilities in the Kingdom of Saudi Arabia,** A. A. Bates, 37 pages (Spring 1975). Order from NTIS as PB248986.

Key words: building codes; industrialization; less-developed country; SASO; Saudi Arabia; standardization; tentative standards.

The Saudi Arabian Standards Organization (SASO) is operating under uniquely difficult circumstances. Basic sources of difficulties are: (1) almost total lack of any industries for consultation and cooperation, (2) extreme speed at which Saudi Arabia

is attempting transformation into an urban-industrial state, (3) unavailability of well-trained indigenous Saudi personnel, either scientific-technical or secretarial-clerical, and (4) lack of SASO laboratory facilities for standardization research work.

Operating procedures which SASO has adopted are based on consensus principles utilized in countries with advanced industrial economies. Such procedures are not now applicable in Saudi Arabia. Only the Saudi Portland Cement industry now offers opportunity for consensus standardization.

Until industrialization has advanced in the Kingdom, SASO should use Interim Procedures to produce Tentative Standards for national use. The Interim Procedures should permit direct and immediate adoption of necessary standards from reliable national and international sources with minimum modification. The nature and terms of use of Tentative Standards must be defined for public understanding.

SASO should not play the central role in the enforcement of SASO standards. SASO should have an advisory relationship with authorities charged with mandatory standards enforcement. SASO should not now undertake the development of a national Saudi building code, although it must produce the standards upon which a building code may be promulgated by a related agency appointed for that purpose.

NBSIR 75-977. **Development of solid state samplers for work atmospheres: Phosphine,** B. Greifer and J. K. Taylor, 32 pages (Jan. 1976). Order from NTIS as PB251220.

Key words: air analysis; air sampling; gas analysis; industrial hygiene; phosphine; sorber; work atmosphere.

Investigations to find suitable solid-state sorber materials for phosphine in work atmospheres at the ppm level are described. The best sorber to date is silver nitrate-impregnated silica gel. Some difficulties remain to be overcome before a procedure for determining the amount of phosphine adsorbed can be recommended.

NBSIR 76-833. **A precision 30 MHz waveguide-below-cutoff attenuator with an absolute electronic readout, NBS model XII,** R. T. Adair, 50 pages (Jan. 1976). Order from NTIS as PB250846.

Key words: absolute (unambiguous) readout; piston; precision attenuator; sensor; waveguide-below-cutoff.

A coaxial precision waveguide-below-cutoff attenuator is described which utilizes an absolute (unambiguous) electronic digital readout of displacement in decibels instead of the usual gear-driven mechanical counter/dial readout in decibels. The attenuator has a fixed-position rf input connector and a movable rf output connector. The attenuation rate for 30 MHz operation is given along with a discussion of sources of errors. In addition, information is included to aid the user in making adjustments on the attenuator should it be damaged or disassembled for any reason.

NBSIR 76-834. **A system for inflating a balloon using helium stored in the liquid phase,** C. F. Sindt and W. R. Parrish, 38 pages (Jan. 1976). Order from NTIS as PB250666.

Key words: balloon; cryogenic balloon inflation; heat transfer; liquid helium; packed bed heat exchangers.

This report covers the design and development of the prototype of a system to be used to fill a balloon that has been launched from an aircraft. The described system uses a hot packed bed heat exchanger to gasify 45.4 kg of liquid helium and warm the gas to 260 K for filling the balloon. The prototype system was successfully demonstrated on the ground by filling an ambient pressure balloon with 300 m^3 of helium gas at an average temperature of 260 K in six minutes and 45 seconds.

NBSIR 76-836. **Low temperature fracture behavior of a Ti-6Al-4V alloy and its electron beam welds,** R. L. Tobler, 49 pages (Apr. 1976). Order from NTIS as PB254459.

Key words: electron beam welding; fatigue; fracture toughness; low temperature tests; mechanical properties; titanium alloy.

The effects of electron beam (EB) welding on the fracture behavior of a recrystallization annealed, extra-low-interstitial Ti-6Al-4V alloy have been investigated at temperatures in the ambient-to-cryogenic range. Plane strain fracture toughness (K_{Ic}) and subcritical crack growth parameters were measured using compact specimens 10 to 25.4 mm-thick. These parameters can be used to predict the safe operating lifetimes of cryogenic pressure vessels and other welded Ti-6Al-4V structures.

Although EB welding transforms the base metal microstructure extensively, its effects on the material's fatigue crack propagation resistance at intermediate stress intensity factors are negligible. The growth rates, da/dN, of fatigue cracks sited in the fusion and heat-affected zones of weldments were temperature insensitive and nearly equivalent to rates for the base metal. However, welding introduces a zone of low fracture toughness at the heat-affected-zone/fusion-zone boundary. The K_{Ic} value for this boundary zone at liquid nitrogen temperature (76 K) was 45 $MN/m^{3/2}$, 16 percent lower than the base metal. The base metal fracture toughness increases between 4 and 295 K, with an abrupt transition to higher K_{Ic} values occurring at temperatures between 76 and 125 K. Static load cracking, temperature effects, and specimen orientation effects on the fracture behavior of this titanium alloy are central topics of discussion.

NBSIR 76-837. **Characterization of a superconducting coil composite and its components,** A. F. Clark, W. F. Weston, V. D. Arp, J. G. Hust, and R. J. Trapani, 143 pages (July 1976). Order from NTIS as PB261709.

Key words: fiberglass cloth; mechanical properties; stress analysis; superconducting coil composite; superconducting wire; thermal properties.

The physical properties of a superconducting coil composite and its components are studied in order to accurately predict the coil behavior under a variety of operating conditions. This second interim report includes data on the Young's moduli, the Poisson's ratios, the shear moduli, and the thermal conductivity of the coil composite as well as the compressive modulus of the fiberglass cloth and the thermal expansion of the superconducting wire. In addition, the development of an acoustic technique for the determination of the elastic moduli of the coil composite and the stress analysis of transversely isotropic magnet coils are reported.

BSIR 76-839. **Semi-annual report on materials research in support of superconducting machinery,** R. P. Reed, J. G. Hust, M. B. Kasen, H. M. Ledbetter, D. T. Read, R. E. Schramm, L. L. Sparks, and R. L. Tobler, 155 pages (Apr. 1976). Order from NTIS as PB252013.

Key words: aluminum alloys; composites; cryogenic temperatures; elastic properties; engineering materials; fatigue; fracture; iron alloys; mechanical properties; nickel alloys; superconducting machinery; thermal conductivity.

Results are reported of a six-month study, ending March 1976, candidate materials for superconducting machinery. The sults cover five areas—advanced composites, elastic proper-s, fatigue resistance and fracture toughness, magnetothermal nductivity, and thermal conductivity. Material properties were idied over the temperature range 4 to 300 K. Materials studied clude: aluminum alloys 1100, 2014, 2219; a nickel-chromium-n alloy; iron-47.5 nickel; and the composite materials ron/aluminum, boron/epoxy, *S*-glass/epoxy; graphite epoxy. me notable results of the study are: First reports of compres-e mechanical testing on composite materials at 4 K; regular nperature behavior of the elastic constants of aluminum 2014 d 2219 and of iron-47.5 nickel, which is magnetic; none of the echanical properties of the nickel-chromium-iron alloy tested ere affected deleteriously by cryogenic temperatures; in alu-num alloy 2219, J_{Ic} and K_{Ic} are not equivalent because of sub-tical crack extension; both electrical and thermal conductivi-s of aluminum alloy 1100 are reduced by magnetic fields.

BSIR 76-840. **FM-CW electromagnetic technique of measuring coal layer thickness,** D. A. Ellerbruch and D. R. Belsher, 38 pages (May 1976). Order from NTIS as PB258324.

Key words: automation; coal; coal mine safety; dielectric constant; energy; microwave measurement; nondestructive testing; thickness of coal layer.

An FM-CW microwave system was investigated for measur-g coal layer thickness. Measurements were made in three dif-rent mines near Pittsburgh, Pa., near Fairview, W. Va., and ar Coffeen, Ill. Microwave frequencies in the range 1-2 GHz ere used to measure samples up to 55 cm thick. All samples ere backed with a naturally occurring shale. Measurements ere also made on coal and shale samples compounded in the poratory at the Bureau of Mines Pittsburgh Mining and Safety esearch Center near Bruceton, Pa.

The results indicate that layer thickness can be determined in ost cases, although large anomalies may, in some cases, oduce misleading results. Many anomalies that were detected th the FM-CW system were verified visually by drilling into e coal layer.

The dielectric constant of coal apparently varies significantly thin a coal seam.

The form of the output signals from the FM-CW system seem simplify the data interpretation and analysis process as com-red to the manually swept microwave system used previously. appears that this technique has the potential of measuring anges in the dielectric constant of a coal seam and providing an tput that can be used for real-time corrections in layer ickness measurement.

BSIR 76-841. **An analytical and experimental determination of the cutoff frequencies of higher-order TE modes in a TEM cell,** J. C. Tippet, D. C. Chang, and M. L. Crawford, 27 pages (June 1976). Order from NTIS as PB256319.

Key words: shielded strip line; TEM cell.

In addition to the TEM mode, higher order TE and TM modes can propagate in a TEM cell. Since only the TEM mode is desired, the higher-order modes restrict the useful frequency range of the TEM cell. In this paper, the cutoff frequency of the first higher-order mode is obtained both analytically and experimentally for several TEM cells of differing geometry. The difference between the experimental and theoretical results is shown to be only a few percent. In addition the field distribution of the first higher-order mode is found explicitly.

NBSIR 76-842. **Error equations used in the NBS precision G/T measurement system,** W. C. Daywitt, 21 pages (Sept. 1976). Order from NTIS as PB258331.

Key words: error analysis; G/T; precision measurements; radio star; satellite communications.

Equations presently being used in the precision NBS G/T measurement system are presented in this report. Included are the assumptions upon which these equations are based and sample calculations showing how the measurement errors vary with antenna elevation angle.

NBSIR 76-844. **A microwave vector voltmeter system,** K. C. Roe and C. A. Hoer, 70 pages (Aug. 1976). Order from NTIS as PB264300.

Key words: amplitude; computer controlled; diode detectors; microwave measurements; phase angle; self-calibration; seven-port junction; vector voltmeter.

This report presents a system description and operating procedure for a vector voltmeter system which covers the frequency range .5 to 12 GHz. The design is based upon a seven-port junction where phase and amplitude information is obtained using only power detectors. The system is computer controlled and self-calibrating for ratio measurements.

NBSIR 76-846. **An NBS phase noise measurement system built for frequency domain measurements associated with the Global Positioning System,** S. R. Stein, 30 pages (Aug. 1976). Order from NTIS as PB258327.

Key words: Global Positioning System; phase-locked loop; phase noise measurement system; spectral density of phase.

A self-contained system is described which was constructed to perform phase noise measurements for the first phase of the Global Positioning System (GPS). It is capable of evaluating a pair of similar oscillators or a single oscillator and a frequency synthesizer using the phase-lock technique. Three features have been included to simplify the operation of the instrument: internal circuitry automatically detects an out-of-lock condition; an optimized second order phase-lock loop reduces phase error by a factor of 10^5 over a first order loop; selection of operating mode is made by a single front panel switch.

NBSIR 76-848. **Semi-annual report on materials research in support of superconducting machinery,** R. P. Reed, J. G. Hust, M. B. Kasen, H. M. Ledbetter, H. I. McHenry, D. T. Read, R. E. Schramm, L. L. Sparks, and R. L. Tobler, 322 pages (Oct. 1976). Order from NTIS as PB261996.

Key words: aluminum alloys; composites; elastic properties; engineering materials; fatigue; fracture; iron alloys; cryogenic mperatures; maraging steels; mechanical properties; nickel alloys; phenolformaldehyde; stainless steels; superconducting machinery; thermal conductivity; titanium alloys.

Results are reported of a six-month study, ending September 1976, on candidate materials for superconducting-machinery

components. The results cover five areas—advanced composites, elastic properties, fatigue resistance and fracture toughness, magnetothermal conductivity, and thermal conductivity. Material properties were studied over the temperature range 4 to 300 K. Materials studied include: aluminum alloy 5083, copper-0.3, cadmium-0.3 tin, copper-28 nickel, iron-48 nickel, 3.5 Ni and 9 Ni steels, titanium-4 aluminum-6 vanadium, titanium-5 aluminum-2.5 tin, stainless steel 21-6-9, several austenitic stainless steels of the 300 series, 300-grade maraging steel, phenolformaldehyde, and the composites boron/aluminum, boron/epoxy, graphite/epoxy, and niobium-titanium/copper. Some notable results of the study are: anomalous elastic properties of stainless steel 21-6-9 due to a Néel transition; complete sets of elastic constants for two composties, B/Al and NbTi/Cu; thermal conductivities of Ti-6Al-4V and Fe-48Ni are reduced by a magnetic field while those of Cu-0.5 Sn and Cu-28Ni are unaffected; a screening method for composites of possible cryogenic use; general trends regarding temperature effects on the fracture toughness and fatigue-crack-growth resistances of structural alloys are correlated with crystal structure class; and the tensile-yield-strength and fracture-toughness data for fourteen commercial structural alloys at 4 K and 295 K are compared demonstrating an inverse relationship between these properties and indicating the optimum combination of properties that are technologically possible. Also, the materials and properties studied experimentally during the three-year program are summarized. This work was supported by the Advanced Research Projects Agency of the U.S. Department of Defense.

NBSIR 76-979. **Intercomparison procedures for gage blocks using electromechanical comparators,** J. S. Beers and C. D. Tucker, 23 pages (Jan. 1976). Order from NTIS as PB248992.

Key words: calibration; comparator; gage blocks; length; measurement process.

The widely used procedures for calibrating gage blocks by comparison with blocks of known length generally lack the redundancy needed to evaluate measurement uncertainty or the controls needed to monitor the process on a continuing basis. A detailed description is given here for the systematized intercomparison of groups of four nominally equal gage blocks using an electromechanical comparator. Two of the blocks are unknowns and two are standards. The process provides the redundancy needed for evaluating uncertainty and for continuous monitoring. Gage block thermal effects, equalization time, handling techniques, and observation sequence are described.

NBSIR 76-980. **NBS space processing research,** E. Passaglia and R. L. Parker, 217 pages (Feb. 1976). Order from NTIS as PB250849.

Key words: convection; crystal growth; crystal perfection; microgravity; purification; space processing.

This report describes NBS work for NASA in support of NASA's Space Processing Program covering the period November 1, 1974 to December 31, 1975. The objectives of the NBS program are to perform ground-based studies (and, where appropriate, space-based studies) of those aspects of space that could possibly provide a unique environment for making materials more perfect or more pure. The approach taken deals primarily with experimental and theoretical studies of the possible effects of the absence of gravitational forces on those materials preparation processes where the presence of gravity may be important in reducing perfection or purity. The materials preparation processes studied comprise six tasks in the areas of crystal growth, purification and chemical processing, and the preparation of composites.

NBSIR 76-982. **Data processing and data analysis procedures fo fire load and live load survey program,** R. M. McCabe, C Culver, L. T. Lee, and J. G. Hirschberg, 344 pages (De 1975). Order from NTIS as PB248699.

Key words: buildings; computers; data processing; fi loads; load surveys.

Data collection and data processing procedures utilized i connection with a nationwide fire load and live load survey pr gram are described. The techniques developed for transferrir the field survey data to a form suitable for computer processi are discussed. Procedures adopted for data analysis are include Documentation of the computer programs developed for th purpose is also presented.

NBSIR 76-983. **A survey of manufacturers' views on the ETI procurement experiment. Volume two: Water heaters,** P. C Goodman, 34 pages (Jan. 1976). Order from NTIS a PB251213.

Key words: energy-efficient products; Experiment Technology Incentives Program; life-cycle costin procurement experiments; water heaters.

This report describes the findings of a survey of seven wat heater manufacturers by the Center for Consumer Produ Technology. The survey was conducted for the Experiment Technology Incentives Program (ETIP) as part of its evaluatic of the Federal Supply Service (FSS) procurement of wat heaters. Survey questions were designed to obtain manufa turers' views on the use of Government procurement policies a means of increasing the rate of introduction of new technol gies into the consumer marketplace. The questions covered tl following areas: (1) reasons for participation or nonparticipatic of a manufacturer in the ETIP experiment; (2) problems that manufacturer encounters with existing Federal procureme practices; (3) acceptability of using life-cycle costing in tl bidding procedure; and (4) effect of the most recent Gover ment procurement on present and future company operations, i cluding support for engineering and investment in researc types of themes used in advertising campaigns, etc. Results the survey are reported, and implications are drawn for futu ETIP involvement in Government procurement activities.

NBSIR 76-984. **Improved ultrasonic standard reference block** G. F. Sushinsky, D. G. Eitzen, D. J. Chwirut, C. J. Bechtolc and A. W. Ruff, 129 pages (Nov. 1976). Order from NTIS PB262020.

Key words: aluminum ultrasonic standards; ASTM-ty reference standards; calibration; fabrication variables; ir mersion testing; interim reference standard; longitudin waves; metallurgical variables; nondestructive evaluatio pulse echo; steel ultrasonic standards; titanium ultrason standards; ultrasonics.

A program to improve the quality, reproducibility and reliabi ty of nondestructive testing through the development of an i proved ASTM-type ultrasonic reference standards system described. Reference blocks of aluminum, steel, and titanium a loys are considered. Equipment representing the state-of-the-a in laboratory and field ultrasonic equipment was obtained a evaluated. RF and spectral data on twenty-two sets of ultrason reference blocks were taken as part of a task to quantify t variability in response from nominally identical block Techniques for residual stress, preferred orientation, and micro tructural measurements were refined and applied to referen blocks rejected by manufacturers during fabrication in order evaluate the effect of metallurgical condition on block respons The effects of certain dimensional variables on block respon

ere studied and new fabrication techniques considered. A udy of the effects of measurement system variables on block sponse was carried out. A calibration service for ASTM E127- pe reference blocks has been established and the development a loaner service for calibration blocks is underway.

BSIR 76-985. **A computer model to determine low cost techniques to comply with the Privacy Act of 1974,** R. C. Goldstein and H. H. Seward, 57 pages (Feb. 1976). Order from NTIS as PB250755.

Key words: computer model; computer security; confidentiality; cost model; data security costs; PL-93-579; privacy; Privacy Act of 1974; privacy compliance techniques; privacy costs; privacy model; security costs.

This document contains a complete description of the steps ecessary to run the Cost of Privacy Model along with a descripon of the computer program which implements the Model. This ocument describes the general system requirements for running e program, how to input information to the Model and how to terpret the output.

The Model, which was developed for the National Bureau of tandards by the D.P. Management Corporation of Lexington, lass., accepts inputs about personal data systems, utilizes algorithms to provide incremental resources required to comply ith the Privacy Act of 1974, and applies cost factors to the sources to provide a cost estimate. Cost estimates of alternave compliance techniques can be generated. These can later be ompared by the user to determine a cost effective method of ompliance.

BSIR 76-986. **Building energy authority and regulations survey: State activity,** R. M. Eisenhard, 52 pages (Jan. 1976). Order from NTIS as PB250858.

Key words: authority; building; energy; legislation; regulations; state.

This report provides the status of State authority to regulate nergy use in new buildings and the status of bills creating such uthority that were pending in the 1975 legislative session. Regutions that have been developed are identified and described. egislation relating to solar energy, retrofitting, insulation and ther building energy matters, is identified and the status inicated.

BSIR 76-987. **Effect of insulation on the surface temperature of roof membranes,** W. J. Rossiter, Jr. and R. G. Mathey, 20 pages (Feb. 1976). Order from NTIS as PB250857.

Key words: built-up roofing; insulation; performance; radiative cooling; roofing; solar heating; surface temperature.

The surface temperatures of black, gray and white roofs were alculated for various thicknesses of insulation located between he membrane and roof deck. The calculations were performed sing a steady-state heat balance equation to illustrate the inrease in roof surface temperatures due to solar radiation.

The calculations indicate that the first increment, about 1 inch 25 mm), of insulation causes a significant rise in the roof surface emperature due to solar radiation. Increasing the amount of inulation above this first increment to greater thicknesses does ot appreciably increase the roof surface temperature.

NBSIR 76-988. **Regional seminar on a system of standardization and metrology for Latin America,** H. S. Peiser and R. S. Marvin, Eds., 100 pages (Feb. 1976). Order from NTIS as PB254469.

Key words: AID; assistance; certification programs; education of metrologists; industrializing nations; LDC's; metrology.

This report contains the papers presented at the first of a series of Regional Seminars, organized under the technical guidance of NBS and sponsored by the U.S. Agency for International Development and the Direccion General de Normas y Tecnologia of Bolivia. The Seminar was held at La Paz on the 24th and 25th of June, 1974, with participants from Bolivia, Brazil, Chile, Ecuador, Korea, Peru, Turkey, Thailand, and the United States of America. The Seminar was organized into four sessions, each of one-half day duration, covering: Session I, "Interactions for Information"; Session II, "Interactions for Standards"; Session III, "Interactions for Solutions to Technical Problems"; and Session IV, "Interaction for Training."

NBSIR 76-990. **Report of fire tests on eight TGS semiconductor gas sensor residential fire/smoke detectors,** R. G. Bright, 17 pages (Apr. 1976). Order from NTIS as PB251769.

Key words: detectors; fire detectors; gas detectors; smoke detectors; Taguchi gas sensors.

At the request of the Bureau of Engineering Sciences Consumer Product Safety Commission, twenty-four Taguchi gas sensor (TGS) detectors, representing eight manufacturers were tested to the requirements of Section 22 (base sensitivity tests) and Section 24 (full-scale fire tests) of Underwriters' Laboratories Standard No. 217, "Standard for Single and Multiple Station Smoke Detectors." Two conventional single-station smoke detectors, one an ionization chamber type and the other a photoelectric type, were included in the test series for comparison. Only one of the TGS detectors was able to meet the requirements of Section 22, base sensitivity tests. None of the TGS detectors were able to meet the requirements of Section 24, full-scale fire tests. The two conventional smoke detectors met the requirements of Section 22 and 24.

NBSIR 76-991. **Evaluation of transparent electro-photographic film and camera system,** T. C. Bagg, 8 pages (Jan. 1976). Order from NTIS as ADA021255.

Key words: add-on films; information storage; microforms; transparent electrophotographic material.

On behalf of the Naval Supply Systems Command, the National Bureau of Standards was requested to assist in the evaluation of new microfilm techniques and materials which permit the adding-on of images at various times. This is an interim report on the initial evaluation of the AB Dick/Scott System 200 which uses transparent electrophotographic materials.

NBSIR 76-992. **Studies of deformation at sliding wear tracks in iron,** A. W. Ruff, 70 pages (Feb. 1976). Order from NTIS as ADA021295.

Key words: electron channeling; iron; metals; plastic deformation; surfaces; wear.

Determinations of strains have been made on the surface and subsurface on specimens of high purity iron after different amounts of sliding wear have taken place. The method involved the measurement of loss of intensity (contrast) of particular electron channeling lines obtained from small selected areas near the wear track. Through the use of a calibration specimen deformed plastically to a range of strain values, the channeling line contrast loss was related to plastic strain. Strain maps lateral to the wear track and below the original surface were obtained for different total sliding distances by removing controlled thicknesses of iron using electropolishing. In all cases the maximum strain was found at the track center location at the surface and the strains

decreased steadily with depth below the track. At 50 g load the strains vanished at about 40 μm depth. Significant strains were found to exist outside the wear track boundaries. The results are compared with other studies previously reported. There was no indication of a soft or less hardened surface layer in any of the specimens studied.

NBSIR 76-993. **The calibration of a pentaprism,** C. P. Reeve and R. C. Veale, 33 pages (Jan. 1976). Order from NTIS as PB253227.

Key words: autocollimator; calibration; constant deviation prism; geometrical model; optical square; pentaprism; reflection; refraction; standard deviation; uncertainty.

A pentaprism, or optical square, is one of a class of objects known as "constant deviation prisms" whose purpose is to bend a beam of light exactly 90° regardless of the angle of incidence of the light. It is used in many optical measurements where the line of sight or a beam of light must be turned at a right angle. The calibration process which is described is fairly simple and requires two mirrors, two autocollimators, and a surface plate. Consideration is given to the effects of small angular errors in both the internal geometry of the pentaprism and the positioning of the pentaprism relative to an autocollimator. An example of the calibration of the important pentaprism parameters is given. A simple statistical test is employed for testing whether the measurement system is in control.

NBSIR 76-996. **Testing for the impact resistance of ophthalmic lenses,** R. E. Berger, 34 pages (Mar. 1976). Order from NTIS as PB251998.

Key words: drop ball test; impact resistance; ophthalmic lens; proof testing; research associate program; sampling test.

The principal findings of the Optical Manufacturers Association's Research Associate Program are summarized. The limitations of the present drop ball test for impact resistance are discussed. Essentially, only a small part of the lens surface and a small part of the edge are subjected to sufficiently high stresses. It is therefore desirable to replace the drop ball test with a sampling procedure from which meaningful information on lens quality can be obtained. Some aspects of the design of a sampling plan, in which the overall quality of a laboratory's lenses is monitored by periodically testing a set of coupon lenses, are discussed.

NBSIR 76-997. **Proceedings of procurement practices symposium—Health care, October 14-16, 1975,** J. G. Berke, Ed., 82 pages (Feb. 1976). Order from NTIS as PB254298.

Key words: certification programs; ETIP; incentives; innovation; life cycle costing; medical products and standards; procurement policies; product testing; specifications; unsolicited proposals; VA.

The general objectives of the conference were to investigate ways for improving interaction between health care personnel and the manufacturers of hospital products and systems, so that the demands of all hospitals for improved and innovative products and systems can be more adequately met; to explore various means available for encouraging innovation and more efficient technological change: from initial research, through product development, user testing and evaluation, marketing and purchasing, to post-delivery assistance for the using services; to develop approaches that will permit hospitals to acquire the latest technologies more expeditiously and economically through the procurement process. Workshops were organized to consider procurement mechanisms, information interchange, testing and evaluation of medical products, and the interrelationshi between marketing, R&D and procurement. Workshops wer grouped as follows: (1) Interaction Between the Hospital Us and the Industry Supplier, (2) Research and Development fo Innovative Products, (3) Product Testing and Evaluation, (4 Specifications, (5) Post Delivery Performance, Warranties an Training by Vendors, (6) Cost Saving and Quality Improvemer Through Innovative Products.

NBSIR 76-998. **Development of a solid sorption tube and analyt cal procedure for hydrogen cyanide in the workplace a mosphere,** B. C. Cadoff and J. K. Taylor, 25 pages (Ap 1976). Order from NTIS as PB253228.

Key words: air analysis; air sampling; gas analysis hydrogen cyanide; industrial hygiene; ion selective ele trode; sodium hydroxide; work atmosphere.

The development of a sampling tube for collecting HCN in th workplace atmosphere is described. The tube contains 4.0 g c flake NaOH and can be readily fabricated in the laboratory. Details are given concerning the construction and use of the tub and data is presented on collection of HCN at levels of five time the TLV, one fifth the TLV, and at the TLV. Analysis of th tube contents using the cyanide ion selective electrode i described. This method is simple, rapid, and relatively free of in terferences. Data on the analyses of tubes containing cyanide i described and estimates of the precision and accuracy of th method are given.

NBSIR 76-1000. **The construction, operation and performance a reactive gas generator; with specific application to HCHO CH_3CHO, CH_2CHCHO, SO_2, HCN and HCl production,** J. A Walker and W. Tsang, 55 pages (Jan. 1976). Order from NTI as PB251219.

Key words: acetaldehyde; acrolein; formaldehyde; ga chromatography; hydrogen chloride; hydrogen cyanide; po lution; pyrolysis; reactive gas generator; sulfur dioxide.

An instrument capable of generating a variety of reactive gase in trace levels has been constructed and tested. Operation details, with specific application to HCHO, CH_3CHO CH_2CHCHO, SO_2, HCN and HCl production are discussed.

NBSIR 76-1002. **Industrial process data for fluids: A survey current research at the National Bureau of Standards,** H. White, Jr., Editor, 55 pages (Apr. 1976). Order from NTIS a PB257469.

Key words: industrial process data; project summaries quantitative numerical data.

This report summarizes current activities sponsored by thre groups within the National Bureau of Standards that are in volved with the production of industrial process data for fluids The three groups involved are the Cryogenics Division, th Equation of State Section of the Heat Division, and the Office c Standard Reference Data; other organizations in NBS and ou side are also involved in various ways. The report takes the for of a listing of projects with some detailed information about eac Some of the projects are designed to provide industrial proces data directly. Others systematically cover types of data that ar of continual utility in industrial process calculations with th result that the data produced will be used for industrial purpose as well as for other purposes. A few of the projects attac problem areas that must be resolved before proper industri process data in the area can be obtained. All of the projects focu on quantitative numerical data obtained for direct measuremen critical evaluation of data from the literature or theoretical est mation or calculation. This report has been prepared to show ir

rested readers the interrelationships within a set of projects at might otherwise pass unnoticed because different organizational units within NBS are involved. Continued interaction tween the program managers involved leads to interactions tween the projects so that the listing is not a listing of independent unreacting projects but rather a listing of interacting projects following broad programmatic lines.

BSIR 76-1003. **Thermal conductivity and electrical resistivity of six copper-base alloys,** M. C. I. Siu, W. L. Carroll, and T. W. Watson, 22 pages (Mar. 1976). Order from NTIS as PB251211.

Key words: copper-base alloy properties; electrical resistivity; Smith-Palmer equation; thermal conductivity.

Measurements of the thermal conductivity, λ, and electrical sistivity, ρ, of oxygen free copper and six copper-base alloys in e temperature range 298 to 924 K are presented. Except for pper, the λ and ρ values of copper alloys having the same emical composition as those given in this paper have not been eviously reported. The measured values of λ(W·m^{-1}·K^{-1}) and Ω·m) were found to conform, within 10 percent, to the predicons of the Smith-Palmer equation, $\lambda=2.39\times10^{-8}$ T/ρ+7.50 W·m^{-1}·K^{-1}], where T is the thermodynamic temperature expressed in kelvins.

BSIR 76-1007. **Psychological deterrents to nuclear theft: A preliminary literature review and bibliography,** P. G. Meguire and J. J. Kramer, 51 pages (Mar. 1976). Order from NTIS as PB252021.

Key words: behavioral impact; cognitive processes; nuclear weapon theft; perceptual processes; psychological deterrence; security systems; sensory processes; threat analysis.

A review of the *unclassified* literature dealing with psychological deterrents was conducted for the Defense Nuclear Agency DNA). Its purpose was to identify techniques that might be useful in DNA's Forced-Entry Deterrent Systems (FEDS) Program for psychologically deterring nuclear weapon theft. The view indicates that while human psychological processes (sensory, perceptual, and cognitive) can be manipulated by various means, definitive empirical data are lacking which *directly* relate deterring nuclear weapon theft. Behavioral impact research hould be undertaken by DNA to (1) ascertain the deterrence alues of the many techniques identified and (2) test the ypotheses implicit in the FEDS concept.

BSIR 76-1008. **Energy conservation through the facilitation of increased blended cement use,** P. W. Brown, J. R. Clifton, and G. Frohnsdorff, 28 pages (Feb. 1976). Order from NTIS as PB251218.

Key words: blast furnace slag; blended cements; energy conservation; fly ash.

About 95 percent of the cement produced in the United States portland cement and its manufacture requires about 2 percent f the energy consumed annually in the nation's industrial rocesses. The production of blended cements containing subantial amounts of fly ash or blast furnace slag and their subitution for portland cement appears attractive from the standoint of energy conservation. While production and utilization of lended cements in other industrialized countries is extensive, lended cements account for less than 1 percent of the total ceent production in the U.S. The reasons for the small U.S. roduction of blended cements are discussed in the contexts of tandards revision and the need for the development of addional data as a basis for this revision.

NBSIR 76-1010. **Optical materials characterization,** A. Feldman, D. Horowitz, R. M. Waxler, I. H. Malitson, and M. J. Dodge, 27 pages (Feb. 1976). Order from NTIS as PB250654.

Key words: birefringence; elastooptic constants; infrared-laser window materials; interferometry; KCl; photoelasticity; piezo-optic constants; refractive index; stress-optical constants; thermal coefficient of refractive index.

Refractive index and the photoelastic constants have been measured on specimens of reactive atmosphere processed (RAP) KCl and KCl nominally doped with 1 percent KI. The refractive indices were measured by the minimum deviation method in the wavelength range 0.25 μm to 15.5 μm. Measurements were made near 20 and near 34 °C on the RAP specimen and near 20 °C on the doped specimen. Each set of experimental data was fitted to a three term Sellmeier-type dispersion equation. The temperature coefficient of index was then computed for the RAP KCl. The data for the different types of KCl were compared to each other and to earlier reported data on commercial KCl. The piezo-optical constants q_{11}, q_{12} and q_{44} and the elasto-optical constants p_{11}, p_{12} and p_{44} were obtained at 10.6 μm for the RAP and doped KCl. The measurements required the use of a modified Twyman-Green interferometer capable of measuring fringe shifts ~0.002 of a wave. Within experimental error the coefficients of the two materials agree. Negligible dispersion was found for q_{11}, q_{12}, p_{11} and p_{12} between the visible and 10.6 μm while a small dispersion was found for q_{44} and p_{44}.

NBSIR 76-1011. **Exploratory study of glowing electrical connections,** W. J. Meese and R. W. Beausoliel, 30 pages (Oct. 1976). Order from NTIS as PB259641.

Key words: arcing/sparking; branch circuit; contact resistance; electrical connections; fire hazard; glowing electrical connections.

This report describes and characterizes with quantifiable electrical and thermal measures the extent to which loose electrical connections in residential-type branch circuits have overheated in the laboratory. With loose electrical connections, which conceivably could be inadvertently duplicated in field installations, but with otherwise normal installation and operating conditions, visible glows have been observed under laboratory test conditions in nominal 120-volt, 15 and 20 ampere branch circuits with both copper and aluminum wire. Characteristics of the glow condition are differentiated from arcing/sparking as sometimes observed in making or breaking electric circuits.

Glowing electrical connections may dissipate as much as 35 watts of power with a current of 15 amps in the circuit and as much as 5 watts with a current of 0.8 amp in the circuit. Temperatures over 750 °F were measured on the "break-off tab" of receptacles. Metal outlet boxes housing glowing connections in an insulated wall test set-up representative of a common type of residential construction attained temperatures in excess of 450 °F. In laboratory tests under repetitive, intermittent and periodic cycles, a connection on a steel wire-binding screw of a receptacle open to the air had sustained glow conditions maintained for over 100 hours. Glowing connections will not perceptibly affect the electrical performance function of lights, appliances or other electrical loads, and will not "blow" fuses, trip circuit breakers or operate ground fault circuit interrupters.

NBSIR 76-1012. **Fire performance testing of bulkhead insulation systems for high strength to weight ship structures,** B. T. Lee. 64 pages (Aug. 1976). Order from NTIS as PB257197.

Key words: aluminum bulkhead; combustion gases; fire endurance; insulation; intumescent paint; potential heat; reinforced plastic; small furnace test; smoke.

Sixteen insulated aluminum bulkhead specimens were subjected to a material screening process as well as evaluated for their comparative fire performance with a 2-foot horizontal slab furnace. Two insulated and two unprotected glass-reinforced plastic specimens were also tested to obtain fire performance data on these structural materials. In addition, painted aluminum and steel panel specimens were included to determine the fire protective merits of two types of intumescent paints. Potential heat release, smoke, and combustion gas generation were also determined for the insulation and coating materials. Specimens insulated with organic base foams released high levels of combustion gases and could contribute considerable heat to an ongoing fire. Specimens insulated with either refractory fibrous material or with mineral wool gave the best overall performance. The same thickness of insulation needed to protect an aluminum panel for over an hour can provide up to 20 minutes of protection for a glass-reinforced plastic panel of the same thickness. The intumescent paints did little to protect the specimens during the fire exposure. Parameters of insulation thickness, heat capacity, density, and thermal conductivity as well as fire duration on specimen temperature were analytically investigated.

NBSIR 76-1013. **Flame spread of carpet systems involved in room fires,** K. M. Tu and S. Davis, 42 pages (June 1976). Order from NTIS as PB256130.

Key words: carpet systems; carpets; fire safety; flame spread; floor coverings; flooring radiant panel test; ignition sources; pill test; room fires.

This study was designed to test the hypothesis that given a situation where a chair or other item of furniture becomes the first item to burn in a room (providing the ceiling and walls are noncombustible), there is little reason to expect involvement of the carpet in the fire beyond the immediate vicinity of the burning object. Four small-sized carpet fire tests and eight full-scale burn room fire experiments were conducted. Experimental data for temperature distribution and incident heat flux to the floor covering were measured in the rooms. General analysis of the experimental results obtained shows this to be the case. It also is evident that the critical radiant flux of the floor covering system is predictive of the extent of burning. From this study, carpet systems used in rooms will not normally spread fire provided they meet the requirements of DOC FF 1-70 (the pill test).

NBSIR 76-1014. **Space heater involvements in fabric fires,** W. D. Hayes, Jr., 25 pages (Mar. 1976).. Order from NTIS as PB251414.

Key words: burns; fabric fires; FFACTS; garments; ignition sources; space heaters.

Space heaters are number six in the ranking of most frequently involved direct fabric ignition sources in the Flammable Fabrics Accident Case and Testing System (FFACTS). Eighty-two of the 1573 direct fabric ignition incidents in FFACTS were caused by space heaters. Gas heaters were responsible for 83 percent of all direct garment ignitions where heater type was known. Nightgowns, dresses and robes account for 82 percent of all the garment items directly ignited. Forty-seven percent of the direct garment ignition incidents would probably not have occurred if the presently existing fabric flammability standards had been in effect at the time.

NBSIR 76-1015. **Management of data elements in information processing.** Proceedings of a Second Symposium Sponsored by the American National Standards Institute and by the National Bureau of Standards, October 23-24, 1975, NBS, Gaithersburg, Md., H. E. McEwen, Ed., 263 pages (Apr. 1976). Order from NTIS as PB249530.

Key words: American National Standards; American National Standards Institute; data; data base systems; data elements; data management; data processing; Federal Information Processing Standards; information interchange; information processing; information systems.

Continuing technological advances in computers and communications make possible the integration of data systems and the exchange of data among them on an expanding scale. However, the full effect of these advances cannot be realized unless the need for uniform understanding of the common information (data elements) and their expression in data systems is recognized and a means provided to effectively manage this information. The increasing interrelationships among the data systems of Federal, State and local governments, and with industry and the public add emphasis and dimension to the need for the improved management of data elements in information processing.

These Proceedings are for the second Symposium on the Management of Data Elements in Information Processing held at the National Bureau of Standards on October 23-24, 1975. Over 300 representatives of Federal and State governments, industry and universities from 29 states, from Japan, and the United Kingdom were in attendance. Twenty-nine speakers discussed the role of the data manager, communications needs for data standards, data element directories, standard codes for character and control, use of check characters, data elements in bibliographic data bases, product coding, coding for clinical medicine, human factors, data resource management, data base management systems, and other subjects related to data standardization and data management efforts. *These proceedings include the following papers (indented):*

On-line tactical data inputting: Research in operator training and performance, I. Alderman, *NBSIR 76-1015,* pp. 1-8 (Apr. 1976).

"Turning the Corner" on MIS, a proposed program of data standards in post-secondary education, D. R. Arnold, *NBSIR 76-1015,* pp. 9-16 (Apr. 1976).

ASCII—The data alphabet that will endure, R. W. Bemer, *NBSIR 76-1015,* pp. 17-22 (Apr. 1976).

Techniques in developing standard procedures for data editing, G. W. Covill, *NBSIR 76-1015,* pp. 23-43 (Apr. 1976).

An adaptive file management system, D. L. Dance and U. W. Pooch, *NBSIR 76-1015,* pp. 45-55 (Apr. 1976).

A focus on the role of the data manager, R. M. Davis, *NBSIR 76-1015,* pp. 57-60 (Apr. 1976).

A proposed standard routine for generating proposed standard check characters, P. A. Desjardins, *NBSIR 76-1015,* pp. 61-67 (Apr. 1976).

Methodology for development of standard data elements within multiple public agencies, L. D. England, S. L. Eberle, B. H. Schiff, and A. S. Huffman, *NBSIR 76-1015,* pp. 69-76 (Apr. 1976).

The role of the internal auditor in data management, R. H. Fahnline, *NBSIR 76-1015,* pp. 77-81 (Apr. 1976).

Semantic coding and data element characterization in medical computing, E. R. Gabrieli, *NBSIR 76-1015,* pp. 83-89 (Apr. 1976).

Principles and concepts of data resource managment system development, A. Hochman, *NBSIR 76-1015,* pp. 91-98 (Apr. 1976).

The design of data elements: A data base perspective, M. A. Huffenberger, *NBSIR 76-1015,* pp. 99-112 (Apr. 1976).

A challenging aspect of word processing, V. G. Kehler, *NBSIR 76-1015,* pp. 113-118 (Apr. 1976).

Data element lexicon needs a new home, R. J. Kirkbride, *NBSIR 76-1015,* p. 119 (Apr. 1976).

Check characters and the "Self-Checking String"—What, where, why, when and how, J. R. Kraska, J. R. Nelson, and E. Hellerman, *NBSIR 76-1015,* pp. 121-138 (Apr. 1976).

The standards implications of the developing interrelationships between on-line bibliographic retrieval, data manipulation and micrographics display, R. M. Landau, *NBSIR 76-1015,* pp. 139-145 (Apr. 1976).

Product coding-one number from maker to user, J. T. Lanigan, *NBSIR 76-1015,* pp. 147-150 (Apr. 1976).

Development of a data dictionary/directory using a data base management system, E. K. C. Lee and E. Y. S. Lee, *NBSIR 76-1015,* pp. 151-162 (Apr. 1976).

Systems design considerations for the U.S. Army Materiel Command (AMC) data element dictionary/directory system, F. Puente, *NBSIR 76-1015,* pp. 163-167 (Apr. 1976).

A data element directory for a state motor vehicles agency, J. Roberts, *NBSIR 76-1015,* pp. 169-190 (Apr. 1976).

An integrated dictionary for systems and data components, C. Shields, *NBSIR 76-1015,* pp. 191-193 (Apr. 1976).

An information documentation language: A framework for deriving information from data, W. M. Taggart, Jr., *NBSIR 76-1015,* pp. 195-210 (Apr. 1976).

International standards for data transmission, V. N. Vaughan, Jr., *NBSIR 76-1015,* pp. 211-220 (Apr. 1976).

An information management view of data management, M. G. Wallis, *NBSIR 76-1015,* pp. 221-230 (Apr. 1976).

Data standardization, H. S. White, Jr., *NBSIR 76-1015,* pp. 231-235 (Apr. 1976).

Data element analysis and use of a relational data, M. E. Williams, S. Preece, and S. Rouse, *NBSIR 76-1015,* pp. 237-252 (Apr. 1976).

Status of the Army Materiel Command's progression from reports control to data element management, E. F. Young, *NBSIR 76-1015,* pp. 253-256 (Apr. 1976).

NBSIR 76-1016. **Mobile home smoke detector siting study,** W. M. Gawin and R. G. Bright, 55 pages (May 1976). Order from NTIS as PB254177.

Key words: detector sensitivity; fire detectors; mobile homes; photoelectric smoke detectors; smoke detector installation; smoke detector placement; smoke detectors.

An investigation was conducted to evaluate the significance of smoke detector locations to response time for a specific set of fire conditions in a mobile home. Parameters having the potential of affecting response time include: the physical location within the mobile home such as inside wall vs. outside wall or wall vs. ceiling installations; the impact of air circulation resulting from the operation of the heating, ventilating, and air-conditioning system; and the basic detector parameter of smoke detector alarm threshold. For the study only photoelectric-type smoke detectors were used. These detectors utilize the Tyndall Effect in their sensing mechanism. This limitation was imposed to limit the number of variables. Detector response was evaluated for fires in both smoldering and flaming modes. The results of the study provide a case for wall installations as opposed to ceiling installations. Further, inside wall installations may be marginally superior to outside wall installations. The most significant finding of the study suggests that, when in operation, the forced-air circulating system has a major delaying effect on detector response time to a given fire size.

NBSIR 76-1017. **Interaction of blood proteins with solid surfaces,** R. R. Stromberg, B. W. Morrissey, L. E. Smith, W. H. Grant, and R. E. Dehl, 38 pages (Mar. 5, 1976). Order from NTIS as PB251917.

Key words: adsorption; blood protein; bound fraction; ellipsometry; implants; polymer adsorption; protein adsorption; synthetic implants.

The overall objective of this investigation is to help characterize materials used for implants in the cardiovascular system and to develop test methods to aid in the selection of the most useful materials. The focus of the work has been an investigation of the adsorption of blood proteins on surfaces with special emphasis on changes in conformation occurring upon adsorption. An important component has been an ellipsometric examination of materials produced by contractors of the NHLI Biomaterials Program that were considered to be of potential clinical value. In contrast to the behavior of serum albumin and prothrombin, conformational changes in γ-globulin and β-lactoglobulin occurring as a consequence of changing surface population were previously reported and were confirmed during this reporting period. An investigation of conformational changes at very short adsorption time was initiated. Adsorption, desorption and exchange of adsorbed protein in solution was studied. The results indicate strong hydrophobic bonding between the protein and the synthetic polymer surface.

NBSIR 76-1018. **Evaluation of the fire performance of carpet underlayments,** S. Alderson and L. Breden, 69 pages (Sept. 1976). Order from NTIS as PB257779.

Key words: carpets; fire; flammability; floor coverings; pad; underlayments.

A series of carpet underlayments was evaluated for fire performance in a corridor configuration using the same carpet in all tests. Carpets with underlayments flashed over during corridor tests. In a series of small-scale tests, such as the smoke density chamber and the radiant panel, the flammability properties of the carpet tended to mask the flammability properties of the underlayment. The exception to this masking effect was the results from the flooring radiant panel test where the thermal conductivity of the underlayment influenced the burning characteristics of the carpet. High concentrations of toxic combustion products were observed at the time of flashover in the corridor, with both cellulosic and synthetic underlayments. Smoke optical density values for the various carpet plus underlayment combinations were approximately the same in the flaming mode, except for the integral pad system which has a higher value.

NBSIR 76-1019. **Notes on the preparation of silicon density artifacts,** R. M. Schoonover, 11 pages (Feb. 1976). Order from NTIS as PB251944.

Key words: density; etching; grinding; sawing; silicon; standard; weighing.

The preparation of single crystal silicon density standards as normally done at the National Bureau of Standards is described.

This description is designed to guide other laboratories in construction of these standard artifacts and to facilitate their intercomparison.

NBSIR 76-1020. **Guide criteria for laboratory evaluation of backflow prevention devices for protection of potable water supplies,** G. C. Sherlin, R. W. Beausoliel, and L. S. Galowin, 44 pages (Mar. 1976). Order from NTIS as PB258256.

Key words: backflow; backflow prevention devices; back pressure; backsiphonage; guide criteria; potable water protection; plumbing guide criteria.

This report describes laboratory evaluation procedures which could be required for the approval of backflow prevention devices used to protect potable water supplies against contamination. Performance-based requirements, criteria, and general evaluation considerations that administrative authorities should require for approval of devices are presented. Recommendations for the development of tracer tests are submitted for further consideration. This document results from an investigation undertaken for the Environmental Protection Agency (EPA).

NBSIR 76-1021. **Fire spread along a mobile home corridor,** E. K. Budnick, 58 pages (July 1976). Order from NTIS as PB257101.

Key words: corridor fire test; interior finish material; intumescent coating; life safety; mobile home; smoke detector; surface flame spread.

A series of tests was conducted in the corridor area of a typically constructed mobile home. These tests were designed to: (1) evaluate the performance of a variety of combinations of wall and ceiling materials as a result of exposure to a typical ignition in a full-scale mobile home corridor, and (2) determine the relationship between full-scale tests and laboratory flammability tests, particularly the ASTM E-84 tunnel test, a measure of surface flame spread.

The tests were restricted to one set of conditions in which the living room at the end of the corridor was exposed to a fire resulting from ignition of a standardized 6.4-kg (14-lb) wood crib. Nine tests were conducted with seven different combinations of wall and ceiling materials.

Performance of the various combinations of wall and ceiling materials was examined based on the time to reach untenable conditions in the corridor. Measurements utilized in evaluating levels of tenability included gas temperatures, surface temperatures, irradiance, concentrations of oxygen and carbon monoxide, and smoke densities.

Under this set of test conditions, it was found that the extent of fire spread and the time to reach untenable conditions are significantly influenced by the surface flame spread characteristics of the wall and ceiling finish materials in the corridor.

For a mobile home corridor with conventional wall and ceiling linings (ASTM E-84:FSC = 200 max), untenable conditions were reached in the corridor in less than four minutes. With class A (FSC = 25 max) wall and ceiling materials in the corridor, untenable conditions were not reached.

NBSIR 76-1022. **Evaluation of thrown objects tests for proposed safety standard for power lawn mowers,** D. C. Robinson and R. B. Clough, 25 pages (June 1976). Order from NTIS as PB259628.

Key words: dispersion tests; lawn mowers; penetration tests; power lawn mowers; safety standard; thrown objects tests.

An evaluation was made of thrown objects dispersion and penetration tests which have been developed for a proposed safety standard for power lawn mowers. To evaluate the proposed laboratory dispersion tests, supplementary outdoor dispersion tests were conducted on walk-behind lawn mowers in which actual grass cutting conditions were simulated. A description of these outdoor tests, a comparison of the outdoor and laboratory dispersion tests for a sample of walk-behind lawn mowers, and an evaluation of the proposed dispersion and penetration tests is given. The evaluation includes a theoretical discussion of the penetration of thrown objects which is related to experimental results in terms of the shape, size and velocity of the thrown projectiles.

NBSIR 76-1023. **Direct comparisons of the NBS absorbed dose calorimeters irradiated with 20 and 50 MeV electrons,** S. R. Domen, P. J. Lamperti, and T. Mikado, 23 pages (July 1976). Order from NTIS as PB256191.

Key words: absorbed dose; calorimeter; calorimetric comparisons; electron beams.

Two NBS absorbed dose calorimeters were compared in 20 and 50 MeV electron beams that were scattered with lead foil of various thickness. The internal structures of the calorimeters are identical. The nonportable model is enclosed in a 40 cm × 40 cm × 30 cm thick graphite medium while a 30 cm diameter × 1 cm thick graphite medium was used to enclose the portable model. Measured results indicate that the three internal bodies of the calorimeters and their measuring circuits were constructed with sufficient care to produce essentially identical calorimetric responses to about 0.1 percent.

NBSIR 76-1024. **Statistical analysis of blood lead levels of children surveyed in Pittsburgh, Pennsylvania: Analytical methodology and summary results,** W. D. Urban, 75 pages (Apr. 1976). Order from NTIS as PB255876.

Key words: blood; blood lead; children; housing; lead paint; lead poisoning; surveys.

A survey was conducted in Pittsburgh, Pennsylvania to estimate the incidence of lead paint in housing and to develop a survey methodology that could be used in other metropolitan communities for that purpose. A secondary objective of the survey was to determine whether a causal relationship could be found between blood lead levels of children aged 7 years or less, living in the surveyed dwellings and the presence of lead paint in those dwellings. This report deals with the latter objective. For the children tested in Pittsburgh, the incidence of elevated blood lead levels defined as 40 micrograms of lead per 100 milliliters of blood or greater, was found to be less than 1 percent, too low to permit the establishment of a causal relationship. There was a significant correlation between the blood lead levels of the children living in the older homes and the fraction of contaminated surfaces within the dwellings. In addition, there was a significant correlation between the blood lead levels and the age of the dwellings in which the children resided. This correlation appeared to be independent of the lead paint levels in the dwellings. This report presents a summary of the survey procedures, the blood lead measurement process and associated problems and the more significant results of the analysis of the housing/blood lead data obtained in Pittsburgh.

NBSIR 76-1025. **Air-mobility rigid shelter systems,** T. W. Reichard and L. F. Skoda, 99 pages (Nov. 1975). Order from NTIS as PB251753.

Key words: durability; field inspection; foam and beam; honeycomb; impact; lightweight structures; military; reliability; sandwich panel; shelter.

This interim report covers the first portion of a long-range investigation dealing with the design and durability of lightweight, d structures (shelters) used by the military as combination pping containers and housing for tactical and life-support ses. This report covers the results of field and laboratory stus intended to correlate functional and structural problems h in-service conditions. It was found that water leakage into shelters and into the sandwich panels was probably the basic blem area although many shelters appeared to have been detive at the time of delivery. It was found that, under adverse nditions, a polyamid paper honeycomb core would be signifintly better for the sandwich panels than is the draft paper core w used. Major delaminations of the sandwich panels could not correlated with impact damage such as would be caused by klift bumps.

Subsequent reports will present the results from a structural alysis of and field test on shelters subjected to typical dynamic d static loading conditions.

BSIR 76-1027. **A survey of manufacturers' views on the ETIP procurement experiment. Volume three: Ranges,** P. C. Goodman, 33 pages (Feb. 1976). Order from NTIS as PB253243.

Key words: energy-efficient products; Experimental Technology Incentives Program; gas and electric ranges; life-cycle costing; procurement experiments.

This report describes the findings of a survey of nine gas and ctric range manufacturers by the Center for Consumer oduct Technology. The survey was conducted for the Experintal Technology Incentives Program (ETIP) as part of its aluation of a Federal Supply Service (FSS) procurement of nges. Survey questions were designed to obtain manufacturers' ews on the use of Government procurement policies to inease the rate of introduction of new technologies into the conmer marketplace. The questions covered the following areas: reasons for participation or nonparticipation of a manufacrer in the ETIP experiment; (2) problems a manufacturer enunters with existing Federal procurement practices; (3) ceptability of using life-cycle costing in the bidding procedure; d (4) effect of the most recent Government procurement on esent and future company operations. Results of the survey e reported, and implications are drawn for future ETIP studies Government procurement activities.

BSIR 76-1028. **A new concept for automatic detection and extinction of fires,** D. Lay, 20 pages (Mar. 1976). Order from NTIS as PB251415.

Key words: automatic sprinklers; carbon dioxide; fire detection; fire extinguishment; flame detection; heat detection; smoke detection.

The use of automatic fire detectors to trigger fire extinguishent systems has gone on for many years. Systems of this type e a variety of extinguishing agents including water, carbon oxide and, most recently, the halogenated agents.

Automatic extinguishing systems with practically an unlimited pply of agent suffer from the fact that these systems often conue in operation long after the fire is out resulting in additional mage. This doesn't occur with those systems having limited pplies such as carbon dioxide systems and the like. However, ese systems are only successful if: (1) their original design was rrect; (2) no unanticipated changes are made in the area or aterials to be protected; and (3) extinguishment commences at ime when successful extinguishment is possible.

This paper describes how the disadvantages recommended óve can be avoided, to a large extent, with a modified design r permanently-installed, automatic extinguishing systems and how systems can be provided which will only discharge extinguishant at the proper time and in the proper amount.

NBSIR 76-1029. **Unitary heat pump specification for military family housing,** C. W. Phillips, B. A. Peavy, and W. J. Mulroy, 30 pages (Aug. 1976). Order from NTIS as PB261199.

Key words: heating and cooling; military family housing; specification; unitary heat pump.

The purpose of this report is to establish, for unitary heat pump equipment, the requirements for performance, testing, rating, design, safety, serviceability and reliability for system and components; and conformance conditions. This report is intended for guidance in military procurement and applies to hermetic electrically-driven vapor-compression unitary heat pumps of the remote (split) and packages (integral) types, the air-to-air and water-to-air classes, and sizes from 17,000 to 84,000 Btu/hr for both heating and cooling functions.

NBSIR 76-1031. **Shape dependence of light-scattering behavior of dust particles,** R. Zerull, 23 pages (June 1976). Order from NTIS as PB253932.

Key words: aerosols; dusts; light-scattering; Mie theory; particles; Rayleigh scattering.

The most important characteristic which determines the light-scattering behavior of particles is their size distribution, their concentration, their shape, and their material composition. This paper concerns itself with the measurement of the effects of shape on light-scattering behavior. Only a few shapes have been appropriately modeled and if the shape dependence can be determined, the remaining characteristics pose no special difficulties.

NBSIR 76-1034. **Chemical thermodynamic properties of compounds of sodium, potassium and rubidium: An interim tabulation of selected values,** D. D. Wagman, W. H. Evans, V. B. Parker, and R. H. Schumm, 76 pages (Apr. 1976). Order from NTIS as PB254460.

Key words: enthalpy; entropy; Gibbs energy; heat capacity; potassium compounds; rubidium compounds; sodium compounds; standard reference data; thermochemical tables.

Selected values are given for the thermochemical properties of the more common compounds of sodium and potassium. A more extensive set of selections is provided for rubidium compounds. The properties included, where data are available, are enthalpy of formation at 0 K and 298.15 K, $\Delta Hf(0)$ and $\Delta Hf(298)$, Gibbs energy of formation, entropy and heat capacity at 298.15 K, $\Delta Gf(298)$, S(298) and Cp(298) and the enthalpy difference between O K and 298.15 K, H(298)-H(O). The values are consistent with the tables issued earlier in the NBS Technical Note 270 series.

NBSIR 76-1037. **Integral measurement procedures for determining particle size in aerosols,** F. J. Kraus, 38 pages (May 1976). Order from NTIS as PB253933.

Key words: aerosols; ionization chambers; light attenuation; scattered light; smoke detectors; test methods.

In assessing the performance of smoke detectors in the laboratory, it is necessary to have standardized smoke measurement devices which function according to the same principles as the smoke detectors under test. In developing these measurement devices, a need exists to determine, as precisely as possible, the effects of the smoke characteristics on the measurement devices. This paper presents the correlation between smoke characteristics and comparative measuring devices important in smoke detector test work and how these measuring devices can also be used as aerosol measuring devices.

NBSIR 76-1038. **NBS InterAgency transducer project, Progress Report No. 3,** P. S. Lederer and J. S. Hilten, 24 pages (Apr. 1976). Order from NTIS as PB251918.

Key words: calibration; dynamic; electronic flash; photoflash bulb; pressure; pressure measurement; pressure transducer; pressure transducer response; response; thermal transient; transducer; zero shift.

Concluding efforts related to the development of a test method for evaluating the effects of short-duration, thermal radiant-energy transients on pressure-transducer response are described. The method consists of monitoring pressure-transducer output (zero shift with the transducer at atmospheric pressure) as the transducer is exposed to radiation resulting from the ignition of a photographic flashbulb or from the discharge of an electronic flash. Thermal energy pulses as great as 0.1 J/cm², with durations of about 6 ms, have been generated using an electronic flash; pulses of up to 2.2 J/cm², with durations of about 37 ms, have been generated using No. 22 flashbulbs. Flood-flash FF-33 lamps were also investigated; their use is not recommended. In tests with No. 22 bulbs, 25 commercial pressure transducers have shown zero shifts ranging from 0.4 to about 400 percent of the full-scale output.

Transducer-related tasks being performed for other agencies are also described briefly, and other recent NBS publications of interest to the transducer community are identified.

NBSIR 76-1039. **Evaluation of selected connectors for aluminum wire in residential structures,** O. B. Laug, 37 pages (Mar. 1976). Order from NTIS as PB254047.

Key words: aluminum wire; splices; terminals.

Systems of connecting aluminum wire for possible use in receptacle outlets and elsewhere in 15 and 20 ampere branch circuits in residences are available as practical alternatives to the presently used mechanisms such as the wire binding screw and the twist-on "wire nut" connector. The alternative systems are based on the principle of high deformation of the wire in the connection to achieve more permanent metal-to-metal fittings and/or wire splice devices of several designs. They involve either crimping the device around the wire or swagging the wire into the device with special tools. Based on tests, basic connection performance of several high-deformation connectors has been established. The results indicate that certain designs of connectors operate with stability and without dangerously over-heating under accelerated laboratory tests. The tools, however, to be used to crimp terminals are not only bulky and awkward to use but quite expensive. Moreover, they must be correctly coordinated with the terminals and sizes of wires used. There is danger that a misadjusted or improper tool and/or terminal may be used with particular wire or wires which could result in a poor connection. Some improvements in the design of the assembly tools and in the devices themselves would reduce certain installation difficulties encountered during testing, and certain connectors could be slightly modified to avoid human errors during assembly. Use of these systems and conformance with established codes and standards do not appear to present major problems.

NBSIR 76-1040. **Points of view in testing flame detectors,** M. Schnell, 24 pages (May 1976). Order from NTIS as PB254178.

Key words: detection; fire detectors; flame detectors; heat detectors; infrared detectors; smoke detectors; testing; ultraviolet detectors.

The general principles for type testing the fire detectors which are already in use in the assessment of heat and smoke detectors are summarized. These include the so-called basic tests and th trial tests. The trial tests were intended to include all test fires i order to ensure comparability of tested fire detectors. Addition test fires are proposed which are intended to permit di ferentiated comparison of flame detectors between one anothe The main problem in assessing the performance of flame dete tors during environmental influences is the selection of a suitab radiation source for reproducibly simulating the characteristi "flame." The requirements that this radiation source must fulfi are dealt with and various realizations involved are discusse The practical testing of infrared flame detectors to the basic tes is described. In addition, a suggested test apparatus for u traviolet flame detectors is dealt with.

NBSIR 76-1041. **Security analysis and enhancements of comput operating systems,** The RISOS Project, Lawrence Livermo Laboratory, 70 pages (Apr. 1976). Order from NTIS a PB257087.

Key words: BBN-TENEX; IBM OS/360; operating syste security; security flaws; software security; taxonomy of i tegrity flaws; UNIVAC 1100 Series OS.

The protection of computer resources, data of value, and i dividual privacy has motivated a concern for security of EDP i stallations, especially of the operating systems. In this repo three commercial operating systems are analyzed and securit enhancements suggested. Because of the similarity of operatir systems and their security problems, specific security flaws a formally classified according to a taxonomy developed her This classification leads to a clearer understanding of securi flaws and aids in analyzing new systems. The discussions security flaws and the security enhancements offer a startir reference for planning a security investigation of an EDP insta lation's operating system.

NBSIR 76-1043. **An economic analysis of residential abando ment and rehabilitation,** P. F. Colwell, 111 pages (May 197 Order from NTIS as PB254347.

Key words: housing; housing demand, supply, needs; hou ing rehabilitation; land economics; market adjustments; o timization and feasibility; rehabilitation, conservation.

This paper is an analysis of market and governmental facto which lead to socially inefficient rehabilitation and abandonme decisions. Its purpose is to abstract from complex problems r lated to the rehabilitation and abandonment of residenti buildings by identifying the essential characteristics of t problems and the role some past and existing social prograr have had on aggravating or mitigating these problems. Altern tive programs are analyzed for their potential effects on the problems, however policy recommendations are not made.

NBSIR 76-1046. **Improved building design through the psychol gy of perception: Perceptual selectivity applied to livability a safety with sample performance requirements,** N. Starnes, Wehrli, and R. Cormack, 103 pages (July 1976). Order fro NTIS as PB256476.

Key words: architectural psychology; architectu research; building research; building safety; perceptio stair safety research.

For over a decade, architects have been calling for applic tions from social science which would contribute to buildi design better suited to the building's users. This report provid such applications relying upon the state-of-the-art knowledge the psychology of perception, showing how human percepti operates in the everyday use of buildings, and then drawing up this rationale to present building requirements to guide t

design and construction of safer stairs in future buildings. The building safety "requirements" have been written in the format and style of the *Guide Criteria for the Design and Evaluation of Innovative Housing Systems*, a housing performance specification written by NBS for HUD's large housing experiment, Operation Breakthrough. The report is directed toward both building designers (who could consider the use of the stair safety requirements for their own building projects) and architectural psychology researchers (who could take the proposed requirements as a set of hypotheses in further research and experimentation).

NBSIR 76-1049. **The electron factor in catalysis on metals electrocatalysis on nonmetallic surfaces,** L. H. Bennett and A. D. Franklin, 71 pages (May 1976). Order from NTIS as PB256600.

Key words: catalysis; electrocatalysis; electrochemistry; electrodes; fuel cells; surface physics and chemistry.

Two related workshops were held at the National Bureau of Standards in Gaithersburg, MD, December 9-12, 1975, in topics of importance for energy conversion. These topics, concerned with some of the science underlying the development of fuel cells for electric utility use, are: (1) The Electron Factor in Catalysis in Metals; and (2) Electrocatalysis on Non-Metallic Surfaces.

This report includes discussions of the needs and expected benefits, lists of attendees, descriptions of the programs, and summaries of the major problems, advances, and opportunities revealed by the workshops.

NBSIR 76-1050. **Tornado-borne missile speeds,** E. Simiu and M. Cordes, 63 pages (Apr. 1976). Order from NTIS as PB253111.

Key words: missiles; nuclear engineering; structural engineering; tornadoes; wind.

At the request of the U.S. Nuclear Regulatory Commission (NRC) the National Bureau of Standards (NBS) has carried out an independent investigation into the question of tornado-borne missile speeds, with a view to assisting NRC in identifying pertinent areas of uncertainty and in estimating credible tornado-borne missile speeds—within the limitations inherent in the present state of the art. The investigation consists of two parts: 1) a study, covered in this report, in which a rational model for the missile motion is proposed, and numerical experiments are carried out corresponding to various assumptions on the initial conditions of the missile motion, the structure of the tornado flow, and the aerodynamic properties of the missile; 2) a theoretical and experimental study of tornado-borne missile aerodynamics, conducted by Colorado State Univ. (CSU) under contract with NBS, to be covered in a separate report by CSU. In the present report, the factors affecting missile motion, and their influence upon such motion, are examined. Information is provided on a computer program developed for calculating missile speeds. Maximum speeds for a number of specified potential tornado-borne missiles are presented, corresponding to a set of assumptions believed by the writers to be reasonable for design purposes. It is pointed out that higher speeds are conceivable if it is assumed that certain circumstances, examined in the body of the report, will obtain. It is the judgment of the writers that the probabilities of occurrence of such higher speeds for any given tornado strike are low. More than qualitative estimates of such probabilities, are however, beyond the scope of this investigation.

NBSIR 76-1052. **Naval shipboard fire risk criteria—Berthing compartment fire study and fire performance guidelines,** B. T. Lee and W. J. Parker, 86 pages (Sept. 1976). Order from NTIS as PB258118.

Key words: fire tests; flame spread; heat release rate; ignition; reduced scale models; room fires.

Judicious application of shipboard materials and choice of compartment furnishings can significantly reduce the threat of serious fire on board ship. Unfortunately the fire performance of materials is currently difficult to ascertain from laboratory fire tests on the materials. Full size and quarter-scale compartment fires in conjunction with an analytical treatment were performed to obtain an improved understanding of the relationships between the laboratory fire test assessment and the observed behavior of materials in actual fires. The compartment fire experiments indicated that the temperature of the hot air layer below the ceiling is a suitable quantitative measure of the level of fire buildup in a compartment. When this temperature exceeds 700 °C there is sufficient radiation from the hot air layer and the heated upper surfaces to cause ignition of all combustible materials in the compartment. For a $3 \times 3 \times 2.1$ m ($10 \times 10 \times 7$ ft) space lined with asbestos millboard having a 0.68×1.9 m (27×75 in) open doorway a heat production rate of about 72 kW/m^2 (6.3 Btu/s/ft^2) of deck area is enough to attain this condition. Fires in some bunk configurations alone could exceed this critical rate of heat generation. Ventilation and its points of application were found to be very important considerations. Observations of the fire scenarios in the compartment tests along with an empirical and analytical analysis of fire growth in compartment spaces have resulted in an improved application of the fire test ratings. Consequently more rational design rules for fire safe material usage have been developed taking into account the ignitability, flame spread, rate of heat release, potential heat and smoke generation potential of materials. The study also indicated the practicality of using quarter-scale fire tests for studying fire performance in full size compartments.

NBSIR 76-1054. **An appraisal of tests and standards for the evaluation of electrical insulating fluids,** D. B. Miller, V. E. Bower, F. R. Kotter, O. Petersons, M. M. Birky, C. M. Huggett, and A. Macek, 124 pages (May 14, 1976). Order from NTIS as PB253110.

Key words: askarel; capacitors; insulating fluids; liquid insulators; polychlorinated biphenyls; transformers.

Based on a literature study and interviews with representatives of the electric utility industry, manufacturers of insulating fluids and electrical apparatus, government regulatory agencies, organizations preparing standards and codes, trade associations and independent testing laboratories, the status of existing standards and test procedures for insulating fluids is reviewed. Askarel-type transformers and capacitors are described and the characteristics of several currently-used as well as new candidate insulating fluids are given. The possible impact of codes and government regulations on the introduction of new fluids into use is reviewed. Needs for new or revised test procedures and standards are noted and recommendations made for research and development efforts as well as administrative actions to facilitate the qualifying of new insulating fluids as acceptable replacements for the askarels currently in use in a certain class of transformers and capacitors.

NBSIR 76-1056. **Analysis of solar energy system for the GSA demonstration office building at Manchester, New Hampshire,** T. Kusuda, S. T. Liu, J. W. Bean, and J. P. Barnett, 35 pages (Mar. 1, 1976). Order from NTIS as PB254179.

Key words: energy conservation; GSA/Manchester building; solar collector; solar heating and cooling; thermal storage.

The energy conservation demonstration building of the General Services Administration to be built in Manchester, New Hampshire, has been planned to be partially heated and cooled by solar energy. Presented in this report are results of a study made at the National Bureau of Standards to determine the effect of solar collector sizes and the amount of storage on the overall energy consumption of the building. It was found that the fuel savings attainable by the use of solar energy for heating and cooling of the building will be less significant as the size of the collector and the amount of storage are increased beyond certain limits.

NBSIR 76-1058. **Performance of mobile homes—Summary report,** J. H. Pielert, W. E. Greene, Jr., L. F. Skoda, and W. G. Street, 143 pages (Apr. 1976). Order from NTIS as PB262097.

Key words: computer techniques; construction; enforcement process; housing; hurricane Agnes; mobile home parks; mobile homes; performance data; regulatory process; standards.

This project was funded at the National Bureau of Standards by the Department of Housing and Urban Development with the objective of documenting mobile home performance problems and relating them to possible inadequacies in the ANSI A119.1 Standard for Mobile Homes and the mobile home enforcement process. Additionally, the durability of mobile home components was a study objective for potential use in mortgage insurance evaluation. Mobile home performance data were obtained for 4,105 mobile homes, categorized and related to the project objectives. This summary report is the last of a series of four project reports. It documents the project approach, results of the various tasks, and presents conclusions and recommendations. This was a problem-oriented study and did not attempt to document the many areas of satisfactory mobile home performance.

NBSIR 76-1059. **Intermediate minimum property standards for solar heating and domestic hot water systems,** Solar Energy Program Team, Center for Building Technology, 171 pages (Apr. 1976). Order from NTIS as PB257086.

Key words: solar buildings; solar collectors; solar domestic hot water systems; solar heating; standards; thermal storage.

This report presents standards for the use of solar heating and domestic hot water systems in residential applications. The standards have been developed for application in numerous housing programs of the Department of Housing and Urban Development and are a companion document to be used in conjunction with the HUD "Minimum Property Standards for One and Two Family Dwellings," 4900 and "Minimum Property Standards for Multifamily Housing," 4910. To the greatest extent possible, these standards are based on current state-of-the-art practice and on nationally recognized standards including the MPS and the HUD "Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings."

NBSIR 76-1060. **NBS interagency transducer project. Progress Report No. 4,** P. S. Lederer, J. S. Hilten, C. F. Vezzetti, and J. F. Mayo-Wells, 26 pages (June 10, 1976). Order from NTIS as PB253934.

Key words: coatings; photoflash bulb; pressure transducer; protective coatings; thermal radiant-energy response; thermal transient response; transducer.

Initial experimental efforts are described relating to the development and evaluation of means to reduce the effects produced by thermal radiant-energy transients and other thermal inputs on pressure-transducer response. Results from earlier work suggest that a major source of the thermally induced zero shifts observed in a number of pressure transducer designs is thermal energy propagated through the diaphragm to the sensing element. For many transducer designs, the temperature at the back side of the diaphragm provides a convenient measure of the energy reaching the sensing element. Accordingly, a series of tests was carried out to investigate the effects of a variety of protective coatings on the amount and rate of energy transmission through the diaphragm as revealed by measurements of the diaphragm back-side temperature. For purposes of experimental simplicity, mounted thin metal disks are used to simulate transducer diaphragms, and the temperature histories of both bare and protected disks are measured with thermocouples following exposure of the disks to thermal radiant-energy transients (of approximately 20 mJ/mm^2 at the disk) generated by No. 22 photographic flashbulbs. Protective means investigated include various materials, such as tapes, greases, and room-temperature-vulcanizing rubbers (RTVs), applied directly onto the disks as coatings. Data are given for each protective material tested.

A description of other transducer-related work and publications is given in an appendix.

NBSIR 76-1061. **An annotated bibliography on proton affinities,** K. Hartman, S. Lias, P. J. Ausloos, and H. M. Rosenstock, 52 pages (July 1976). Order from NTIS as PB256328.

Key words: basicity; bibliography, appearance potential; heat of formation; ion-molecule equilibrium; proton affinity; proton transfer.

This bibliography consists of approximately 150 references about proton affinities which covers the period from 1932 through 1975. This includes experimental determinations of proton affinities in the gas phase (through observation of proton transfer reactions, ion-molecule equilibria, and appearance potential measurements) as well as determinations from crystal lattice energies and other miscellaneous techniques. Also included are reviews concerned with or related to proton affinity determinations.

NBSIR 76-1063. **Air leakage measurements in a mobile home,** C. M. Hunt, S. J. Treado, and B. A. Peavy, 27 pages (Aug. 1976). Order from NTIS as PB257102.

Key words: air infiltration measurement; air leakage measurement; mobile home tightness; sulfur hexafluoride tracer measurement.

Air leakage measurements were made in a mobile home using sulfur hexafluoride (SF_6) as a tracer gas. The home was located in an environmental chamber where it was possible to measure and control the temperature outside the home. The effect on infiltration rate of a number of variables was determined. These included inside-outside temperature difference, simulated wind, installation of storm windows, opening of doors, and operation of the furnace fan. Experiments were also performed in which a fan was sealed to an opening in the house and inside-outside pressure difference measured as the fan blew air into or out of the structure at measured rates.

NBSIR 76-1064. **Existing architectural information indexing systems,** R. J. Kapsch, 68 pages (Mar. 1976). Order from NTIS as PB254181.

Key words: architectural indexing systems; architecture; building; construction; design; information; information retrieval system.

Architectural indexing systems are those mechanisms which we use to organize information concerning how and what t

build. Architectural indexing systems are a means of organizing available information in a manner that can readily be grasped by the user. As such, architectural indexing systems are an important component part of architectural information systems. This report reviews and summarizes existing architectural indexing systems presently used in the United States and overseas. Indexing systems reviewed are classified into (1) one way divisions, (2) two way divisions, (3) thesauri and other indexing systems.

NBSIR 76-1066. **Center for consumer product technology publications, November 1974 to April 1976,** S. Halpin, 13 pages (June 1976). Order from NTIS as PB254473.

Key words: bibliographies; consumer product safety; consumer product standards; consumer product technology; law enforcement equipment; law enforcement equipment standards; product performance; product safety.

"Center for Consumer Product Technology Publications, November 1974 to April 1976" lists only publications prepared by the members of the Center for Consumer Product Technology staff, by NBS personnel under contract or grant to the Center or by NBS personnel or external laboratories under contract or grant from the Center are cited. Articles published in NBS house publications also are cited.

NBSIR 76-1067. **Mathematical approaches to evaluating aircraft vertical separation standards,** J. F. Gilsinn and D. R. Shier, 50 pages (May 1976). Order from NTIS as PB257195.

Key words: aircraft; air transportation; air traffic control models; altimetry; altitude; aviation; collision risk; error analysis; mathematical models; safety; separation; vertical separation.

Above Flight Level 290, current regulations require aircraft to be separated vertically by at least 2000 feet. Because of increased traffic desiring to fly at these altitudes, the possibility of reducing the required separation (while maintaining acceptable safety levels) is under study. This report details many of the components of vertical position error and classifies them into three major categories: static pressure system error, altimeter instrument error, and pilot response error. Two models for use in evaluating separation standards, the root sum of squares (RSS) approach and the Reich collision risk model, are described together with their respective advantages and disadvantages. A final section includes recommendations for a carefully designed data collection effort and discusses potentially important considerations for such a design.

NBSIR 76-1069. **Environmental effects on the strength of a glass fiber-reinforced-plastic rod material,** N. Halsey and L. Mordfin, 38 pages (July 1976). Order from NTIS as PB256296.

Key words: antenna-support materials; environmental degradation; guys, nonmetallic; marine atmospheres; plastics, fiber-reinforced; pultrusions; stress-rupture testing; sunlight; ultraviolet radiation; weatherability.

Environmental stress-rupture test methods were developed for studying the weatherability of materials under stressed exposure in marine atmospheres and intense sunshine. These laboratory test methods were applied to a coated, pultruded, glass fiber-reinforced-plastic rod product, with the marine atmosphere simulated by a saltwater fog and intense sunshine simulated by ultraviolet radiation. Static tests of the material, conducted both before and after the environmental exposures, were used to characterize both the as-received mechanical properties of the product and the reductions in tensile strength attributable to the weathering actions. The experimental results essentially confirmed the rod manufacturer's contention that the effects of sunlight and weathering on the product range from none to slight. For applications as antenna guys, the results suggest that the strength limitations imposed on rods by conventional end fittings, and by the fact that rods are frequently bowed rather than straight, tend to overshadow any strength reductions attributable to environments of the types considered here.

A failure analysis of a tower guy, fabricated from material of the type tested in this investigation, is given in an appendix.

NBSIR 76-1070. **Evaluation of backflow prevention devices: A state-of-the-art report,** G. C. Sherlin and R. W. Beausoliel, 142 pages (June 1976). Order from NTIS as PB260913.

Key words: backflow; backflow preventers; back pressure; back-siphonage; cross connections; health hazard; potable water; vacuum breaker; water supply.

A significant potential for potable water supply contamination exists within all water supply systems due to backflow and cross connections. Surveillance of the water supplies to protect from such hazards requires continuing vigilance by the administrators of cross-connection control programs, and continuing upgrading of technical criteria and methods of evaluation.

The Environmental Protection Agency assists local (usually municipal) authorities, through the State water supply agency, in establishing and operating cross-connection control programs. Essential to these programs are (1) information on the suitability of commercially available devices for use in potentially high-hazard locations, and (2) practical and effective standardized test methods for evaluation of devices. The National Bureau of Standards investigation reported herein addresses the two needs identified.

This study includes a systematic review of the literature, together with consultations and visits with water purveyors, plumbing officials, laboratory officials and researchers in this field. Emphasis has been placed on those devices, test methods, and laboratory practices considered most essential to an effective assessment of the state-of-the-art. Also, test development needs were identified in a few areas of greatest concern.

NBSIR 76-1072. **Back-up report for the proposed standard for the flammability of general wearing apparel,** E. Braun, V. B. Cobble, S. Helzer, J. F. Krasny, R. D. Peacock, and A. K. Stratton, 51 pages (June 1976). Order from NTIS as PB255446.

Key words: apparel; burn injury; ease of ignition; fabrics; fire; flammability tests; garments; heat transfer; standards.

A "Proposed Standard for the Flammability of General Wearing Apparel" was submitted to the Consumer Product Safety Commission in February 1976. This report discusses the reasons for the choices of experimental arrangement for the flammability test and the choices of pass-fail criteria. The specimen is cylindrical, to simulate a garment, and to eliminate framed specimens which often burn differently from garments. Criteria for the fire hazard of fabrics are the time to ignite with a specified gas flame and the heat transferred to sensors inside the burning specimen. The proposed standard specifies that fabrics which transfer little heat to the inside of the specimens could be used in all garments but would have to be used in garments which cover most of the body and/or fit loosely. They would also have to be used in children's dresses and skirts (children's nightwear is covered by an earlier standard). Fabrics which transfer larger amounts of heat, and thus have larger injury potential, could be used in garments with normal or tight fit such as most present-day shirts, slacks, etc. If such fabrics ignite in 1/2 second or less, they would be excluded from use in garments. These provisions in the proposed

standard were based on the need to reduce the number and severity of apparel fires with minimum economic and technological impact on the fiber, textile, and apparel industry. The present report summarizes the available knowledge in the area covered by the standard, and points out areas in which additional work is indicated.

NBSIR 76-1074. **Operation manual for 30,000 lbf constant-load testing machine,** D. E. Marlowe and W. H. Appleton, 31 pages (Oct. 1976). Order from NTIS as PB261497.

Key words: creep; instrumentation; stress rupture; testing machine.

A 30,000 lbf (133 kN) constant-load testing machine has been designed, and ten of these machines have been delivered to the NASA Langley Research Center. Each machine is equipped with a self-contained, closed loop load controller which is maintained at a constant temperature, independent of the external ambient conditions.

NBSIR 76-1076. **Flammability limits: Thermodynamics and kinetics,** A. Maček, 27 pages (May 1976). Order from NTIS as PB254180.

Key words: chemical kinetics; diffusion flames; flame extinction; flame temperature; flame velocity; flammability; flammability limits; oxygen index test; thermodynamics.

Extinction limits for both premixed and diffusion flames for n-alkanes and n-alcohols found in the literature are assembled. Several sets of theoretical flame temperatures corresponding to the limits are defined and presented. The implications of the view that flames fail to propagate at temperatures at which reaction rates become too low to overcome the dissipation processes are discussed. Equilibrium flame temperatures indicate that at lean limits the excess oxygen does not act merely as a diluent but takes an active part in promoting the kinetics of flame reactions. The burning-rate data and the results of ignition experiments are shown to be pertinent to the interpretation of flammability limits. Extinction characteristics of methane are shown to be atypical (compared to other alkanes and alcohols) and demand a special explanation. It is also shown that the assumption of thermodynamic equilibrium at the limits is unrealistic, so there is need for experimental temperature and concentration measurements in both premixed and diffusion flames. When the assumption of equilibrium is removed, the chemical kinetic considerations suggest a simple qualitative explanation of the limit phenomenon, based on the stipulation of incomplete combustion. Quantitative data are presented in support of this view.

NBSIR 76-1081. **Progress report on the corrosion behavior of selected stainless steels in soil environments,** W. F. Gerhold, E. Escalante, and B. T. Sanderson, 77 pages (Aug. 1976). Order from NTIS as PB256329.

Key words: coatings; corrosion behavior; field tests; galvanic couples; soil environment; stainless steels; stress-corrosion behavior.

In order to obtain more definitive information regarding the corrosion and stress corrosion of stainless steels in soil environments, NBS in cooperation with the Committee of Stainless Steel Producers, AISI, initiated in 1970 a soil burial program in representative soil environments. Test materials included coated and uncoated sheet specimens in the annealed and sensitized condition, uncoated welded tubing specimens and galvanically coupled and uncoupled stressed and unstressed specimens. To date approximately 10,000 specimens have been buried at six soil test sites. This report contains the results obtained for specimens buried for up to approximately four years.

NBSIR 76-1082. **A survey of State legislation relating to solar energy,** R. M. Eisenhard, 166 pages (Apr. 1976). Order from NTIS as PB258235.

Key words: architecture; buildings; design; energy; legislation; solar; State.

This report reviews enacted State legislation dealing with solar energy. Acts involving tax incentives, reduced property assessments, research and development, solar easements and solar energy promotion are identified and abstracted. The responsible State agency and official are listed. Acts and supporting forms and other information are included as appendices.

NBSIR 76-1083. **Report to AID on a Philippines survey on standardization and measurement services,** H. S. Peiser and R. S. Marvin, Eds., 124 pages (June 1976). Order from NTIS as PB255803.

Key words: building technology; information handling; measurement services; Philippines; standardization; testing facilities.

A survey of standardization and measurement services in the Philippines was carried out in May 1975 as part of a National Bureau of Standards Program sponsored by the Office of Science and Technology of the Agency for International Development. The Survey Team included five NBS staff members, one other U.S. participant, three third-country participants, and a number of Philippine specialists. The Survey was made under the direction of Mr. Vidalito F. Ranoa, Director of the Philippine Bureau of Standards.

The team was divided into five groups which concentrated on: Technical Standards Committee Management, Metrication, Building Technology, Technical Information Handling, and Testing Facilities. Each group made extensive visits to the governmental, academic, and private organizations and facilities relevant to their topic. In each area the report summarizes the existing situation, identifies current problems, and offers suggestions and recommendations for their resolution.

NBSIR 76-1084. **Nondestructive examination of glass-reinforced-plastic rod end fittings,** G. F. Sushinsky and L. Mordfin, 28 pages (Aug. 1976). Order from NTIS as PB257180.

Key words: end fitting; glass-reinforced-plastic rod end fitting; nondestructive examination; neutron radiography; ultrasonics; x-radiography.

An exploratory study was performed on the feasibility of using nondestructive examination techniques to detect voids in two types of potted compression end fittings. Four methods of nondestructive examination were tried: conventional pulse-echo ultrasonics, ultrasonic holography, x-radiography, and neutron radiography. The ultrasonic and x-ray methods that were tried proved unsatisfactory as a nondestructive examination tool for the two types of end fittings, and the neutron radiographic procedures successfully displayed the internal structure of only one of the specimen types. The procedures and results from the different methods of examination are summarized. Additional comments are given regarding the application of the methods to aluminum-jacketed specimens, and regarding improved methods for the inspection of steel-jacketed specimens.

NBSIR 76-1087. **On a scattered-light measuring device for use in testing types of smoke detectors,** M. Pistor, 35 pages (July 1976). Order from NTIS as PB257202.

Key words: fire detection; light extinction; light scatter; light-scatter measurements; photoelectric smoke detectors; smoke detectors.

Generally, the response threshold value of fire detectors is ested with measuring instruments which operate on the same hysical principle as the detectors to be tested. For example, this neans that the response threshold value of an ionization measur- ng chamber and the response threshold value of an optical-type moke detector operating on a light extinction principle is hecked using an extinction measuring instrument. However, ptical-type smoke detectors operating on a light-scatter princi- le (photoelectric in U.S. parlance) have also been checked using n extinction measuring instrument.

Since the light-scatter type of smoke detector is by far the nost commonly used of the optical type of smoke detector it eems appropriate to use a light-scatter measuring instrument to heck the response threshold value of these detectors. In addi- on, the need for such a measuring instrument is emphasized by ne fact that both the parameters of the smoke aerosol and the esign features of the measuring instrument are affected in dif- erent ways by light scatter and light extinction.

The author describes the technical features and design details f a newly-developed, light-scatter measuring instrument along ith some experiments to determine its response to artificially- enerated aerosols.

BSIR 76-1089. **An analysis of inertial seismometer-galvanome- ter combinations,** D. P. Johnson and H. Matheson, 205 pages (June 1976). Order from NTIS as PB254475.

Key words: accelerometer; calibration; electromechanical transducer; galvanometer; galvanometer amplifier; seismic system; seismometer.

This report develops the fundamental equations for an inertial eismometer with an electromechanical transducer. If the in- uctance as well as the resistance of the system are included, the quations of motion are of the third order. These are discussed some detail. Response curves are developed for several ismometer-galvanometer combinations, some of which are uitable for telemetry. Techniques are discussed for calibration, oth in the laboratory and in the field. Practical and theoretical mitations are treated for circumstances in which thermal agita- on is a major source of instrumental noise. The bibliography in- udes lists of equivalent notations.

BSIR 76-1090. **Environmental effects on microphones of vari- ous constructions,** G. R. Hruska, E. B. Magrab, W. B. Penzes, 36 pages (July 1976). Order from NTIS as PB255505, $4.00

Key words: calibration; ceramic; condenser; electret; humidity; microphones; reciprocity; sensitivity; temperature.

The pressure sensitivities of two "1/2-inch" electret, two "1- ch" ceramic, and two back-vented "1-inch" condenser icrophones were measured for numerous combinations of tem- erature, percentage relative humidity, and frequency. The two ondenser microphones were calibrated by the reciprocity chnique at each combination of temperature, relative humidity d frequency. The condenser microphones were then used as libirated sources to determine the pressure sensitivities of the her microphones. Insert voltage techniques were used to minate the environmental effects on the electronics. It was und that the back-vented condenser microphones are insensi- e to changes in relative humidity. At frequencies considerably low their resonance frequencies they exhibited only a very nall change in sensitivity with temperature. At frequencies oser to the resonance frequency the temperature coefficient in- eases approximately fourfold. The temperature and humidity efficient for the electret and ceramic microphones could not be termined due to the instability in their sensitivities which produced changes that were larger than those induced by the temperatures and humidities.

NBSIR 76-1091. **Materials for fuel cells,** L. H. Bennett, M. I. Cohen, A. L. Dragoo, A. D. Franklin, and A. J. McAlister, 39 pages (May 1976). Order from NTIS as PB257768.

Key words: cerium dioxide; degradation; electrocatalysis; fuel cells; refractory hard metal; solid electrolytes.

This report describes the research plans and initial progress on the NBS program of research on Materials for Fuel Cells. Transition metal carbides, borides, and nitrides ("refractory hard metals," or RHM) are being examined as potential hydrogen oxidation electrocatalysts for use in acid fuel cells. Preliminary screening of 19 carbides and borides has revealed apparent stability in hot (up to 160 °C) phosphoric acid for TaB, MoB, NbC, TaC, Mo_2C, and WC. More sophisticated tests for acid stability for these materials are under way. Equipment for examination of the electrochemical behavior of these materials as hydrogen oxidation electrocatalysts in phosphoric acid electrolytes at temperatures up to 150 °C is being completed, and tests will be started on these materials shortly. Additional materials in the general RHM class, including a number of nitrides, have been ordered and will be screened for acid stability. More extensive exploration will be made of the properties of TaC and WC as a function of stoichiometry and presence of other metals and of oxygen. Plans exist for a parallel study of oxides as oxygen reduction electrocatalysts for acid fuel cells not under support of this project. The current effort is devoted to improving and expanding the facility for electrochemical measurements. The long-term stability of CeO_2-based solid electrolytes, which are promising new candidate materials for the high-temperature fuel cells, is under study. Materials for fabricating specimens of CeO_2 doped with Gd_2O_3 or Y_2O_3 have been obtained or ordered, and arrangements made to hot press them. Experiments have been designed to examine degradation of the electrical properties at temperatures from 500 to 1100 °C, with and without a constant current throughout the degradation anneals. Compositions will be chosen around those giving a maximum conductivity, and the oxygen partial pressure will be fixed at a convenient value. AC admittance measurements will be used to monitor the electrical properties. Furnaces and ancillary equipment are being assembled or constructed.

NBSIR 76-1093. **The application of test structures and test patterns to the development of radiation hardened integrated circuits: A review,** K. F. Galloway and M. G. Buehler, 15 pages (Aug. 1976). Order from NTIS as PB256318.

Key words: hardened integrated circuits; integrated circuits; radiation effects; radiation hardening; test patterns; test structures.

Government sponsored research and development on semiconductor devices intended for application in radiation environments often relies on test structures arranged into test patterns for device design information and process characterization. Problems unique to a radiation environment are often analyzed using test structures such as MOS capacitors and break-out transistors. The work reviewed in this report clearly demonstrates the importance of test structures in isolating and identifying problem areas. However, the measurement methodology associated with test structures is seldom reported which makes it difficult to compare the results of different workers. Also, the work reported to date using test structures and test patterns for assessing radiation effects has involved the relatively slow-speed laboratory testing of statistically insignificant numbers of test structures. Test patterns could be used by buyers of radiation hardened devices for (1) vendor selection and qualification, (2)

process validation for hardness screening and hardness assurance, and (3) identification of circuit parameters critical to hardness assurance. However, before this can effectively be done, it is necessary that standardized modular test structures be designed to measure parameters of known importance to device hardness, that statistically significant numbers of test structures be measured with high-speed integrated circuit testers, and that the data reduction and analysis routines be well established.

NBSIR 76-1095. **Properties and interactions of oral structures and restorative materials,** J. M. Cassell, 77 pages (Aug. 1976). Order from NTIS as PB255808.

Key words: adhesion; adsorption; alloys; composites; dental; grafting; investments; polymer; resin; wear.

A diversity of techniques is being directed toward development of new and improved dental restorative and caries-preventive materials. These have included: surface characterization of dental materials and coupling agent-coated hydroxyapatite by water adsorption; further evaluation of a novel testing approach for investigating the adhesive capability of coupling agents; synthesis of selected monomers for potential application as components of a dental composite restorative system or a pit and fissure sealant application; and investigation of techniques such as grafting with 2-cyanoacrylates and urethanes containing free isocyanate groups for modifying natural tooth and bone surfaces so as to achieve a more compatible surface for adhesion. Failure of the data acquisition and control system of a prototype pin on disc *in vitro* wear test procedure for dental restorative materials to record data consistently and to maintain proper measurement point trigger position have dictated construction of a new wear test unit that incorporates the successful design of the prototype unit, but that will allow for testing of multiple specimens and should permit data to be accumulated with a confidence level of 95 percent, as compared to the 90 percent level previously attained. Procedures have been developed for the investigation of nonprecious alloys used in crown and bridge application.

NBSIR 76-1096. **Guidelines for the determination and development of generic safety standards,** R. G. Hendrickson, 58 pages (Aug. 1976). Order from NTIS as PB257076.

Key words: management need; operations research – NS.

These guidelines were prepared to assist the CPSC in the development of generic safety standards. This development is based on conceptual models of product hazard interactions and analyses of accident sequences, product clustering, and hazard characteristics.

The motivation for these guidelines derives from a perceived need to expedite the standard development process and to enhance the efficiency of standards for consumer product safety.

NBSIR 76-1097. **Illustrative generic standard for the control of thermal burn hazards in household appliances,** R. G. Hendrickson, E. M. Robertson, and R. V. Kelly, 49 pages (Aug. 1976). Order from NTIS as PB257141.

Key words: burn hazards, household appliances; fault-tree diagrams; generic safety standards; household appliances; operations research; thermal burn hazards.

This document reports on the development of an illustrative generic standard for controlling hot surfaces associated with certain categories of consumer products. The development includes evaluations of accident data, fault-tree diagrams, theoretical heat-flow phenomena, current standards, and application of the thermesthesiometer as a test instrument.

This work is a companion to the Guidelines for the Development of Generic Safety Standards, and as such, it applies the methods and techniques provided in the Guidelines. The principal tool of analysis is the fault-tree method. This method brings to safety problems a versatile and insightful way of depicting events, conditions, and causes associated with hazards and accidents.

The intent is to demonstrate the feasibility of the generic approach to controlling safety aspects of consumer products. Although the illustrative standard is based on a study of actual data, the conclusions are not to be construed as final or authoritative.

NBSIR 76-1098. **Daylighting of buildings. A compendium and study of its introduction and control,** J. K. Holton, 39 pages (Oct. 1976). Order from NTIS as PB259523.

Key words: daylight gathering; daylighting of buildings; energy conservation; lenses; light conduits; light control; reflectors; skylights; windows.

We can no longer ignore daylight as a valuable natural resource for building illumination. Significant reductions in the energy consumption of buildings are possible by decreasing the dependence on artificial illumination and decreasing air conditioning loads by employing methods which bring in cool light. In order to design buildings utilizing daylight effectively there must be an understanding of the design principles of daylighting. This requires a knowledge of illumination to meet the needs of the building users, an understanding of characteristics of daylight at the location of the building, and imagination in developing ways to introduce and control daylight. This paper is directed toward the identification of innovative techniques for the introduction and control of daylight. It is arranged in three sections: a Compendium, a Study section, and a Reference section. The Compendium presents a number of state-of-the-art methods to assist the designer in successfully employing daylight more extensively. The Study section provides more detailed information on these methods so an increased understanding can be developed of those which appear to have suitability in a given situation. Finally, the References provide background for further investigation.

The Study organizes daylighting methods as they relate to three zones of a building, the perimeter, the intermediate and the deep zone. Each has different characteristics and is suited to daylighting by different methods.

NBSIR 76-1099. **Standardization and measurement services in Bolivia,** H. S. Peiser, R. S. Marvin, and J. Mejeur, Eds., 105 pages (Sept. 1976). Order from NTIS as PB258612.

Key words: Bolivia; measurements; quality control; standardization; testing facilities.

A survey of standardization and measurement services available in Bolivia was carried out in June 1974 as part of a National Bureau of Standards program sponsored by the Office of Science and Technology of the Agency for International Development. The Survey Team included 4 NBS staff members, 3 third-country participants, and 11 leaders of technology and standardization in Bolivia. The Survey was made under the direction of Engineer Orlando Donoso Torrez, then the Director General of the Bolivian General Directorate of Standards and Technology.

After two days of joint activities, the Team was divided into three groups which visited various industrial, university, and government installations in the Cochabamba, Santa Cruz, and La Paz areas respectively. This report contains brief summaries of these visits and of the problems related to standards and measurements reported by the organizations visited. It also includes

the results of a questionnaire distributed to most of the organizations visited in advance of the Survey.

A brief report of the conclusions and recommendations of the Survey Team is included in "Peiser, H. Steffen, and Marvin, Robert S., ed., Regional Seminar on a System of Standardization and Metrology for Latin America, NBSIR 76-988 (U.S.), 96 pages (1976)."

NBSIR 76-1100. **Appraisal of Federal Government Cobol standards and software management: Survey results,** D. R. Deutsch, 75 pages (June 1976). Order from NTIS as PB258371.

Key words: ADP; COBOL; Federal ADP installations; Federal Standard COBOL; impact evaluation; sample; software management; survey.

This report summarizes the results of a survey of selected Federal Government Automatic Data Processing (ADP) installations. Undertaken primarily as an evaluation of National Bureau of Standards (NBS) activities in support of the standardization of the COBOL programming language, the study also dealt with software management tools and practices.

The survey sample was selected from a subset of all known Federal Government ADP units; specifically, only domestic installations with at least one general purpose hardware system capable of supporting a modern COBOL compiler were included. Responses were received from over 70 percent of the 190 installations included in the sample.

The major portion of this document is made up of tabular summarizations of all responses for each survey question. Gross statistics and frequency distributions are presented on a question-by-question basis. No interquestion relationships are analyzed. The appendices include a comprehensive discussion of the sampling methodology and survey mechanics and a reproduction of the survey instrument with cross references to response tabulations appearing in the report.

NBSIR 76-1102. **Computer programs for structural chemistry: STATUS. A FORTRAN program for statistical analysis of crystallographic quantities,** L. W. Schroeder and B. Dickens, 152 pages (July 1976). Order from NTIS as PB257729.

Key words: crystallographic data; errors; probability plots; residuals; statistics; uncertainties.

This report describes a FORTRAN computer program for evaluation of (i) the results of crystallographic least-squares refinements by examination of the residuals, (ii) differences in sets of data collected by different methods from the same crystal, (iii) differences in data sets collected by the same method from different crystals of the same material, and (iv) the differences in parameters in different models representing the crystal structure of the same material.

Part of the evaluation is accomplished by plots of residuals against the expected normal distribution quantiles. Additional plots compare residuals with the independent variable, d*, and with the calculated variable $Fc^2/\sin 2\theta$. The Miller indices can be used to divide a data set into various classes and octants so that the possibility of anisotropic effects can be examined.

The program will treat up to 7200 data points in each of two experimental data sets or 1000 structural parameters, and is oriented specifically towards examining crystallographic data.

NBSIR 76-1107. **Considerations in developing test methods for protective headgear,** R. E. Berger, 55 pages (Aug. 1976). Order from NTIS as PB258322.

Key words: head injury; helmets; math model; protective headgear; safety; test methods.

The purpose of this report is to outline the relationship between test methods for protective headgear and injury prevention. The state-of-the-art concerning the mechanisms of head injury and the relationship of these injuries to the modes of energy input are briefly reviewed. The general guidelines in the design of protective headgear are discussed, and the difficulties with present test methods for helmets are summarized.

In order to provide a quantitative framework, a simple model which incorporates many features of present test methods is defined and executed. The model predicts the effect of changes in test method parameters (headform, impact surface, drop height) for a range of helmet parameters. Among the indications suggested by the model are: 1) the occurrence of reversals in the order of helmet performance when the maximum acceleration is used as a performance measure, 2) the absence of reversals when biomechanical measures are used, and 3) the indicated suitability of compensating for the resiliency of the headform by the resiliency of the impact surface.

NBSIR 76-1109. **Architectural glazing safety standard: Survey of codes and standards,** S. C. Adler, 65 pages (Aug. 1976). Order from NTIS as PB257194.

Key words: architectural glazing; codes; Consumer Product Safety Committee; Consumer Safety Glazing Committee; glazing; impact tests; safety glazing; standards; state law.

The report describes 34 test procedures extracted from 97 codes and standards identified in an extensive library search of English language codes and standards relating to architectural glazing. The report also contains summaries of existing state laws relating to safety glazing. Test descriptions include procedures, kinetic energy levels, purpose of tests, and acceptance/rejection criteria. Test methods, codes and standards, and sources are cross-referenced.

NBSIR 76-1110. **The acoustic pressure field alongside a manikin's head with a view towards *in situ* hearing aid tests,** E. D. Burnett and G. F. Kuhn, 26 pages (Aug. 1976). Order from NTIS as PB257073.

Key words: audiometry; diffraction; head diffraction; hearing aids; instruments for hearing; manikin.

To simulate actual usage conditions, the frequency response of hearing aids was measured on the head of a manikin over the frequency range of 0.2 to 8 kHz. The acoustic pressure around the head can vary rapidly as a function of frequency and location. In order to compare and interpret the hearing aid response at various frequencies and locations on the head, it is necessary to precisely know the pressure variations. The amplitude and phase of the acoustic pressure were measured in increments ranging from 2 mm to 5 mm alongside a manikin's head with frontal sound incidence. The acoustic driver was located in front of the manikin at a distance of 1.0 m from the ear canal axis. The test frequencies were the octave band center frequencies from 0.5 kHz to 4.0 kHz and the third octave band center frequencies from 4.0 kHz to 8.0 kHz. It will also be shown that pink noise of 6 percent and 29 percent bandwidth at 6.3 kHz and 8.0 kHz has a smoothing effect on the acoustic pressure variation with location.

NBSIR 76-1112. **Technical assessment of safety for hair dryer/stylers,** Y. C. Wu, 36 pages (Sept. 1976). Order from NTIS as PB259636.

Key words: air flow rate; electrical, mechanical and thermal hazards; hair dryer/stylers; heat flux; safety; technical analysis; temperature.

The handheld dryer/styler is an efficient and popular small appliance, but a high injury trend associated with such products has been reported. Hazards commonly associated with the product are electrical, mechanical and thermal. In this study, the relation between these hazards and human tolerance limits were analyzed and experiments to investigate the probable cause and potential of such hazards were conducted. Randomly selected samples of the product were subjected to relevant safety performance tests of the UL Standard 859. In addition, air flow rate, heat flux and surface temperature were measured on several samples in order to determine their thermal hazard potential. Based on the results of these investigations, corrective measures are suggested.

NBSIR 76-1115. **Optical materials characterization,** A. Feldman, D. Horowitz, R. M. Waxler, and M. J. Dodge, 20 pages (Aug. 1976). Order from NTIS as PB257196.

Key words: BaF_2; CaF_2; fused silica; interferometry; photoelasticity; piezo-optic constants; refractive index; thermal coefficient of refractive index; thermal expansion coefficient; ZnSe.

The refractive index of a sample of hot-forged CaF_2 was measured from 0.25 μm to 8.0 μm by means of the minimum-deviation method on a precision spectrometer. Data were obtained near 20 and 34 °C. Each data set was fitted to a three-term Sellmeier-type dispersion equation, which permits interpolation of refractive index as a function of wavelength within a few parts in 10^5. With the index values obtained at the two temperatures, the change in index with temperature was calculated. The refractive index and values obtained for this specimen are compared with data previously published. Two new experimental arrangements have been constructed for the interferometric measurement of the thermal coefficient of refractive index, thermal expansion, and piezo-optic constants. The first permits measuring dn/dT and thermal expansion from − 180 to + 200 °C. The second is a highly stable and sensitive interferometer for measuring photoelastic constants in the visible, the near infrared, and the near ultraviolet. Thermal expansion data are obtained on CVD ZnSe, CaF_2 and BaF_2 between − 100 and + 120 °C and fitted to a third degree polynomial in temperature. We obtain dn/dT for CVD ZnSe at 632.8 nm over the same temperature range. The piezo-optic constants of fused silica and CVD ZnSe obtained with the new interferometer at 632.8 nm are in excellent agreement with values obtained by other methods.

NBSIR 76-1120. **Fire research publications, 1975,** N. H. Jason, 17 pages (Sept. 1976). Order from NTIS as PB257837.

Key words: bibliographies; building fires; construction materials; fire departments; fire detection system; fire tests; flame detectors; flammability tests; hazard analysis; interior furnishings; toxicity.

"Fire Research Publications, 1975" is a supplement to the previous editions which covered the years 1969-1972(NBSIR 73-246), 1973 (NBSIR 74-511) and 1974 (NBSIR 75-736). Only publications prepared by the members of the Center for Fire Research (CFR), by National Bureau of Standards (NBS) personnel or external laboratories under contract or grant from the CFR are cited. Articles published in NBS house organs also are cited.

NBSIR 76-1124. **Evaluation system proposal preparation and evaluation procedure,** C. W. N. Thompson, 89 pages (Feb. 1976). Order from NTIS as PB261846, $5.00

Key words: evaluation systems; Experimental Technology Incentives Program; procurement experiments; procurement procedures; proposal evaluation procedures; proposal preparation procedures.

As part of its program with respect to the conduct of procurement experiments, the Experimental Technology Incentives Program of the National Bureau of Standards developed an integrated set of documents to provide information for use by both bidders and the proposal evaluation team in the procurement of two evaluation systems. The set of documents includes the following: (1) Introductory Notes; (2) Some Definitions; (3) Proposal Preparation Procedure (with revisions); (4) Evaluation System Design Process; (5) Statement of Work; (6) Statement of Work (with illustrative subitems for Phase One); (7) Proposed Schedule—Overall; (8) Proposed Schedule—Phase One; (9) Proposal Evaluation Factors; (10) Proposal Evaluation Factors (with Illustrative Questions); (11) Numerical Weights for Proposal Evaluation Factors; and (12) Scope of Effort. Except for introductory and descriptive material, all of the documents are organized on the basis of seven factors (and thirty-three subfactors) to facilitate both preparation and evaluation of proposals. Each subfactor measures the bidder's understanding, present or proposed approach, and present or potential capability to perform with respect to an important problem or characteristic of the program. While the procedure is considered limited to certain systems and related procurements, it is considered a significant departure from prior procedures.

NBSIR 76-1126. **Field investigation of residential smoke detectors,** R. W. Bukowski, 53 pages (Nov. 1976). Order from NTIS as PB260878.

Key words: detector sensitivity; detector siting; escape time; fire tests; heat detectors; residential fires; smoke detectors.

A test program was undertaken to evaluate the effect of sensitivity and placement of residential smoke detectors on their response to fires in homes. The tests were conducted in two homes scheduled for demolition and used actual furnishings in typical configurations. In addition to the detector response times, the homes were highly instrumented with data on smoke, temperature, and gas concentration measured for all tests.

The tests showed that smoke detectors can be highly effective in providing adequate warning of a fire before conditions in the home become dangerous.

NBSIR 76-1130. **Program and abstracts. Symposium on nonbiological transport and transformation of pollutants on land and water: Processes and critical data required for predictive description, May 11-13, 1976, National Bureau of Standards, Gaithersburg, MD,** L. H. Gevantman, Ed., 199 pages (May 1976). Order from NTIS as PB257347.

Key words: adsorption; nonbiological transformation; nonbiological transport; pollutant photochemistry; pollutants; soil pollution; solar spectrum; water pollution.

Program, abstracts and extended abstracts of 21 papers presented at a symposium on nonbiological transport and transformation of pollutants on land and in water are documented. Most of the extended abstracts are detailed and contain figures and references to pertinent literature on the subject matter discussed at the symposium. The subject matter reviewed deals with the physical and chemical behavior of pollutants, including pollutant photochemistry, adsorptive behavior of pollutants, hydrolysis, rates of pollutants, and mathematical models for documenting pollutant behavior in soils and water.

NBSIR 76-1131. **A model performance standard for guardrails,** S. G. Fattal, L. E. Cattaneo, G. E. Turner, and S. N. Robinson, 31 pages (July 1976). Order from NTIS as PB259242.

Key words: design; dynamic loads; guardrails; industrial accidents; nonstructural safety; occupational hazards; performance standard; personnel railings; personnel safety; static loads; stiffness; structural safety.

A model performance standard and design illustrations are presented for the design, construction and evaluation of guardrail systems, which will be used for the protection of employees against occupational hazards. The standard stipulates both structural and nonstructural safety requirements. Each criterion includes a commentary section describing the rationale used in its formulation. This rationale is for the most part, based on independent experimental and analytical research investigations conducted at NBS in behalf of OSHA.

NBSIR 76-1132. **Personnel guardrails for the prevention of occupational accidents,** S. G. Fattal, L. E. Cattaneo, G. E. Turner, and S. N. Robinson, 80 pages (July 1976). Order from NTIS as PB260363.

Key words: anthropometric measurements; guardrails; industrial accidents; nonstructural safety; occupational hazards; performance standard; personnel railings; personnel safety; structural safety.

Existing information is compiled which would assist in determining structural and nonstructural safety requirements for guardrails used for the protection of employees against occupational hazards. Critical aspects of guardrail safety are identified through exploratory studies consisting of field surveys of prototypical installations, reviews of existing standards and industrial accident records, and compilation of relevant anthropometric data. These exploratory studies will be utilized to design an experimental program which will consist of structural tests to determine design loads and nonstructural tests to determine geometric requirements for guardrail safety.

NBSIR 76-1133. **Skid resistance measurement tests of FHWA reference systems at the Western Field Test Center,** R. W. Kearns and J. F. Ward, 167 pages (Oct. 1976). Order from NTIS as PB261228.

Key words: accident reduction, skidding; correlation, skid resistance; highway safety; measurement, skid resistance; pavement, skid resistance; pavement wetting system; tire-pavement interface forces; wet pavement.

The Federal Highway Administration (FHWA) is developing a program to improve the method of measuring wet weather pavement skid resistance (SN) and to reduce the variation in results. At the national level, an interim reference system (IRS) is maintained and operated by the National Bureau of Standards. At the regional level, an area reference system (ARS) is maintained and operated at each FHWA field test center. Intercomparisons between these reference systems and the highway measuring systems at the state level, provide measurement assurance.

In this report, the first correlation results between the IRS and the Western ARS (WARS) are given: $SN_{WARS} = 4.55 + 0.99\ SN_{IRS}$ where the computed standard deviation of a mid-range predicted value is 1 SN. SN is described as a function of test speed, V, in mph (1 mph = 1.609 km/h): for surface 2; $SN(V) = 76.5 - 0.71 + 0.0070V^2$ and the speed gradient is $d(SN)/dV = -0.71 + 0.014\ V$.

The test program is explained from test preparations, tuning and calibration of subsystems, through dynamic measurement of the surfaces. Controlled and uncontrolled variables are identified, discussed, and in some cases, experimentally verified. A ranking of the sources of dispersion is given. A discontinuity in SN of surface 1 is identified due to the unique test plan. A ground station for improved SN calculation precision and on-site statistical analysis is found to meet design objectives.

NBSIR 76-1136. **Failure analysis of fiberglass insulator rods,** L. Mordfin and N. Halsey, 57 pages (July 1976). Order from NTIS as PB261965.

Key words: breakdown, electrical; failure analysis; fiberglass-reinforced plastics; flammability; guy insulators; high-voltage tests; insulators, tower guy; Loran C; pultruded rods; rods, insulator.

Failure analyses were carried out on a group of coated fiberglass-reinforced-plastic insulator rods that had sustained burn damage and loss of coating in service on a radar tower. The investigation included chemical, flammability, electrical and mechanical tests as well as a variety of measurements and inspections. The burn damage, consisting chiefly of carbonaceous tracking and charring, was attributed primarily to the occurrence of electrical discharges, from the energized end fittings to the rods, under conditions in which the electrical leakage path resistance had been reduced by moisture from rain, fog and ocean spray. The effects of this damage on the structural integrity of the rods were evaluated. Recommendations were made for reducing the incidence of such damage in the future, based on the use of skirted insulator rods or more effective coating materials. The principal cause of the coating loss was not positively identified. This form of damage was not found to have serious consequences except as a secondary factor which may have contributed to the occurrence of some partial electrical discharges.

NBSIR 76-1137. **Thermal data requirements and performance evaluation procedures for the national solar heating and cooling demonstration program,** E. Streed, M. McCabe, D. Waksman, J. Hebrank, and T. Richtmyer, 86 pages (Aug. 1976). Order from NTIS as PB257770.

Key words: data requirements; measurement uncertainty; solar energy systems evaluation; thermal performance.

This report presents the results of a study to determine the data requirements and performance evaluation factors to be used in the National Solar Heating and Cooling Demonstration Program. Solar energy systems used for heating hot water, space heating, and space cooling have been considered and specific measurements and analytical procedures have been recommended to determine the thermal effectiveness for daily, monthly, seasonal, or annual operating periods. The sensor accuracy and sampling rate effects on measurement uncertainty for several performance factors is presented. Application of the individual performance factors for the comparison of subsystem and system thermal performance as a function of building type and climatic region is discussed.

NBSIR 76-1138. **A proposed experiment to evaluate environmental dependence of the measurement of noise from medium and heavy duty trucks,** C. I. Holmer and R. D. Kilmer, 68 pages (Sept. 1976). Order from NTIS as PB259522.

Key words: acoustics; environmental conditions; noise measurement; noise (sound); transportation noise; truck.

Increasing concern with the impact of transportation noise on communities has led to an increase in the number of motor vehicle noise regulations at all levels of government. As regulations become more widespread, the accuracy and precision of vehicle noise measurements become more critical since each uncertainty in the measurement requires a corresponding increase in the margin that manufacturers must allow between the regulated noise limit and vehicle design levels. Although considerable uniformity has been achieved by existing voluntary standards,

there remain significant variations between noise measurements made at different sites or at different times on the same site. These variations are attributable to differences in the environment, including site and meterological influences. Thus, there is a need for systematic investigation of the various environmental and test site effects on noise generation, radiation and/or propagation. This report presents the findings of a feasibility study for an experiment to investigate environmental effects on truck noise emission measurements. The result of this study is a proposed experiment designed to examine the systematic and nonsystematic dependence of observed truck driveby noise on the environmental effects present during the measurement. The experiment is designed in such a manner as to permit separation of emission and propagation effects. Although it may not be feasible to determine "correction factors" for environmental effects within the time and financial constraints of this experiment, it is fully expected that the data obtained from this experiment will reveal the magnitude of variations in the measurement and provide a broad enough information base for study of the underlying physical mechanisms.

NBSIR 76-1140. **Standards referenced in selected building codes,** B. M. Vogel, 447 pages (Oct. 1976). Order from NTIS as PB259626.

Key words: building codes; building regulations; building regulatory system; standards.

This publication provides a compilation of the standards that are referenced in the building codes promulgated by: (1) the three model building code organizations; i.e., Building Officials and Code Administrators International, Inc. (BOCA); International Conference of Building Officials (ICBO); and the Southern Building Code Congress International, Inc. (SBCC); (2) the twenty States that have either mandatory or voluntary building codes; and (3) the thirty largest U.S. cities. In addition to identifying each standard referenced in the above named codes, this publication lists the current date of the standard, its current title, the codes referencing it, the date of the code, the locations within the code where the standard is referenced, and the date of the standard referenced in the code. This publication is intended to provide a base for assisting the building community in updating, utilizing and maintaining the standards referenced in building codes.

NBSIR 76-1141. **Study of initial stages of wear by electron channeling. I. Measurement of plastic strain in copper due to sliding wear, II. Quantitative methods in wear debris analysis,** A. W. Ruff, 53 pages (Sept. 1976). Order from NTIS as ADA031530.

Key words: copper; electron channeling; electron microscope; metals; particle analysis; plastic deformation; surfaces; wear; wear debris; x-ray analysis.

Wear experiments have been conducted to determine the plastic strains that are introduced in the surface material near sliding wear tracks. Both oil lubricated and dry sliding experiments have been carried out at different sliding distances on surfaces of copper. The strain values were determined from selected area electron channeling patterns obtained using a scanning electron microscope from regions as small as 10 μm in size and 0.05 μm deep around the wear track. A deformed calibration specimen was used to relate electron channeling band contrast to deformation strain. Strain maps were obtained on the wear surface lateral to the wear track and also below the surface using electropolishing metal removal techniques. Particular attention was placed on the near-surface strain values. In all cases, the maximum strain was found at the wear surface located at the track center and the strains decreased uniformly with depth. Significant, large strains were also found outside the wear tracks. The results are compared with those previously reported for iron and with recent theoretical models.

Wear debris has been removed from a number of test systems and analyzed using different methods. Those methods produced specific information concerning the particulate size and composition. A magnetic debris recovery method was quantitatively evaluated using actual debris samples and also using collections of manufactured particulates having known sizes and compositions. Small 5 μm diameter SiO_2 spheres, some containing nickel, were used to simulate debris. Other particulates of iron and nickel in different size ranges were also used in order to investigate such matters as size resolution, lubricant dilution techniques, particle overlap difficulties, and the general problem of calibration of debris recovery systems. A comparison between chemical analysis and particulate analysis findings is presented. The application of optical and electron microscope methods and x-ray microanalysis in characterizing the wear particulates was carried out directly on the recovery substrate; those techniques are described.

NBSIR 76-1142. **Considerations and standards for visual inspection techniques,** G. T. Yonemura, 17 pages (Oct. 1976). Order from NTIS as PB263099.

Key words: nondestructive testing; modulation transfer function; vision; visual acuity; visual capacities.

When we look at the capacity of the human visual system we see that it has many capacities depending on the circumstances under which it is used. The sensory data show that man can adjust to a wide variety of operating conditions. But, unless we have detailed information of the conditions for which these processes are to be optimized and quantitative descriptions of the tasks to be performed, the advantages to be obtained by visual science applications cannot be optimally utilized. Physical correlates of the response should be quantified, followed by a systematic scaling of the physical correlates for application to nondestructive testing. The Modulation Transfer Function widely used in optical imaging assessments would be an evaluation technique applicable to hardware, processing and image description.

NBSIR 76-1143. **Plan for the development and implementation of standards for solar heating and cooling applications,** D. Waksman, J. H. Pielert, R. D. Dikkers, and E. R. Streed, 55 pages (Aug. 1976). Order from NTIS as PB257769.

Key words: buildings; solar energy; standards.

A plan is presented concerning the need, implementation and general scope of standards which may be required for solar heating and cooling applications. Overviews of the building regulatory system in the United States are given along with a listing of the various standards which will be required for the various solar systems, subsystems, components and materials. These include Test Method Standards, Recommended Practice Standards and Specification Standards. Activities relative to standards implementation include laboratory accreditation, certification, training and manuals of accepted practice. The development of standards for solar applications by the Federal Government are outlined, as well as the potential interface and utilization of the existing consensus standards generating organizations.

NBSIR 76-1144. **NBS interagency transducer project—Progress report No. 5,** J. S. Hilten, C. F. Vezzetti, J. F. Mayo-Wells, and P. S. Lederer, 26 pages (Nov. 1, 1976). Order from NTIS as PB259243.

Key words: coatings; dynamic; dynamic response; pressure transducer; protective coatings; shock tube; tape; thermal radiant-energy response; thermal transient response; transducers; zero shift.

Experimental efforts are described in the development and evaluation of means to reduce the effects produced by thermal radiant-energy transients on pressure-transducer response. Both unbonded strain-gage and piezoelectric pressure transducers were used in this work with protective coatings applied directly to the diaphragms. The test method employed is to expose a pair of transducers—one protected and the other unprotected, but otherwise nominally identical—to a known radiant-energy transient with an energy density of approximately 20 mJ/mm^2. The resulting zero shift is measured and taken as an index of coating effectiveness.

The effect of the presence of the coating on transducer dynamic response was investigated by means of a shock tube, with a protected and an unprotected transducer pair exposed to the same pressure step of approximately 280 kPa (40 psi). Each transducer output was recorded as a function of time.

Test results with nine coatings and two transducer pairs are presented.

NBSIR 76-1147. **A combined least sums and least squares approach to the evaluation of thermodynamic data networks,** D. Garvin, V. B. Parker, D. D. Wagman, and W. H. Evans, 41 pages (July 1976). Order from NTIS as PB259637.

Key words: computerized data analysis; data evaluation; least squares (L2); least sums (L1); thermochemistry; thermodynamic data networks.

A description is given of a system for computer-based evaluation of interrelated thermodynamic measurements of enthalpies of reaction, equilibria and entropies. This system is an extension of the CATCH program developed by J. B. Pedley, University of Sussex. In the new system linear least sums and least squares techniques are used to solve networks of thermodynamic equations to obtain the enthalpies and free energies of formation and the entropies of chemical substances. The least sums technique is shown to be useful in assessing the consistency of the data. A method combining least sums and least squares solutions, provides a weighted solution that reproduces closely the solutions that are obtained by a detailed analysis of the data using the customary sequential procedure. The results from tests on four large networks involving compounds of B, U, Rb and salts of Sn, Pb, Cd and Hg are discussed.

NBSIR 76-1153. **Microstructural aspects of deformation and oxidation of magnesia-doped silicon nitride,** N. J. Tighe, 11 pages (Sept. 1976). Order from NTIS as PB259638.

Key words: cristobalite; deformation; electron microscopy; microstructure; oxidation; silicon nitride; slow crack growth enstatite.

The microstructural changes that occurred in magnesia-doped silicon nitride as a result of slow crack growth, plastic deformation and oxidation were studied by transmission electron microscopy. Specimens which exhibited slow crack growth showed extensive crack branching along the fracture path and ahead of the primary crack tip. These primary and secondary cracks followed intergranular paths. In samples which were deformed by bending at 1400 °C, dislocation arrays were found as well as intergranular cracks and voids. Silicon nitride oxidized during heating in air at 1400 °C and enstatite and cristobalite were present in the oxide layer. At lower oxidation temperatures, crystalline and amorphous silica formed a semiprotective layer on the silicon nitride surfaces.

NBSIR 76-1154, Vol. 1. **Consideration of fracture mechanics analysis and defect dimension measurement assessment for the Trans-Alaska Oil Pipeline girth welds,** H. Berger and J. H. Smith, Eds., 183 pages (Oct. 18, 1976). Order from NTIS as PB260400.

Key words: fracture control; fracture mechanics; mechanical properties; nondestructive evaluation (NDE); radiography; welding.

In anticipation of a request for waivers on defective girth welds in the Trans-Alaska oil pipeline, DoT requested assistance from the National Bureau of Standards (NBS) in evaluating the fracture mechanics analysis and the nondestructive evaluation (NDE) methods used to detect and determine dimensions of weld defects.

NBS measured the required mechanical properties of the weld metal, developed and evaluated fracture mechanics methods to determine the allowable defect sizes, and evaluated various methods of measuring the size of defects present in the welds from existing field radiographs.

Results of this investigation show that the fracture mechanics analysis can be used to determine the allowable defect sizes concerning the integrity of the pipeline, but that these analyses have not been experimentally verified at this time. Defect dimensions can be determined with sufficient accuracy to be useful in the fracture mechanics analyses if the radiographs are made under carefully controlled conditions. If the radiographs are not made with close control, the accuracy of the defect sizes may not be sufficient to permit their use in establishing allowable defect sizes.

NBSIR 76-1154, Vol. 2. **Consideration of fracture mechanics analysis and defect dimension measurement assessment for the Trans-Alaska Oil Pipeline girth welds,** H. Berger and J. H. Smith, Eds., 135 pages (Oct. 18, 1976). Order from NTIS as PB260401.

Key words: fracture control; fracture mechanics; mechanical properties; nondestructive evaluation (NDE); radiography; welding.

In anticipation of a request for waivers on defective girth welds in the Trans-Alaska oil pipeline, DoT requested assistance from the National Bureau of Standards (NBS) in evaluating the fracture mechanics analysis and the nondestructive evaluation (NDE) methods used to detect and determine dimensions of weld defects.

NBS measured the required mechanical properties of the weld metal, developed and evaluated fracture mechanics methods to determine the allowable defect sizes, and evaluated various methods of measuring the size of defects present in the welds from existing field radiographs.

Results of this investigation show that the fracture mechanics analysis can be used to determine the allowable defect sizes concerning the integrity of the pipeline, but that these analyses have not been experimentally verified at this time. Defect dimensions can be determined with sufficient accuracy to be useful in the fracture mechanics analyses if the radiographs are made under carefully controlled conditions. If the radiographs are not made with close control, the accuracy of the defect sizes may not be sufficient to permit their use in establishing allowable defect sizes.

NBSIR 76-1159. **Fatigue and weatherability studies of aramid-fiber rope slings,** N. Halsey and L. Mordfin, 35 pages (Sept. 1976). Order from NTIS as PB261994.

Key words: aramid fiber rope; breaking load, rope; cable, aramid-fiber; end fittings, rope; fatigue damage; rope, aramid-fiber; slings, cargo; terminations, rope; weathering, simulated.

Tests were carried out on twenty-six sling-leg specimens, fabricated from aramid-fiber ropes, as part of a program to develop improved external cargo slings for helicopters. The ropes included both parallel-strand and cabled-strand varieties, in three different tensile capacities. The tests were intended to evaluate the reductions in rope strength caused by fatigue loading and by exposure to simulated weathering. It was found that the fatigue capabilities of some of the ropes may not be entirely satisfactory; but, because of inadequacies in the end fittings installed by the rope manufacturers, thorough evaluations were not possible. The results indicate that the performances of the ropes could be enhanced through the use of more efficient end fittings, and suggestions for the development of such end fittings are offered.

NBSIR 76-1162. **FY 1975-1976 international building research activities, Center for Building Technology,** S. G. Webber, 67 pages (Nov. 1976). Order from NTIS as PB260879.

Key words: building research; cooperative programs; information exchange; international building research; international organization memberships; special foreign currency programs.

This report documents international building research activities of the Center for Building Technology (CBT) during Fiscal Year 1975 and 1976 (July 1, 1974-June 30, 1976). CBT carries out extensive interactions with foreign and international research organizations to exchange building research efforts. This report presents a summary of CBT's cooperative programs in building technology, international organization memberships, exchange programs, information exchanges, and foreign visits to NBS.

NBSIR 76-1172. **A new test method for automatic fire detection devices,** R. G. Bright, 29 pages (Dec. 1976). Order from NTIS as PB261217.

Key words: fire detector; test methods.

An analysis of the test methods for automatic fire detection devices in the U.S. reveals the fact that different types and different sizes of fires are used to evaluate different classes of detectors. The result is a lack of comparison test data for each detector class and, as a consequence, intelligent decisions cannot be made in the selection of automatic fire detectors for specific fire risks. A new test method is proposed in which all automatic fire detectors, regardless of sensor type, would be subjected to a series of the same test fires. In addition, each test fire series would consist of three different test fire sizes. From the results obtained, it should then be possible to match a detector's characteristics against a specific fire risk resulting in a more intelligent application of automatic fire detectors.

NBSIR 76-1176. **Regional seminar on OMNITAB II,** D. Hogben and S. T. Peavy, 27 pages (Dec. 1976). Order from NTIS as PB261995.

Key words: acceptance tests; AID; Bolivia; CENACO; computing using Spanish; foreign relations; international agreement; lectures; OMNITAB II computing system; technology transfer; terminals.

The authors visited La Paz, Bolivia, from May 11 to May 26 to conduct an AID Regional Seminar on applications of the OMNITAB II computing system. A Spanish, interactive version of OMNITAB II was implemented on the CENACO DEC-10 system computer. From May 17 to 22, lectures were given to thirty participants from five Latin American countries and sessions were held for the participants to gain experience in the use of OMNITAB II from terminals. At the beginning, the computer was not being used; at the end, OMNITAB II was being used extensively to solve important problems. An international agreement was signed by participants from the Latin American countries to cooperate in the utilization of computers.

NBSIR 76-1187. **Interim performance criteria for solar heating and cooling systems in commercial buildings,** 100 pages (Nov. 1976). Order from NTIS as PB262114.

Key words: buildings; cooling; heating; hot water; performance criteria; solar energy; standards.

Public Law 93-409, the Solar Heating and Cooling Demonstration Act of 1974, provides for "demonstration within a three-year period of the practical use of solar heating technology, and .... the development and demonstration within a five-year period of the practical use of combined heating and cooling technology." Under the provisions of the Act, in February 1975, the NASA developed a first edition of this document containing interim performance criteria for the design and evaluation of solar heating and cooling systems to be demonstrated in commercial buildings. Since that time, responsibility for further development of the document has been assumed by the NBS. This second edition of the "commercial criteria" represents the first revision to the NASA document. It is expected that this document will be updated periodically as data and information are gained from the demonstration program.

3.20. GRANTEE/CONTRACTOR REPORTS AND NBS PATENTS

Grantee/contractor reports are prepared by non-NBS persons or organizations working under grant or contract from the National Bureau of Standards. Those contract reports not incorporated into the formal NBS publication series are available directly from the National Technical Information Service (NTIS, Springfield, VA 22161) in paper copy or microfiche form unless otherwise stated. When ordering a report from NTIS you must order it by the "COM, PB, AD, or N" number as indicated.

Patents—legal documents which fully describe inventions in return for the right for 17 years to exclude others from making, using, or selling the inventions—are obtained on NBS inventions of high commercial potential, in order to establish Government ownership of the patent rights. The patents are then made available for the grant of nonexclusive licenses to all qualified applicants. A limited exclusive license may be granted under a particular patent, however, if it appears that some period of exclusivity is necessary as an incentive for the investment of risk capital. For information on licensing any of the patents, write to the Office of the Legal Adviser, National Bureau of Standards, Washington, DC 20234. Copies of patents may be obtained from the U.S. Patent and Trademark Office, Washington, DC 20231 for 50 cents each.

NBS-GCR-73-1. **Characterization of bedding and upholstery fires,** C. A. Hafer and C. H. Yuill, 46 pages (Mar. 1970). Order from NTIS as PB192365.

Key words: bedding; beds; carbon dioxide; carbon monoxide; combustion products; fire gases; fire hazards; furniture; life hazard; oxygen; smoke; temperature; toxicity; upholstery.

Many accidental deaths are attributed to fires started from smoking in bed or in upholstered chairs. Frequently, the victims die as a result of exposure to smoke, heat, or noxious fumes that develop as materials burn rather than from skin burns. The objective of this program was to conduct full-scale tests using bedding and upholstered furniture to determine the life hazards that may be present during fires starting with a small ignition source.

Thirty individual tests were conducted using various combinations of materials. The ease of ignition of bedding and upholstery was demonstrated and the pattern of development of smoke, heat, noxious gases, and oxygen depletion was recorded.

NBS-GCR-73-2. **Fabric flammability test development,** W. R. Brown and F. A. Vassallo, 87 pages (May 1970). Order from NTIS as PB194614.

Key words: fabric flammability; flammability testing; heat transfer; smoldering fabrics.

Heat meter instrumentation and a test chamber are developed for the measurement of heat transfer from burning and smoldering fabrics. The meters yield a signal proportional to heat flux, and a four-channel electronic integrator provides total heat input data as a function of time. Literature data on skin damage vs. heat input are employed in a graphical overlay method of interpreting data in terms of skin damage. Data demonstrating good reproducibility in tests of cotton fabrics at various spacings are presented. Thermoplastic fabrics tended not to burn or smolder regularly in the flat panel form employed in the test, but recommendations are given for study of strip specimens which may be amenable to test by the suggested methods. It was found that all of the fabric specimens which burned regularly in the chamber produced heat inputs at least double those required to inflict second-degree burns.

NBS-GCR-73-3. **Conversion of scientific and technical resources economic challenge—Social opportunity,** E. R. Mottur, 204 pages (Mar. 1971). Order from NTIS as COM 71-00605.

Key words: economic challenge; scientific and technical resources, converting; social opportunity.

This excerpt from the forthcoming overall project report describes the economic challenge and social opportunity presented by conversion of scientific and technical resources, and sets forth 26 policy proposals as a national program for conversion.

The report is concerned solely with conversion of the nation's scientific and technical resources, including manpower (scientists, engineers, technicians, support personnel, and technical management), facilities and equipment, and scientific and technical information. Conversion of scientific and technical resources from the defense sector must be to civilian R&D aimed at ameliorating national social problems.

Need for Conversion: About 100,000 scientists, engineers, and technicians are currently unemployed. About 200,000 (one out of ten technical personnel in the nation) are likely to be unemployed by the end of 1971.

Need for National Program: Report contends conversion can succeed only through cooperation of Federal, State, and local governments, with private industry, universities, and the scientific and technical community; with strong federal leadership.

Existing conversion programs and proposals are reviewed and characterized as essentially job-placement activities. Conversion bills pending in Congress are also analyzed.

NBS-GCR-73-4. **The influence of fine structure on the pyrolysis and combustion of cellulosics,** M. Lewin and A. Basch, 62 pages (1972). Order from NTIS as COM 73-10323.

Key words: cellulosic fibers; combustion; cotton fibers; flame retardant treatments; phosphorous acids; pyrolysis; ramie; rayon; sulfur.

A series of cellulosics comprising cottons, ramies and rayons differing in degrees of crystallinity and orientation were purified, characterized and pyrolyzed in vacuum and in air at low and high temperatures. The kinetics of the low temperature pyrolyses were studied and activation energies were derived by dynamic TGA. The rates of the low temperature pyrolyses in both vacuum and air are shown to be dependent upon the crystallinities and orientations of the cellulosics. In addition, the rates of vacuum pyrolysis are also a function of the D.P., while the rates of air pyrolysis are influenced by the crystallite accessibility. A novel IR technique was developed which indicates that levoglucosan formation during combustion is also a function of crystallinity and orientation. A correlation was found between energies of activation and cellulose crystallinities which suggests that the measured values are the sum of separate contributions from the crystalline and less-ordered regions. Cottons, rayon and ramie were given a variety of flame-retardant treatments with reagents

containing either sulfur or phosphorous as the principal flame-retardant component.

NBS-GCR-73-5. **National fire data system, system design project, final report,** 175 pages (Mar. 9, 1973). Order from NTIS as COM 73-10951.

Key words: design criteria; fire hazards; fire losses; fire reporting; fire safety; information systems; National Fire Data System; specifications; state governments; systems analysis.

The design for a multi-file National Fire Data System is described. Data concerned with fire incidents, deaths, injuries, and fire loss will be collected from the fire service, the insurance industry, health service organizations, and a number of special sources. A time-sharing computer center will be utilized through remote terminals to store, manipulate, and aid the reporting of the collected data. Input consists of a series of specified reports from designated data suppliers of a number and type to provide statistically valid coverage for national projection purposes. Each type of input will be stored as a separate system file. The Auerbach report describes the data sources, the proposed processing facility including staffing requirements, probable outputs, and data base specifications; the procedures for data acquisition, encoding, data preparation, data base maintenance, and quality control; and a plan for implementing the system.

NBS-GCR-73-6. **A study of preignition heat transfer through a fabric-skin system subjected to a heat source,** G. Heskestad, A. S. Kalelkar, and H. C. Kung, 53 pages (Dec. 1971). Order from NTIS as COM 73-10959.

Key words: apparel fabrics; fabrics; fire hazards; flammability testing; ignition; skin; thermal burns; thermal measurements.

Theoretical and experimental studies of preignition events transpiring in fabric-skin systems upon exposure to a radiant heat source are reported. Particular emphasis is placed on determining relationships between time to ignition of the fabric and time to pain in the skin of the fabric wearer which allows assessment of probabilities of ignition. Several common fabrics are ranked in order of decreasing safety as the pain time increases relative to the ignition time and evasive action by the fabric wearer becomes less and less effective.

NBS-GCR-73-7. **Study of ignition and exposure,** L. Fourt, 52 pages (Dec. 31, 1971). Order from NTIS as COM 73-10958.

Key words: apparel fabrics; fabrics; fire hazard; flammability testing; ignition; thermal burns.

Simulated sleeves were exposed to a gas range burner, and the time to ignition determined. For cottons and polyester/cellulose blends, the ignition time was proportional to fabric weight, except for napped flannel and terry cloth which ignited rapidly for their weight. Woven and knit fabrics were similar. Nylon and polyester and, in some cases, acetate, shrunk away from the flames unless seams sewn with cotton thread were exposed.

NBS-GCR-73-8. **A study of hazards from burning apparel and the relation of hazards to test methods,** A. Alkidas, R. W. Hess, W. Wulff, and N. Zuber, 208 pages (Dec. 1971). Order from NTIS as COM 73-10954.

Key words: apparel fabric; fabric; fire hazard; flammability testing; thermal measurements; thermodynamic properties.

The following thermal properties of a selected set of cotton, nylon, polyester, acetate, and blend fabrics were measured: thermal conductance, specific heat, ignition or melting temperature, infrared reflectance and transmittance, activation energy, reaction enthalpy, and ignition time under radiative fabric heating. Detailed distributed-parameter ignition models and simplified analyses based on lumped-parameter models were considered, and seven characteristic groups established which govern the heating and reaction processes. Experimental and theoretical results were compared.

NBS-GCR-73-9. **Study of hazards from burning apparel and the relation of hazard to test methods: Flammability of clothing assemblies,** J. F. Krasny and A. L. Fisher, 50 pages (Jan. 19, 1972). Order from NTIS as COM 73-10953.

Key words: apparel fabrics; fabrics; fire hazard; flammability testing; skin; thermal burns; thermal measurements.

The objective of the project was to estimate the area of the body burned and the depth of burn as a function of the garment assemblies worn by clothing fire victims. Such fires were modeled by burning garment assemblies on mannequins covered with temperature indicators; the temperature indicator measurements were correlated with depth of burn into the skin of rats. Chimneys on garments were found to increase very significantly the area of the mannequin raised to elevated temperatures in a given time from ignition; belts tended to act as fire stops. Tighter fit of dresses appeared to cause higher mannequin temperatures, but direct contact of dress and mannequin slowed down fires. Thermoplastic (nylon and polyester) dresses and fire retardant cotton dresses did not ignite in these experiments unless combined with a flammable slip, though the area of potential injury in such combinations was relatively small. Similar areas were raised to elevated temperatures by burning polyester/cotton dresses with or without polyester/cotton slips, but nylon slips seemed to reduce the area.

NBS-GCR-73-10. **Firefighters' breathing system study,** 171 pages (Apr. 1972). Order from NTIS as COM 73-10952.

Key words: breathing apparatus; closed loop breathing apparatus; equipment design; fire fighters; fire fighting; fire fighting equipment; fire gases; open loop breathing apparatus; protective clothing; smoke inhalation; standards.

This report is the result of a study to produce research and development plans for each of three types of firefighters' breathing support equipment. The three design types are the open loop, the semiclosed loop, and the closed loop. The study identified the improvements possible for each design type. This report includes the recommended improvements and lists the time and cost likely for each development.

In addition to the recommendations and development plans for breathing systems improvement, the report includes sections of specifications, breathing gas sources, materials, and other significant elements of the breathing systems. To support the development plans, there are also recommendations for needed laboratory and engineering studies.

NBS-GCR-73-11. **Study of hazards from burning apparel and the relation of hazards to test methods,** O. A. A. Naveda, P. Durbetaki, P. T. Williams, W. Wulff, A. Alkidas, E. R. Champion W. E. Giddens, R. W. Hess, and B. Kumar, 274 pages (Dec. 31, 1972). Order from NTIS as PB242597.

Key words: apparel, burn injuries; burn injuries, fabric related; burning apparel; fabric related burn injuries.

It was shown that the hazard from fabric-related burn injuries can be quantitatively assessed in terms of the probability that such injury is suffered. This probability depends upon the probabilities associated with the possible events leading to the injury, such as ignition after exposure combustion after ignition and tissue decomposition during and after burning. It was also shown

that the probability of fabric ignition under given exposure depends on the ratio of fabric ignition time to exposure time; hence that the ignition time is an important characteristic required to assess the hazards of fabric-related burn injuries.

NBS-GCR-73-12. **Ease of ignition of fabrics exposed to flaming heat sources,** G. Heskestad, 113 pages (Jan. 1973). Order from NTIS as COM 73-10955.

Key words: apparel fabrics; fabrics; fire hazards; flammability testing; ignition; thermal burns; thermal measurements.

The ease of ignition of fabrics exposed to flames was studied. Ignition or melting times were at a minimum close to the luminous tip of diffusion and to the tip of the inner cone of premixed flames. These minimum ignition times were found to be insensitive to fabric orientation, burner tube diameter, and flame height but varied appreciably for diffusion and premixed flames. With the exception of fabrics with prominent surface structures (e.g., terry cloth), ranking of fabrics by ignition and melting times would be preserved through a large number of exposure modes. A simple theoretical model, which considers the fabric to be impervious and inert, to possess a unique ignition temperature, and to be heated solely by convection, is consistent with the experimental findings. Fabric variables found to be of importance were the fabric weight, average specific heat over the heating interval to ignition and the ignition temperature. Porosity, humidity, proximity to a skin simulant, and weave (except structures like terry cloth) were less important: Flame source variables of importance are the temperature and velocity at the tip, and possibly the diameter of the gas plume at the tip.

NBS-GCR-73-13. **Hazards from burning garments,** G. Arnold, A. Fisher, and G. Frohnsdorff, 85 pages (Mar. 26, 1973). Order from NTIS as COM 73-10957.

Key words: apparel fabrics; fabrics; fire hazard; flammability testing; simulation; skin; thermal burns.

Experiments were carried out to determine the area of the body burned, and the depth of burn likely to be suffered by clothing fire victims as a function of the garment worn, by burning full clothing assemblies on mannequins. It was found that single layer dresses made from nylon, polyester, Nomex, and flame retardant cotton fabrics self-extinguished and could be assumed to cause no injury; single layer dresses of cotton burned somewhat faster than similar weight polyester/cotton blends but the total heat transferred was similar; double layers consisting of dress and slip burned if at least one of the layers was a fabric which would burn in a single layer. The rate of burning and the heat transferred depended on the fabrics used as the dress and the slip; the use of a belt with dresses at least slightly reduced the initial rate of burning and the total heat transferred to the mannequin; all garment combinations which burned transferred sufficient heat to the mannequin to cause second degree and deeper burns, with the greatest burn depth usually on the lower region of the torso.

NBS-GCR-73-14. **Measurement of flammability and burn potential of fabrics, summary report, December 1, 1970-November 30, 1971,** A. K. Mehta and F. Wong, 69 pages (Feb. 15, 1973). Order from NTIS as COM 73-10950.

Key words: apparel fabrics; fire hazard; flammability testing; heat conductivity; simulation; skin.

The objective of this work was to study local skin burn damage due to burning apparel fabrics. Three skin simulants were constructed: two copper-air rod systems simulating the thermal properties of skin with a large depth stretch factor; and one system without depth magnification. Twenty apparel fabrics were burned in the horizontal, 45°, and vertical positions, in the latter two cases with the flame traveling up and down. The injury potential of each fabric was then evaluated.

NBS-GCR-73-15. **Measurement of flammability and burn potential of fabrics,** A. K. Mehta and F. Wong, 331 pages (Feb. 15, 1973). Order from NTIS as PB242582.

Key words: burn, fabric; fabric, burn; flammability.

Two types of inanimate materials having the average thermal properties of human skin were studied. The thermal properties of both types of skin simulants, which were checked by exposing them to known radiant fluxes and monitoring the temperature response, were found to agree closely with the design values.

A set of twenty different fabrics, widely used in apparel, were tested. The depth of thermal damage was found to increase approximately linearly with increase in the total thermal dose to skin, for the exposure times and the magnitudes of the heat fluxes involved in these specific fabric burning experiments. This finding indicates the possibility of rating the burn damage potential of fabrics, crudely, by only two measurements, namely flame spread rate and total thermal damage to skin.

Measurements of the heat transfer rates from the leading edge to the fuel were conducted with the flame spread burner. These experiments indicate that about 2/3 of the preheat energy is delivered ahead of the leading edge of the flame while the highest intensity of energy is confined to a small region under the flame extension.

NBS-GCR-73-16. **Status and prospects for flame resistant polyester/cellulose blend fabrics,** G. C. Tesoro, 56 pages (Mar. 15, 1973). Order from NTIS as COM 73-11265.

Key words: cotton; fabrics; flame retardants; flammability; phosphorus; polyester; rayon; treatments.

This report describes the status of flame retardant finished polyester/cotton and polyester/rayon blend fabrics. While these fabrics represent a large part of the present market, there exists presently no commercial flame retardant treatment for them, though such treatments are available for 100 percent cellulose and 100 percent polyester fabrics. Self-extinguishing behavior can be attained by insolubilizing sufficient phosphorus on the blends, and the amount of phosphorus needed is lowered by the presence of bromine. Phosphorus in the form of phosphine oxide, derived from treatment with tetrakis-hydroxymethyl phosphonium derivatives, has been shown to be more effective than phosphonate or phosphoramine phosphorus. The amount of finish necessary to obtain self-extinguishing behavior, however, tends to stiffen the fabric and raises its cost. Suggestions are made for further research in this area.

NBS-GCR-73-17. **A candidate standard for fundamental BASIC,** J. A. N. Lee, S. R. Bechhardt, and A. 1. Karshmer, 148 pages (Oct. 19, 1973). Order from NTIS as COM 74-10932.

Key words: ADP standards; BASIC; compilers; compiler validation; computer programming; formal language; programming language standards.

Under contract to the National Bureau of Standards, a candidate standard specification and supporting analyses have been developed for a nucleus or fundamental subset of the BASIC programming language. This report, in four parts described below, will be immediately considered for Federal standardization, and is intended also to assist national standardization efforts. Part 1: *Standard Specifications for BASIC*. This specification establishes the form and the interpretation of programs

which are written in the BASIC language, for the purpose of promoting a high degree of interchangeability and transportability of such programs among automatic data processing systems. Part 2: *Explanations, Examples and Recommendations.* This part provides explanations, examples, and recommendations which are additional to, but not part of the BASIC specifications. Part 3: *Programs for the Validation of BASIC Implementations.* The BASIC programs contained herein provide a set of routines for the testing and validation of BASIC language implementations. Part 4. *Formal Description of BASIC.* The formal description of BASIC is composed of three parts: the concrete syntax, the abstract syntax, and a semantic description of the operational meanings of the elements of the program.

NBS-GCR-73-18. **Source mechanisms of microearthquakes associated with underground mines in Eastern Utah,** R. B. Smith, P. L. Winkler, J. G. Anderson, and C. H. Scholz, 46 pages (Oct. 1973). Order from NTIS as COM 73-11783.

Key words: acoustics; coal; earthquakes; geologic faults; mining; tectonics.

A detailed microearthquake survey, with acoustic monitoring, was conducted in the Sunnyside coal district of eastern Utah to investigate the possible relationship between earthquakes and mining. Rates of earthquake activity averaged hundreds of events per day with magnitudes from − 0.5 to + 2.0. The zone of greatest earthquake activity was centered 1 km beneath a portion of the mine which exhibited floor and roof failures. A composite fault plane solution for the main zone of activity defines reverse faulting with nodal planes striking N15°E. The P axis has an azimuth of N75°W and dips 25°W. This is in agreement with the general stress pattern attributed to the tectonic development of the nearby San Rafael Swell and suggests that the main earthquake energy may be derived from regional tectonic stress. Acoustic emissions recorded within the mine showed an average rate of 180 per hour and appear to be due to shear failures near the mine walls. The rate of acoustic activity decreased with time after the latest mining activity. Spectral analyses of direct shear waves from the sub-mine quakes yielded estimates of source parameters at hypocentral distances from 1.3 km to 3.0 km. The data are in agreement with the results of other work and extend the previous studies of source spectra down to magnitudes less than + 1 for short hypocentral distances.

NBS-GCR-73-19. **Regulation and evaluation of industrialized building: A literature review with annotated bibliography,** J. N. Thompson and C. T. Grimm, 60 pages (Dec. 1973). Order from NTIS as COM 74-10481.

Key words: building codes; building laws and regulations; building materials—testing and evaluation; building systems; industrialized housing; mobile homes; modular construction; prefabrication; zoning.

This review, annotated bibliography and index covers literature published in the English language on the regulation and evaluation of industrialized building. The scope of the review includes the period from 1940 to April, 1972.

A summary of the literature precedes the review. The summary follows the subject divisions used in the review.

The review is divided into two parts, titled "Regulation" and "Evaluation." The first part deals with methods used to regulate industrialized housing, including: building codes (local, state, and model); standards; and zoning. The second part deals with the methods used to evaluate industrialized housing, including administration of the evaluation process. Each section of the review presents the literature in chronological order in an attempt to show the development of attitudes, trends, and accomplishments affecting the progress of industrialized housing.

The annotated bibliography is divided into subject sections which correspond to those used in the review. Key words are included for each bibliographic entry. For reference purposes, a comprehensive index includes subjects, authors, and titles cited in the literature review and annotated bibliography.

NBS-GCR-73-21. **Research study on the socioeconomic aspects of low-cost housing in the Philippines,** 149 pages (May 1972). Order from NTIS as COM 74-10722.

Key words: construction; design; developing countries; earthquakes; low-cost housing; natural disasters; Philippines; socioeconomic aspects; typhoons.

The report presents a survey of the historical occurrence of damages by typhoons, selected comparative indices for climate and housing construction, an economic profile of the Philippines, as well as a regional demographic profile. A discussion is also presented on size and density of household dwelling units, trends in housing space expansion, community and municipal facilities; household income and household expenditures; financing sources for housing construction; availability and prices of construction materials and of labor; the capabilities of the housing industries; public reaction to new designs and materials; methods of housing construction and building codes.

NBS-GCR-74-22. **Mechanical and acoustical signature analysis of engine-generator units to be used at the Department of Housing and Urban Development Total Energy Plant, Jersey City, New Jersey,** R. F. Burchill, 374 pages (May 1973). Order from NTIS as COM 74-10934.

Key words: diesel-electric sets; gears; looseness; signature analysis; unbalance; vibration.

This report summarizes the acoustical vibration and stack gas temperature and conditions of each of five diesel-electric sets tested in the vendor's factory. The data in this report was collected simultaneously with fuel, cooling water and electrical transient data during the factory acceptance tests. The tests were supervised by NBS staff and were required by the purchase specifications. The purchase specifications were based upon a total energy performance specification developed by NBS for this project (A Performance Specification For A Total Energy Plant At The Jersey City Breakthrough I Site, NBS Report No. 10313, December 29, 1970). Signature analyses of each engine over the test load range were calculated and plotted. The signature analyses show machinery unbalance rotating component looseness, ball and roller bearing deterioration and gear damage or wear.

These signature analyses are baseline data which will be compared with signature analyses taken at future dates as the engines age. Changes in the signature analysis will be used to predict required maintenance services.

NBS-GCR-74-23. **Survey of lube oil analysis techniques to be used at the Department of Housing and Urban Development Total Energy Plant, Jersey City, New Jersey,** 21 pages (Sept. 1973). Order from NTIS as COM 74-10929.

Key words: chip detectors; ferrograph; lube oil analysis; magnetic drain plugs; oil filters; oil monitors; particle detectors; spectrograph.

Lube oil analysis can be an important consideration in the preventive maintenance program of diesel-engine-generators which provide prime power to a housing site. This report surveyed possible lube oil monitors that would scientifically "in

rm" plant operators when oil needed changing rather than anging the oil after a fixed amount of operating hours.

Several lube oil monitors are discussed. Filter check is used r aircraft gas turbine oil analysis; however, in diesel engines, e presence of combustion products requires a high level of de- ctive skill. Magnetic drain plugs are useful but a failing gear ay only show a small amount of ferrous particles while normal ear from cylinder liners, etc. produces large amounts of ferrous rticles. Other monitors discussed are: chip detectors, oil parti- e detectors; spectroscopic oil analysis and ferrograph chniques.

The report recommends that samples of the lube oil be regu- rly spectroscopically analyzed for wear particles and lubricant egradation. The report also recommends the engine lube oil stems be set-up so that other types of lube oil monitors can be sed.

BS-GCR-74-24. **Development of a test for impact protection,** J. M. Akridge, W. J. Freeston, Jr., W. L. J. Leverett, W. D. McLeod, M. K. Rao, and W. Wullff, 78 pages (Apr. 1973). Order from NTIS as COM 74-10983.

Key words: energy absorption; impact test; protection; protective equipment.

An Impact Test Apparatus has been designed and testing rocedures have been proposed to measure systematically on exible, semi-rigid and rigid impact protection systems their bilities to absorb kinetic energy and to distribute peak impact ressure away from the point of impact.

The proposed impact simulation is based on impact descrip- ons extracted from the findings of an intensive literature search n impact injuries, primarily car crash impact studies.

An impact modeling analysis was performed and solutions are resented. Modeling parameters and procedures for experimen- al impact data evaluation have been derived from the analysis.

A multitude of impact modes on practically all parts of the uman body, namely skull, torso, leg and arm, have been in- luded in the impact simulation. The proposed versatile Impact est Apparatus is considered to be a research tool which is eeded for the fundamental work that could lead to simple stan- ard test methods for specific impact situations.

NBS-GCR-74-25. **Use type tests for comfort and effectiveness of firemen's turnout coats,** N. R. S. Hollies, L. Fourt, G. A. Arnold, and N. Custer, 129 pages (May 1974). Order from NTIS as COM 74-11075.

Key words: clothing; firemen's turnout coats; use type tests for comfort and effectiveness.

This report describes five tests involving the interaction etween a fireman's turnout coat and the fireman working in it. he amount of replication necessary to establish major recog- izable differences in present designs is ascertained, together ith the standard deviation of typical groups of measurements. he man-hours of subjects and observers required to carry out uch comparisons are reported. The tests include the metabolic ost of clothing, rate of mixing of air in spaces inside the coat ith outside air, thermal insulation of clothing while being worn, effect of clothing on sweat production and evaporation, and the water uptake by clothing worn under the spray of a fog nozzle.

NBS-GCR-74-26. **Planning computer compatibility for uniform building regulation documents; final report; advanced information systems,** J. Eberhard, T. Tiedeman, and C. Green, 106 pages (May 1973). Order from NTIS as COM 74-11633.

Key words: automatic data processing; building codes; building regulations; computer applications; computers; enforcement; evaluation; information systems; microfilm; microform; state-of-the-art study.

This report provides an introduction to the use of Automated Data Processing (ADP) and microform systems in the administration and enforcement of building regulation, particularly relating to factory manufactured buildings and mobile homes. The focus of the report is to make the reader aware of the planning considerations which must be dealt with when use of these information handling systems is contemplated. A background knowledge of building regulatory functions is assumed of the reader, but not technical knowledge of ADP or microform. Topics covered include: 1. Basic introduction to ADP and microform use. 2. State-of-the-art examples of microform use in building regulation. 3. State-of-the-art examples of computer use in building regulation. 4. Basic planning guidance for ADP and microform use. 5. Potential building regulatory use areas for ADP and microform. 6. Selected references.

NBS-GCR-74-27. **State-local interface relationship in the regulation of manufactured building,** 102 pages (Oct. 1974). Order from NTIS as COM 75-10143.

Key words: building codes; factory-built housing; industrialized building; inspection; manufactured building; model codes; model documents; NCSBCS; on-site construction; prefabricated construction; standards; state-local relationship; state regulations.

A key element in the statewide regulation of manufactured building is the state-local interface relationship. This study sought to isolate existing interface problems and to provide recommended solutions. Problem analysis and solutions presume a regulatory framework drawn along the lines suggested by the proposed Model Manufactured Building Act and Coordinated Evaluation System Documents. Inadequacies in the legislative areas coupled with the lack of a well defined communication system constitute the prime interface problems. Suggestions for legislative changes, including revisions to the Model Act, are presented in this report together with recommendations designed to achieve better communications. Results of the data collection and analysis of existing state legislation are included.

NBS-GCR-74-28. **Study of teletypewriter interface and communications standard. Volume I,** 265 pages (Jan. 16, 1967). Order from NTIS as PB176912.

Key words: alphanumeric symbols; AUTODIN (Automatic Digital Network); JOSS; keyboards; MAC project.

The final report consists of two volumes. The first volume (PB176912) contains the results of the investigations of existing standards, teleprinters, modems, multiplexors, and data processors, and the systems in which they are used. The second volume (PB176913) contains the Formulation and Recommendations of Factors for Standardization.

NBS-GCR-74-29. **Study of teletypewriter interface and communications standard formulation and recommendation of factors for standardization. Volume II,** 69 pages (Jan. 16, 1967). Order from NTIS as PB176913.

Key words: acceptability; coding; costs; data transmission systems; decisionmaking; economics; errors; information theory; input-output devices; interfaces; malfunctions; man-machine systems; remote control systems; systems engineering; state-of-the-art reviews.

The final report consists of two volumes. The first volume (PB176912) contains the results of the investigations of existing

standards, teleprinters, modems, multiplexors, and data processors, and the systems in which they are used. The second volume (PB176913) contains the Formulation and Recommendations of Factors for Standardization.

NBS-GCR-74-30. **Study of teletypewriter interface and communications standards. Task 1. Review of previous standardization programs and existing standards,** P. J. Mellett, 43 pages (Sept. 15, 1966). Order from NTIS as COM 74-11732.

Key words: coding; interfaces; modems; signal processing; standards; teletypewriters.

The report discusses previous and existing standards for the interfaces between data processing equipment and communications systems.

NBS-GCR-74-31. **Study of teletypewriter interface and communications standards. Task 3. Review and comparison of communications terminal equipment of common carriers and other suppliers,** P. J. Mellett, 25 pages (Sept. 30, 1966). Order from NTIS as COM 74-11733.

Key words: common carriers; computer networks; interfaces; modems; telecommunication.

Interface between the communications line and the data processing equipment is provided by line termination equipment. The function of this equipment is to change the digital pulses of the data processor into signals suitable for transmission over telegraph or telephone channels. This type of equipment is usually referred to as a MODEM (modulator-demodulator). Generally, this equipment is available through the common carriers on a lease basis as part of their communication services. There are some commercial suppliers of such terminal equipment, which is generally used in conjunction with private or military communications networks. This task consists of comparing the available communication line terminals that are suitable for coupling teletypewriter equipment and computer multiplex units to communication lines for speeds less than 300 baud. The various units are discussed and are presented on a comparison chart (appended to report), so that corresponding parameters for each equipment may be directly compared.

NBS-GCR-74-32. **Design concepts for safer matches and lighters,** 60 pages (Sept. 29, 1972). Order from NTIS as COM 75-10039.

Key words: burns; fabric fires; fire injuries; flammable fabrics; ignition hazards; ignition sources; lighters; matches.

A match or cigarette lighter is frequently the source of ignition in fires involving the accidental burning of fabric items. Consequently, any design of book matches or lighters which would contribute to their utilization in a safer manner would be highly desirable.

In this report, eight design modifications for book matches and seven modifications for cigarette lighters are described and discussed. The objective of the new designs is to prevent the accidental ignition of clothing or other fabric material when used by children in a play situation or when used for a bona fide application by the adult population. The designs proceeded from a study of ignition sequences gleaned from accident reports filed with the National Bureau of Standards.

Emphasis was placed on developing a safer match design for the protection of the very young, the 0-10 age group. The judgments of the investigators, when applied to a devised rating system, indicated the following: (1) A matchbook designed with a sleeved striker which requires insertion of a thin match and coordinated action of both hands, is the most promising; (2) A lighter concept which utilizes a screened flame is considered the most desirable. Other designs also show a reasonable degree of improvement and it is a conclusion of this report that one or more of the designs described, if adopted, will lead to increased safety for the entire population.

NBS-GCR-75-33. **Impact noise testing and rating,** T. J. Schultz, 245 pages (Dec. 1974). Order from NTIS as COM 75-10133.

Key words: acoustics; building acoustics; impact noise; noise; structural vibration.

This report presents a review of the historical development of and the current state-of-the-art in testing and rating floor/ceiling building construction assemblies with respect to their capability for isolating against annoying impact noises. This review was prepared in order to identify the technological basis underlying the current state-of-the-art and the relevant analytic and experimental methods. Recommendations for future research directed toward the evolution of improved standard test procedures are presented.

NBS-GCR-75-34. **Dynamics of textile fires,** G. H. Markstein and J. deRis, 54 pages (Mar. 1974). Order from NTIS as COM 75-10128.

Key words: edges; fabric construction; fabric flammability; fire spread; flame spread; flame spread rate; surfaces; textiles.

This report is concerned with fire spread rates over the surface and along the edge of textile fabrics and their controlling mechanisms. In a previous study, upward two-dimensional turbulent fire spread was investigated using side-walls to prevent sideways air entrainment. This resulted in a continuously accelerating flame spread over heights of practical interest. In the present study, three dimensional flow was permitted by eliminating the side walls. The resultant flame spread becomes steady soon after ignition. There is evidence for some correlation between the various tests: (1) the small scale 45° upward-burning test (CS 191-53); (2) Miller's measurements on his rotating drum apparatus; (3) our realistic-scale upward tubulent spread; (4) our edge-spread data; and finally (5) the fundamental downward creep spread. The large scale upward spread experiments tend to emphasize the chemical composition differences of fiber materials due to enhanced radiation from the larger flame while the smaller scale tests emphasize fabric construction differences due to the closer similarity of flame and fabric detail length scales.

NBS-GCR-75-35. **Characterization of pavement macrotexture by profile spectral analysis,** J. M. Lawther and J. J. Henry, 93 pages (June 1974). Order from NTIS as COM 75-10341.

Key words: noise; pavement macrotexture; profile tracer; tires.

This report presents the results of a study by the Pennsylvania State University to demonstrate the feasibility of utilizing a profile tracer to measure pavement macrotexture. Four test pavements – part of the Pennsylvania Transportation Institute Skid Test facility – were measured and spectrum analysis plots of the pavement profiles are presented. In addition, space frequency spectrum analyses of the profiles were generated and site-to-site comparisons were made. The results are presented in terms of their potential relationship to tire noise.

NBS-GCR-75-36. **Methodology for hazard evaluation of buildings, Vol. I: Technical report,** J. H. Wiggins, G. C. Hart, T. Hasselman, and R. W. White, 353 pages (Dec. 1973). Order from NTIS as PB261144.

Key words: buildings; damage; disaster; dynamic analysis; earthquakes; hurricanes; natural hazards; structural engineering; tornados; wind.

A methodology is presented for evaluation of existing buildings to determine the risk to life safety from natural disasters and to estimate the amount of expected damage. Damage to both structural and nonstructural building components resulting from the extreme environments produced by earthquakes, hurricanes, and tornados is considered. The methodology is capable of treating a large class of structural types including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. The procedure for the methodology is based on a computer analysis of the entire structure and is based on the current state-of-the-art. Numerical examples illustrating applications of the procedure are included.

NBS-GCR-75-37. **Methodology for hazard evaluation of buildings, Vol. II: Computer program users manual,** T. K. Hasselman, R. W. White, and G. Brandow, 112 pages (Dec. 14, 1973). Order from NTIS as PB261145.

Key words: buildings; damage; disaster; dynamic analysis; earthquakes; hurricanes; natural hazards; structural engineering; tornados; wind.

A methodology is presented for evaluation of existing buildings to determine the risk to life safety from natural disasters and to estimate the amount of expected damage. Damage to both structural and nonstructural building components resulting from the extreme environments produced by earthquakes, hurricanes, and tornados is considered. The methodology is capable of treating a large class of structural types including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. The procedure for the methodology is based on a computer analysis of the entire structure and is based on the current state-of-the-art. Numerical examples illustrating applications of the procedure are included.

NBS-GCR-75-38. **Methodology for hazard evaluation of buildings, Vol. III: Demonstration report,** J. H. Wiggins, G. C. Hart, and R. W. White, 76 pages (Dec. 1973). Order from NTIS as PB261021.

Key words: buildings; damage; disaster; dynamic analysis; earthquakes; hurricanes; natural hazards; structural engineering; tornados; wind.

A methodology is presented for evaluation of existing buildings to determine the risk to life safety from natural disasters and to estimate the amount of expected damage. Damage to both structural and nonstructural building components resulting from the extreme environments produced by earthquakes, hurricanes, and tornados is considered. The methodology is capable of treating a large class of structural types including braced and unbraced steel frames, concrete frames with and without shear walls, bearing wall structures, and long-span roof structures. The procedure for the methodology is based on a computer analysis of the entire structure and is based on the current state-of-the-art. Numerical examples illustrating applications of the procedure are included.

NBS-GCR-75-40. **Polymer flame retardant mechanisms,** D. J. Holve and R. F. Sawyer, 34 pages (Feb. 1975). Order from NTIS as COM 75-10696.

Key words: fire retardant mechanisms; fire retardant polymers; fire retardants; mass transfer number; opposed flow diffusion flame; oxygen index.

An opposed flow diffusion flame technique (Holve and Sawyer, 1974) was used to measure steady state burning rates and extinction velocities for several polymers (with and without added flame retardants) at varying oxygen concentrations in the oxidizing stream. From these results and an analysis based on extinction Damkohler numbers, overall gas phase activation energies and effective mass transfer numbers were derived. Preliminary findings for flame retardant PMMA show that while flame stability is reduced, (i.e., it takes a higher oxygen concentration to sustain combustion) the burning rate increases. In another case for particle board, boric acid flame retardant is found to reduce the burning rate, but not to have any substantial effect on flame stability. These results suggest that both types of retardants are necessary for effective flammability reduction.

NBS-GCR-75-42. **Technological innovation for civilian, social purposes,** E. R. Mottur, 574 pages (July 1971). Order from NTIS as COM 75-10805.

Key words: civilian, technological innovation; social purposes, civilian; technological innovation.

This book presents the results of the Technological Innovation Policy Project which has been carried out in the Program of Policy Studies of George Washington University, under National Bureau of Standards contracts CST-395 and CST-463. The principal sponsors of the research have been the Office of Invention and Innovation, National Bureau of Standards and the U.S. Arms Control and Disarmament Agency. Supplemental research support has been provided by the National Aeronautics and Space Administration, under NASA Institutional Grant NGR 09-010-030 to the Program of Policy Studies in Science and Technology.

NBS-GCR-75-43. **Feasibility study for a diesel engine condition monitoring system for 1179 class LSTs,** M. B. Peterson, 102 pages (Aug. 1975). Order from NTIS as AD-16782.

Key words: diagnostic systems; diesel engines; maintenance costs; monitoring systems.

A study of the maintenance costs and practices on the LST 1179 class ship has been made to determine if a propulsion diagnostic system would result in cost savings to the Navy or other advantages. In the course of this study, a determination of the current propulsion system malfunctions was made and a listing prepared of the necessary sensor measures to detect these malfunctions. Based upon this information, a diagnostic system was proposed and costed. For the LST 1179 ships a simple data system, which measures the trend analysis parameters (plus critical malfunctions), was found to be cost effective.

NBS-GCR-75-44. **Computer/communications networks on a communitywide basis,** E. F. Clark, S. B. Harvey, C. B. Robbins, R. S. Tall, S. S. Tyler, and G. R. Weinberg, 215 pages (June 1975). Order from NTIS as COM 75-10991.

Key words: broadband interactive terminals; cable television uses; checkless society; computer/communications networks; computer/communications services; computer/communications standards; interactive cable television; nonentertainment television; two-way television; wired city; wired nation.

The purpose of this study is to project the possible impact of computer/communications networks on a communitywide basis and to make recommendations for action required by government and/or industry in order to take advantage of such networks and, hopefully, avoid some of the problems inherent in their development. This report reviews, in general, the issues involved with the future development of cable television as one

possible means of "wiring" the community. This report does not attempt to offer detailed solutions to, or discussions of, specific technical, economic, regulatory, legal, or social problems which may be isolated. The report contains a description of two-way cable services, results of a selected opinion survey, the technical and regulatory status of cable television, an outline of network technology, two future contrasting scenarios, a financial model, and conclusions, recommendations, and standards needed. There is a bibliography of 60 sources. The report was prepared under NBS Contract No. 3-36006.

NBS-GCR-75-45. **Pilot investigations into the effect of glare on psychomotor performance,** R. J. Senter, 13 pages (July 1975). Order from NTIS as PB257835.

Key words: glare; lighting; perceptual/motor; psychomotor; safety.

Empirical investigations measured the effects of glare on human psychomotor performance as assessed by a rotary pursuit apparatus. Experiment I demonstrated a minimal performance decrement when glare was reflected off the surface of the pursuit rotor into the subjects' eyes. Following an initial "startle" response, subjects' performance was observed to recover rapidly and at times improve. In Experiment II, then, the glare source was redirected to produce more intense and less diffuse visual interference. Subjects experienced one of two glare levels on three different occasions. A control group was also employed. Again, the major deleterious effect on human performance was a "startle" response produced after intitial exposure to high glare levels. Recommendations were made for future research involving a more complex psychomotor task.

NBS-GCR-75-46. **Methodology for the effective test case selection, Part 1,** W. Howden and L. G. Stucki, 171 pages (Jan. 1974). Order from NTIS as PB247235.

Key words: automatic testing; computer program testing; FORTRAN programs; program analysis; software verification.

The intent of this project was to develop a methodology for partitioning the input domain of a program into equivalence classes. Two sets of input values are to be contained in the same equivalence class if and only if they cause execution of the same path (perhaps to within the number of loop iterations) through a program. The equivalence classes define, therefore, sets of input values which are treated "the same way" by the program. This mapping of input data classes into program execution paths yields a functional description of the program and provides a basis for a systematic approach to test case selection. The investigation began by analyzing the structure of a program and by considering conditions under which certain logical paths are taken. The loop was selected as one of the more complicated structures which had to be investigated. In order to handle loops a boundary-interior methodology was developed. A four phase approach to the general partitioning problem evolved from this methodology. The first phase defines the implicit path description of the partition elements. These descriptions are then simplified in the second phase. The third phase transforms the implicit path descriptions into partially explicit descriptions. The fourth phase consists of predicate solution routines. This boundary interior methodology currently works with simple loops only. Some complex loop structures or improperly nested loops are excluded.

At this point in time, the research efforts documented in this study describe an approach which will achieve the original objective of selecting test data in programs subject to some constraints.

NBS-GCR-75-47. **Methodology for the effective test selection Phase II, Volumes I and II,** W. Howden and L. G. Stucki, 381 pages (Apr. 1975). Order from NTIS as PB247236.

Key words: automatic testing; computer program testing; FORTRAN programs; program analysis; software verification.

The intent of the Effective Test Case Selection Project is to explore and develop methodologies for partitioning the input space of a program into representative subsets. This ongoing research effort addresses in detail one important aspect of the Automated Verification System Concept being developed at McDonnell Douglas. The problem of providing automated assistance in the selection and construction of meaningful test cases is explored in this study. One key issue of concern involves the identification of a set of criteria for grouping together "similar" program paths. We are faced with the problem of forcing ourselves to find a means of cutting down the number of paths through a program which are significant for testing. Structured programming assists us in the better organization of our programs but yet we still find that exhaustive testing of even structured programs is rarely feasible.

Investigation in the area of automatic selection and construction of test cases has led to the design of a general methodology addressing this problem. The goal of Phase II of this research was to design and implement a prototype system in order to assess its utility and come to a better understanding of the basic program testing problems. The approach taken was general and can be applied to programs in different languages although it was designed with FORTRAN programs in mind.

The prototype system breaks a program down into a finite number of standard sets of program paths. It then attempts to simplify and display the relevant statements and predicates for each class to be tested.

NBS-GCR-75-48. **The avoidance of progressive collapse: Regulatory approaches to the problem,** E. F. P. Burnett, 180 pages (Oct. 1975). Order from NTIS as PB248781.

Key words: abnormal loading; building regulations; design process; European; progressive collapse; regulatory process.

The progressive-collapse related provisions of the building regulations of the United Kingdom, Sweden, Denmark, West Germany, Netherlands, Canada, France, and Eastern Europe are studied in detail. The various regulations are discussed individually for their content, background and interpretation. The report is concluded with a discussion of both building regulatory and design problems associated with the implementation of progressive collapse design requirements. A comparative evaluation is then made of the regulations discussed in the report.

NBS-GCR-75-50. **A theoretical analysis of the ASTM E-119 standard fire test of building construction and materials,** A. M. Kanury and D. J. Holve, 141 pages (Aug. 1975). Order from NTIS as PB247939.

Key words: ASTM Standard E119; building construction; charring; combustion; fire endurance; fire test; flame emissivity; heat transfer; pyrolysis; radiant heat; thermal inertia.

This report describes a theoretical analysis of the ASTM E-119 Standard Fire Test. Both analytical and numerical analyses of the test are performed, indicating how various physical, chemical, and structural variables influence the fire endurance of a construction member. Walls, door, floors and ceilings in heavy timber construction are considered, represented mathematically

as "slabs." Wood, gypsum board, and composite wood-gypsum board "slabs" are discussed. The effects of various fire exposure conditions on the endurance time are assessed. Radiant heat transfer is the dominant heat transfer mode and reradiation properties of the exposed material have a strong influence on the fire endurance time. Thus, the true measure of fire severity is given by the heat flux to the specimen, a function of both the furnace temperature and emissivity.

The exact temporal distribution of temperature exposure has little effect on the fire endurance time as compared to the standard ASTM temperature-time curve. Future improvements of the ASTM E-119 test should focus more on the control, measurement, and specification of the heat flux exposure condition rather than the furnace temperature history.

NBS-GCR-75-51. **Detector sensitivity and siting requirements for dwellings,** R. W. Bukowski, T. E. Waterman, and W. J. Christian, 337 pages (1975). Order from NTIS as PB247483.

Key words: detector sensitivity; detector siting; heat detectors; ionization smoke detectors; photoelectric smoke detectors; residential fires; smoke detectors; tenability levels.

A test program was undertaken to investigate the operation of residential smoke detectors under actual field conditions. The main objectives were to determine: 1) minimum sensitivity, 2) best location and 3) escape time provided by a group of typical detectors. Instrumentation was used to determine theoretical response times of an "ideal" detector as a base line for evaluation of detector performance. The tests were conducted using smouldering or flaming ignition of sofas, chairs and mattresses in various rooms in two abandoned, single-family houses scheduled for demolition. Work was carried out during winter and summer seasons with central heating and cooling on and off.

In addition to a description of the tests and discussion of the results, the report contains all raw data for further analysis by the reader.

The tests indicate both photoelectric and ionization detectors at a sensitivity of approximately 1 percent per foot provide adequate escape time from all the test fires when installed using the following guidelines: 1. The detectors should be installed at the head of each stairway; 2. Outside each separate sleeping area; 3. At least one detector on every level of a multi-level home.

NBS-GCR-76-54. **Characterization of the Stanford Research Institute large-scale heat-release-rate calorimeter,** S. B. Martin, 81 pages (Oct. 1975). Order from NTIS as PB251682.

Key words: calorimeter; combustion; fire test; heat release; limiting thermal index; pyrolysis; radiant heat; thermal sensitivity index.

A scaled up version of the NBS heat release rate calorimeter was constructed at SRI. It can measure specimen sizes up to 18 × 24 inches over an incident radiant flux range of 1.5 to 7.0 W/cm². The performance of the instrument is evaluated and various calibration procedures are described. The effect of specimen size and irradiance is investigated and data is compared with that taken in the NBS instrument. The use of the heat release rate calorimeter as a research tool is discussed. In particular a "limiting thermal index" and a "thermal sensitivity index" are defined.

NBS-GCR-76-55. **Technology for the formulation and expression of specifications. Vol. I: Final report,** J. R. Harris, J. W. Melin, R. L. Tavis, and R. N. Wright, 72 pages (Dec. 1975). Order from NTIS as PB250571.

Key words: building codes; computer model; decision theory; networks; specifications; standards; system engineering.

This report describes a systematic approach to the formulation and expression of specifications that is designed to aid in producing complete, clear, and correct documents. The approach is primarily concerned with the format of specifications, however, it is not possible to entirely separate content and format. It is not expected that the technology will be applied to the formulation of project specifications for construction projects without future study. Three basic tools are used: decision tables for examining the detailed logic contained in each provision, a network for representing the precedence of information in the entire specification, and an outline for organizing all of the provisions in the specification. The report is designed for use by individuals concerned with the preparation of specifications. It does not contain rigorous definitions and proofs of the theorems and algorithms used. Two companion volumes to this report contain a user's manual and a reference manual for the computer software developed as a part of the technology. None of the concepts or algorithms require a computer to be understood or used. Many benefits can be realized by the proper understanding and application of the concepts without using the computer programs.

NBS-GCR-76-56. **Technology for the formulation and expression of specifications. Vol. II: Program user's manual,** J. R. Harris, J. W. Melin, and C. Albarran, 63 pages (Dec. 1975). Order from NTIS as PB250572.

Key words: building codes; computer program; decision theory; networks; specifications; standards; systems engineering.

This report describes the use of three computer programs (DECISION TABLE, NETWORK, and OUTLINE) produced as a part of the study, "Technology for the Formulation and Expression of Specifications." The programs are designed for interactive use from a remote console, and the communication with the programs is in free format, making the programs easy to use for those with limited experience in working computers. The programs are operational on the Burroughs B6700 computer at the Civil Engineering Systems Laboratory (CESL) at the Department of Civil Engineering, University of Illinois, Urbana, Illinois. The principles on which the programs are based and examples of the application of these principles are contained in volume I of this report while a more technical description of the three programs, including logic diagrams, data structure, and program listings, is contained in volume III. This volume contains a description of the use of each program preceded by a chapter describing access to and use of the computer facility at which the programs are operational.

NBS-GCR-76-57. **Technology for the formulation and expression of specifications. Vol. III: Technical reference manual,** R. N. Wright, J. R. Harris, J. W. Melin, and C. Albarran, 118 pages (Dec. 1975). Order from NTIS as PB250573.

Key words: building codes; computer program; decision theory; FORTRAN; logic design; networks; specifications; standards; systems engineering.

This report describes the three computer programs produced as a part of the study, "Technology for the Formulation and Expression of Specifications." The programs are written in FORTRAN IV and are operational on the Burroughs B6700 computer at the Civil Engineering Systems Laboratory (CESL), Department of Civil Engineering, University of Illinois, Urbana, Illinois. Transfer of these programs to other computing facilities will be aided by the contents of the manual, because the pro-

grams are not entirely machine independent. The programs make use of the characteristic word size of the Burroughs equipment (6 characters). Transfer to IBM equipment (which uses 4 characters) will require some reprogramming of the input and output routines. The programs are designed for interactive use from a remote terminal. The input is entered in free format and interpreted by a package of scanning routines at CESL known as PARSE. A manual for PARSE will soon be available from CESL. These programs are envisioned to be prototypes for a more refined computer aid for use with the technology described in volume I of this report.

NBS-GCR-76-58. **Residential sprinkler-protection study,** H. C. Kung, 126 pages (Nov. 1975). Order from NTIS as PB256291.

Key words: automatic sprinklers; bedroom fires; droplet size; heat absorption; pool fires; residential sprinkler protection; sprinkler operation.

A research program was initiated to study sprinkler control of residential fires. Hexane pool fires were selected to simulate source fires. The key parameters of investigation were water-discharge rate and drop size. Results show that as the median drop size decreases at constant discharge rate, an increased reduction is observed in: 1) heat-release rate of the fire, 2) convective heat flux through the room opening, 3) ceiling temperature, 4) gas temperature inside the room, and 5) outflow gas temperature. A correlation has been established between heat-absorption rate and the relative median drop size of the spray. The ratio of the heat-absorption rate to the heat release rate, normalized with the water discharge rate, varies as the minus-0.68 power of the relative median drop size.

A realistic bedroom fire test with flaming ignition was also conducted to evaluate the optimum water discharge rate and sprinkler-orifice diameter determined in the pool-fire tests. The result demonstrated that the suggested optimum sprinkler discharge rate is capable of controlling a realistic bedroom fire.

NBS-GCR-76-59. **Sound power measurements in reverberation chambers,** J. Tichy, M. Brien, and K. Roy, 233 pages (Jan. 1976). Order from NTIS as PB256639.

Key words: measurement technology; reverberation rooms; sound measurement; sound power; sound power levels.

Determination of the sound power emitted by small sources using reverberation rooms is becoming increasingly important as society seeks to implement noise control measures. Many of the critical measurement processes are indicated in American National Standard S1.21-1972, "Methods for the Determination of Sound Power Levels of Small Sources in Reverberation Rooms." This standard, as now embodied, represents a major advance in the state-of-the-art of reverberation room measurement of sound power. It incorporates the best currently available interpretation of measurement technology which is the subject of ongoing research.

NBS-GCR-76-60. **Fire fighter mortality report,** T. Balanoff, 170 pages (Mar. 1976). Order from NTIS as PB253588.

Key words: fatalities; fire fighter; occupational safety and health.

This 15-month study involved the investigation of 101 fire fighters in-the-line of duty deaths. The breakdown of cause of death was: 45 heart attacks, 13 building collapse, 12 burns, 9 smoke inhalations, 6 apparatus accidents, 5 electrocutions, and 1 equipment failure. There tended to be a higher incidence of fatalities occurring in the Mid-Atlantic, East, and New England areas. The mean age of fire fighter's fatality was 43.5 and the mean years of service was 15.8. Sixty percent of the fatalities occurred to men holding the rank of fire fighter. The vast majority of fire fighters who died in the line of duty worked either a split shift (10/14) or a 24-hour shift. There were 14 volunteer fire fighter fatalities.

Summaries of every case are provided in one of three sections: *Fire Fighters Killed While Fighting Fires, Fire Fighters Killed in Non-Fire Situations,* and *Fire Fighters Killed by Heart Attack.*

NBS-GCR-76-61. **Method to determine quality of sapphire,** M. T. Duffy, P. J. Zanzucchi, and G. W. Cullen, 88 pages (Sept. 1975). Order from NTIS as PB253553.

Key words: differential reflection; epitaxial semiconductor devices; Kramers-Kronig relation; multiple reflection; sapphire surfaces; silicon films; specular reflection.

Infrared optical techniques including specular reflection, multiple reflection and differential reflection measurements have been used to evaluate the quality of sapphire surfaces used in epitaxial semiconductor devices. The specular reflection data have been analyzed by use of the Kramers-Kronig relations. These data give a basis for interpreting multiple reflection measurements which are being evaluated for both research and production quality control of sapphire substrates. Correlation of optical reflectance data to x-ray, electrical (e.g., Hall measurements), optical microscopy, and chemical (etch) data is in progress to establish the validity of inferring the extent of lattice damage from reflectance measurements. Application of optical techniques to the characterization of sapphire surfaces, and to semiconductor and dielectric materials in general, is considered. In this context, the optical properties of epitaxial silicon films (on sapphire) have been investigated and, where possible, correlated with the electrical properties of the films as well as with the surface condition of the starting substrates.

NBS-GCR-76-63. **Disk drive interface characteristics,** 105 pages (Apr. 9, 1976). Order from NTIS as PB256440.

Key words: computer disk controllers; computer disk drives; computer disk interface; disk controllers; disk drive characteristics; disk pack interchangeability; disk track format; interface electrical characteristics; interface functional characteristics; removable disk packs.

This report describes and compares the various characteristics of the interface between computer disk drives and disk controllers for those drives using removable disk packs having a storage capacity of approximately 100 million bytes or greater. It presents the findings of an investigation conducted for the National Bureau of Standards in support of the possible development of a Federal Information Processing Standard. Disk pack interchangeability, drive performance characteristics, interface functional characteristics, and interface electrical characteristics are described. The conclusion is reached that although nearly all of the drives reviewed use the same type of disk pack, at the circuit and electrical level substantial differences of a detailed engineering nature exist in the interfaces. Two appendices are given describing (A) details of track format (IBM-compatible) and (B) drive cable attachments and pin numbers. Thirty-three tables and five figures are given. This report was prepared under NBS Contract No. 5-35924.

NBS-GCR-76-64. **Automated integrated circuit processing and assembly,** H. G. Rudenberg, 84 pages (Apr. 1975). Order from NTIS as PB255445.

Key words: automation; electronics; integrated circuits; measurement technology; semiconductor devices; semiconductor process control; silicon.

This report describes the results of a study on automated procedures for integrated circuit (IC) processing and assembly by the semiconductor industry. Emphasis is on automated IC production, especially processing of wafers and assembly of chips into devices. Major operations that are already or may be automated are identified, and future directions are recommended. Information has been derived primarily from interviews in industry and analysis of automated production equipment. The report discusses the susceptibility of processes to automation: a major requirement for automation is that measurement and control techniques be available to provide consistent results from the processes chosen. The automation status of the key process steps is outlined, and the expected evolution to complete computer control is characterized. Measurement techniques reported are directed towards categories suitable for automation of production in respect to accuracy, range and type. The report cites economic and technical factors likely to inhibit automation in the future, and some factors favoring its adoption. A number of priorities for further action are presented. Differences between the criteria used in automating commercial IC production and automating fabrication of devices for DOD electronic systems are described. Additional information includes references listed in the last section of the report; and summaries of the companies contacted or making equipment analyzed, and of important problems in IC processing or automation perceived by respondents are presented in appendices.

NBS-GCR-76-69. **Methodology for the effective test case selection, Phase III. Final report,** W. Howden and L. G. Stucki, 123 pages (Mar. 1976). Order from NTIS as PB254276.

Key words: automatic testing; computer program testing; FORTRAN programs; program analysis; software correctness; software verification; symbolic program evaluation.

The intent of the Effective Test Case Selection Project is to explore and develop methodologies for improving the tasks of computer program analysis and testing. This research effort explores in detail the problem of providing automated assistance in the selection and construction of meaningful test cases for computer applications programs. Key issues involve the identification of criteria for grouping together "similar" program paths, and a means of reducing the number of paths through a program which needs to be analyzed to ensure correctness. The investigation has led to design of a general methodology addressing this problem. Phase III of this research has resulted in the completion of a prototype software testing tool called DISSECT. The DISSECT system addresses the general methodology as well as the design and implementation of additional features whose importance was indicated by experiments with an initial Phase II system. DISSECT provides capabilities to analyze FORTRAN program paths and to symbolically evaluate the potential execution results. Commands are available to select program paths based upon branches and number of loop iterations, and to select DISSECT outputs such as path descriptions or the set of input predicates that cause paths to be followed. DISSECT is an experimental program, written in LISP for a Digital Equipment Corporation PDP-10 computer.

NBS-GCR-76-70. **An investigation of test methods for determining the flammability hazards of fabrics,** K. N. Yeh, I. Block, B. F. Smith, and S. Spivak, 67 pages (June 21, 1976). Order from NTIS as PB254748.

Key words: fabric flammability; fabrics; ignition; heat energy; tests.

The measurement of char length and burn time of a variety of sample specimens was conducted to determine the effects of varying sample size, sample shape, ignition source and air flow past the sample, on these two parameters.

In addition, samples tested in the DOC FF3-71 cabinet were subjected to conditioning at various relative humidities prior to evaluation.

The results of this work indicate that flammability test methods should conform to the following guidelines: (1) the suspension method should be such as to exert as little force in the plane of the fabric as possible, (2) the test specimen should be wide enough to permit unlimited burning in all directions, (3) the ignition source should be capable of providing a precise energy input at a constant rate to the fabric, (4) a forced air flow through the cabinet may be required, (5) although preconditioning humidity may not greatly affect the results when testing nonhydrophilic thermoplastics, moisture sorption can be important, and (6) seamed samples are unnecessary except where the added thread is a significant portion of the weight of the fabric under test.

NBS-GCR-76-71. **Extinguishment in apparel textiles,** G. Tesoro and S. Backer, 60 pages (Oct. 1975). Order from NTIS as PB254751.

Key words: cotton; cotton/polyester; extinguishment; fabric flammability; fabrics; fibers; finishes; flame retardant treatments; nylon; wool.

An experimental investigation of the extinguishability during combustion of various apparel fabrics was conducted. Cotton, wool, nylon, cotton/polyester and FR cotton/polyester were ranked according to burning behavior under test conditions of DOC-FF-3-71 with the addition of heat sinks near the fabric. Stationary and movable heat sinks of various thermophysical properties, geometries, dimensions and speeds were considered.

It was found that extinguishability is affected by fiber type and finish, by weight per unit area and structure. Two parameters were identified to measure relative extinguishability: (1) minimum constant spacing (between fabric and heat sink) needed to induce extinguishment, and (2) the maximum char length obtained after extinguishment in the case of a variable fabric to heat sink spacing. It is concluded that relative differences in ease of extinguishment of nonthermoplastic fabrics can be quantitatively and reproducibly measured.

NBS-GCR-76-72. **Evaluation of fire protection spray devices: The state-of-the-art,** W. G. Labes, 102 pages (June 30, 1976). Order from NTIS as PB256190.

Key words: automatic sprinklers; bibliography; droplet size; fire suppression; spray nozzles; spray patterns; test methods; water distribution; water spray.

This report represents a descriptive review of the state-of-the-art on spray nozzle characteristics, drop-size measurement, and drop-size distribution and spray pattern analysis. A discussion of significant information gaps is also included. A list of references supporting these findings has been prepared and appears as an appendix to this report.

It is concluded that the evaluation of fire protection spray devices must be updated to include considerably more than the volume distribution of water at some standardized distance below the deflector of a sprinkler. Since both the fire environment and the spray structure are three dimensional by nature, and, as these opposing forces occur simultaneously in real fire situations, it is desirable to understand in greater detail the application of water to fire by fire protection spray devices.

NBS-GCR-76-73. **Mapping of recurrent behavior patterns in institutional building under fire: Ten case studies of nursing facilities,** L. Lerup, D. Greenwood, and J. S. Burke, 165 pages (July 1976). Order from NTIS as PB257424.

Key words: building fires; case studies; critical events; decisions; episodes; fires; home for the aged; hospital fires; human behavior; institutions; mapping; models; nursing homes; realms.

Report provides a graphical and narrative mapping of the fire and people behavior patterns in 10 institutional buildings under fire conditions. The case studies concentrate on nursing home type facilities. The report maps out the progress of the fire by realms of fire development and critical events separating these realms. A parallel mapping is included for human behavior covering the episodes and decisions involved. A conceptual framework and analysis of the basic concepts and approaches are included.

NBS-GCR-76-74. **Low-rise low-cost housing and extreme wind related problems in Bangladesh,** J. R. Choudhury, 39 pages (Apr. 1975). Order from NTIS as PB256771.

Key words: Bangladesh; housing; low-cost housing; low-rise buildings; wind.

This report furnishes information on socioeconomic factors, the present conditions of urban and rural housing, and housing needs in Bangladesh for the next 10 years. It also provides data on available wind speed records and wind damage statistics and discusses some special problems unique to Bangladesh.

NBS-GCR-76-75. **Accident research methodologies,** N. W. Heimstra, 27 pages (Dec. 10, 1976). Order from NTIS as PB261201.

Key words: accident research; countermeasures; epidimiology; laboratory research; methodology; naturalistic studies; safety.

This overview paper discusses some of the problems encountered and methodologies used in accident research. Several methodologies are briefly presented—the epidimiological approach, laboratory studies, case studies, and naturalistic observations. Special problems in childhood accident research and in countermeasures are emphasized and a model of human accident behavior is presented. Selected references are included.

NBS-GCR-76-76. **Home accidents and safety,** M. Werber, 100 pages (Dec. 10, 1976). Order from NTIS as PB261200.

Key words: accidents; accident research; consumer accidents; epidimiology hazards; home safety; methodology; safety.

This report briefly summarizes published research in home accidents and safety. Areas covered are: theoretical approaches to safety, behavorial interpretations, research design, hazardous products and conditions, childhood and old age accidents, epidimiology and public health, and accident prevention. In addition to the reference and general bibliographies, an author index, a subject index and permuted title index are included.

NBS-GCR-76-79. **A problem in fire safety: Flame spreading across liquid fuels,** F. L. Dryer, I. Glassman, and W. A. Sirignano, 30 pages (Sept. 15, 1976). Order from NTIS as PB259127.

Key words: combustion models; flame spread; fluid flow; laser doppler velocimetry; liquid fuels; solid fuels; surface tension.

This report provides a brief summary of experimental and theoretical work carried out at Princeton University on flame spreading across liquid fuels. The importance of surface tension driven flows ahead of the flame front in controlling flame spread across liquids at temperatures below the flash point was demonstrated experimentally. Buoyancy and radiation effects were also present but were of lesser importance. Variations in the temperature of the liquid surface are attributed to eddies in the gas phase ahead of the flame front. These eddies may also play a role in flame propagation across solid combustibles. It is proposed to investigate these eddies by means of laser doppler velocimetry. A two-dimensional, steady-state computer program is under development for use as a tool in studying flame propagation above liquid and solid fuels.

NBS-GCR-ETIP 73-01. **Study of strategies for market aggregation,** J. D. Lewis and H. S. Kleiman, 253 pages (May 11, 1973). Order from NTIS as COM 73-11373.

Key words: aggregation, market; market aggregation; tool, market.

This report considers the opportunities for stimulating the development and application of technology in the civilian sector through the use of the tool of market aggregation. Market aggregation is defined as a restructuring of demand to reduce variability in the marketplace. Such reduced variability might be manifest in an increased concentration of the purchasing activities of different buyers or in new standards for products or for their use. In addition to discussions of background and methodology, the report develops a conceptual framework for market aggregation that provides a specific aggregation strategy to treat a given problem. Next four case studies are presented to provide insights for the conceptual framework. These are followed by a discussion of major factors to be considered when contemplating or using market aggregation. The report concludes with suggestions on possible experiments with the market aggregation tool. One appendix to the report discusses antitrust considerations in market aggregation and another provides full details on the four case studies.

NBS-GCR-ETIP 73-02. **Government procurement as an incentive to commercial technology and innovation,** 159 pages (Mar. 1973). Order from NTIS as COM 73-11375.

Key words: ETIP; government procurement; performance specifications; procurement mechanisms; technology incentives.

The Federal Government influences the development and application of technology through its procurement of R&D to meet federal needs, its purchase of goods and services for federal use, and its subsidization of purchases made by other bodies. By altering certain aspects of its procurement practices and procedures, which are described and discussed in this study, the government may further stimulate private investment in technological innovation. Some suggested procurement approaches can be implemented within the confines of existing legislation and without major regulatory change. These include incentives (patent and financial) to commercialize the results of government R&D, the increased use of performance specifications in the procurement of commercial goods and services, and a government-wide policy to procure innovative goods and services that impact favorably on particular national needs. The procurement approaches can be tested by experiments of the one-time "demonstration" type or of the more practical "piggy-back" type, in which a planned or ongoing procurement is modified so as to stimulate innovation. Several examples of experiments that meet appropriate criteria are given in the report,

nd recommendations for selecting, designing, performing, and valuating additional experiments are presented.

NBS-GCR-ETIP 73-03. **Technology transfer and technological innovation: Annotated and selected bibliographies,** 107 pages (July 10, 1973). Order from NTIS as COM 73-11374.

Key words: bibliography, technological innovation; innovation, technological; technological innovation.

The works included in the bibliographies have been ategorized according to their relevance to federal and nonederal activities as well as to the general quality and significance f their discussions on technology transfer or technological inovation. The annotated bibliography includes 315 entries relevant to federal government action and all are of high quality. Approximately 50 additional entries for work of high quality with elevance to nonfederal action are also included. The selected ibliography contains approximately 375 entries, categorized in he same manner.

NBS-GCR-ETIP 73-04. **Experimental technology incentives program procurement experiment plan 1: Stimulating noise control technology in consumer products through federal government procurement action,** 18 pages (Oct. 1973). Order from NTIS as COM 74-10256.

Key words: ETIP; government procurement policy; noise reduction; performance specification; technology incentives.

The Experimental Technology Incentives Program (ETIP) of he National Bureau of Standards (NBS) is part of the continuing effort to understand how the federal government can work more effectively with industrial partners from the private sector in the application of science and technology in the nations interest. ETIP has selected the Federal government procurement policy as one of the specific areas in which to focus its investigations. This experimental plan details the particulars of one of a series of experiments to be conducted by ETIP in association with the Federal Supply Services of the General Services Administration. The specific objective of this experiment is to seek the introduction of improved noise control technology into power lawn mowers that are used by both the government and consumers generally. A 2-step fixed-price negotiated procurement experiment will be conducted utilizing a new performance specification relative to noise emission of the lawn mowers.

NBS-GCR-ETIP 73-05. **Experimental technology incentives program procurement experiment plan 2: Stimulating efficiency and noise abatement in room air conditioners through federal government procurement action,** 51 pages (Nov. 1973). Order from NTIS as COM 74-10257.

Key words: energy conservation; ETIP; government procurement policy; noise reduction; performance specification; technology incentives.

The Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards (NBS) is part of the continuing effort to understand how the federal government can work more effectively with science and technology in the nations interest. ETIP has selected the federal government procurement policy as one of the specific areas in which to focus its investigations. This experimental plan details the particulars of one of a series of experiments to be conducted by ETIP in association with the Federal Supply Services of the General Services Administration. The specific objective of this experiment is to seek the introduction of improved noise control technology and improved energy technology into room air conditioners that are used by the government and by consumers. The procurement approach to be tested will be the approach of performance factors in evaluation of bids responding to a formally advertised procurement.

NBS-GCR-ETIP 73-06. **Experimental technology incentives program procurement experiment plan 3: Stimulating increased efficiency in frostless household refrigerators through federal government procurement action,** 45 pages (Nov. 1973). Order from NTIS as COM 74-10258.

Key words: energy conservation; ETIP; government procurement policy; technology incentives.

The Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards (NBS) is part of the continuing effort to understand how the federal government can work more effectively with industrial partners from the private sector in the application of science and technology in the nations interest. ETIP has selected the federal government procurement policy as one of the specific areas in which to focus its investigations. This experimental plan details the particulars of one of a series of experiments to be conducted by ETIP in association with the Federal Supply Service of the General Services Administration. The specific objective of this experiment is to see improved energy technology in production of frostless household refrigerators to be used by government and by consumers. The procurement approach to be tested will be the use of life cycle cost comparison bid evaluation in a formally advertised procurement.

NBS-GCR-ETIP 73-07, Vol. 1. **Development of criteria and an operating procedure for screening government owned patents,** P. G. Dickey, K. D. Brown, R. W. Aaron, and S. A. Lambert, 82 pages (Apr. 30, 1973). Order from NTIS as COM 74-10939.

Key words: ETIP; government-owned patents; patent screening; technology incentives.

This two volume report describes the development of procedures to screen government-owned patents for commercial potential, based on the patent screening practices of a selected sample of industrial firms; results of the research show that the operating procedure developed satisfies the basic requirements of the study. Technology Generalists were about to apply the developed procedure with a minimum of assistance from Technology Specialists. The procedure, however, cannot readily be applied by nonexperts. Test results of screening selected patents were consistent and in accordance with expected results. The conclusion is drawn that the results indicate that the developed operating procedure replicates the approaches both formal and intuitive commonly used by industrial executives and experts to screen patents. The benefits and usefulness of operating procedures are summarized as follows: 1. Systematization of a screening process which heretofore was essentially random; 2. Uniform application of eight criteria consistently regarded as most important by industrial executives in patent screening; 3. A means for prioritizing patents in terms of some quantitative measurement of commercial potential; 4. A means of screening large numbers of patents in an efficient manner; 5. Procedure can be utilized by generalists as well as specialists.

NBS-GCR-ETIP 73-07, Vol. 2. **Development of criteria and an operating procedure for screening government owned patents,** P. G. Dickey, K. D. Brown, R. W. Aaron, and S. A. Lambert, 316 pages (Apr. 30, 1973). Order from NTIS as COM 74-10940.

Key words: ETIP; government-owned patents; patent screening; technology incentives.

This two volume report describes the development of procedures to screen government-owned patents for commercial

potential, based on the patent screening practices of a selected sample of industrial firms; results of the research show that the operating procedure developed satisfies the basic requirements of the study. Technology Generalists were about to apply the developed procedure with a minimum of assistance from Technology Specialists. The procedure, however, cannot readily be applied by nonexperts. Test results of screening selected patents were consistent and in accordance with expected results. The conclusion is drawn that the results indicate that the developed operating procedure replicates the approaches both formal and intuitive commonly used by industrial executives and experts to screen patents. The benefits and usefulness of operating procedures are summarized as follows: 1. Systematization of a screening process which heretofore was essentially random; 2. Uniform application of eight criteria consistently regarded as most important by industrial executives in patent screening; 3. A means for prioritizing patents in terms of some quantitative measurement of commercial potential; 4. A means of screening large numbers of patents in an efficient manner; 5. Procedure can be utilized by generalists as well as specialists.

NBS-GCR-ETIP 75-01. **Fiber, textile and apparel research—Cotton polyester blends, July 1974-75,** 143 pages (Aug. 1975). Order from NTIS as COM 75-11369.

Key words: cotton polyester blends; ETIP; flame retardants; flammability; R&D contracting; radiation grafting; research consortia.

As a part of its experimental program with respect to the funding of civilian research and development by the Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract where the basis for award was rather unique. The two major criteria for the award were: (1) the identification of specific research to be pursued in a general problem area and (2) the efforts at commercialization that the contractor indicated he would pursue. The contract was awarded to a consortium headed by Clemson University. This report covers the technical progress made during the first year of the research activity.

Based on this research, it is now possible to predict with a high degree of certainty, the types of chemical agents which should be effective in rendering cotton and polyester fabrics flame retardant. The interaction which occurs between fiber systems in a blend have been elucidated. Further, it has been possible to determine the effect of various distributions of the flame retardant chemicals among fibers in several systems. Four specific approaches are now under investigation.

NBS-GCR-ETIP 76-03. **Federal funding of civilian research and development, Vol. 1. Summary,** 62 pages (Feb. 1976). Order from NTIS as PB251266.

Key words: decisionmaking; Experimental Technology Incentives Program; federal funding of civilian R&D; federal policies; policies; private sector; R&D; technological change.

As a part of its program with respect to the funding of civilian research and development by the Federal Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract to Arthur D. Little, Inc. to conduct a study whose purpose was "To better understand how federal funding of civilian research and development has functioned as an agent of technological change in the private sector."

The fundamental conclusion reached in the study was "Federally-funded civilian research and development is not sufficient to bring about technological change in the private sector to any significant extent." This is true because R&D cost is a small part of the total cost of bringing technological innovation into the marketplace. The study finds that this fact is often overlooked by federal policy makers in both the Executive and Legislative Branches. It is cited as one of the reasons why many United States companies with proven records of developing and marketing new products often shun federal R&D funds, and why so many federal R&D projects are shelved.

The authors suggest that the results of the study indicate that federal funding of civilian R&D should be formulated in the larger context of the complex process of technological innovation. This volume provides a summary of the study.

NBS-GCR-ETIP 76-04. **Federal funding of civilian research and development, Vol. 2. Case studies,** 335 pages (Feb. 1976). Order from NTIS as PB251683.

Key words: decisionmaking; Experimental Technology Incentives Program; federal funding of civilian R&D; federal policies; policies; private sector; R&D; technological change.

As a part of its program with respect to the funding of civilian research and development by the Federal Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract to Arthur D. Little, Inc. to conduct a study whose purpose was "To better understand how federal funding of civilian research and development has functioned as an agent of technological change in the private sector."

The fundamental conclusion reached in the study was "Federally-funded civilian research and development is not sufficient to bring about technological change in the private sector to any significant extent." This is true because R&D cost is a small part of the total cost of bringing technological innovation into the marketplace. The study finds that this fact is often overlooked by federal policy makers in both the Executive and Legislative Branches. It is cited as one of the reasons why many United States companies with proven records of developing and marketing new products often shun federal R&D funds, and why so many federal R&D projects are shelved.

The authors suggest that the results of the study indicate that federal funding of civilian R&D should be formulated in the larger context of the complex process of technological innovation. This volume provides details of the case studies upon which the findings were based.

NBS-GCR-ETIP 76-05. **Analysis of federally funded demonstration projects, Vol. 1. Executive summary,** W. S. Baer, L. L. Johnson, and E. W. Merrow, 32 pages (1976). Order from NTIS as PB253108.

Key words: demonstration projects; Experimental Technology Incentives Program; federal funding of civilian R&D; federal policies; guidelincs; policies; R&D; technological change; technology.

As a part of its program with respect to the funding of civilian research and development by the Federal Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract to RAND, Santa Monica, CA, to conduct a study whose purpose was "To develop cost benefit and market/industrial/institutional criteria and guidelines for the use of Federally procured demonstration projects as catalysts for technological change."

The analysis indicated that projects successful in diffusion tend to have the following attributes: (1) A technology well in hand, (2) Cost and risk sharing with local participants, (3) Project initiative from non-Federal sources, (4) The existence of a strong industrial system for commercialization, (5) Inclusion of all ele-

nents needed for commercialization, and (6) Absence of tight time constraints.

The study developed guidelines for demonstration projects. These are grouped under the headings of (1) Strategies for Demonstrations, (2) Initial Exploratory Study, (3) Project Planning and Implementation, (4) Management, Monitoring, and Evaluation, and (5) Dissemination of Results. This volume provides an Executive Summary of the research.

NBS-GCR-ETIP 76-06. **Analysis of federally funded demonstration projects, Vol. 2. Final report,** W. S. Baer, L. L. Johnson, and E. W. Merrow, 197 pages (1976). Order from NTIS as PB253918.

Key words: demonstration projects; Experimental Technology Incentives Program; federal funding of civilian R&D; federal policies; guidelines; policies; R&D; technological change; technology.

As a part of its program with respect to the funding of civilian research and development by the Federal Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract to RAND, Santa Monica, CA, to conduct a study whose purpose was "To develop cost benefit and market/industrial/institutional criteria and guidelines for the use of Federally procured demonstration projects as catalysts for technological change."

The analysis indicated that projects successful in diffusion tend to have the following attributes: (1) A technology well in hand, (2) Cost and risk sharing with local participants, (3) Project initiative from non-Federal sources, (4) The existence of a strong industrial system for commercialization, (5) Inclusion of all elements needed for commercialization, and (6) Absence of tight time constraints.

The study developed guidelines for demonstration projects. These are grouped under the headings of (1) Strategies for Demonstrations, (2) Initial Exploratory Study, (3) Project Planning and Implementation, (4) Management, Monitoring, and Evaluation, and (5) Dissemination of Results. This volume provides a detailed Final Report.

NBS-GCR-ETIP 76-08. **An analysis of venture capital market imperfections executive summary,** 46 pages (Feb. 1976). Order from NTIS as PB254078.

Key words: capital market imperfections; federal technology policy; SBIC's; securities and tax regulation; small firm finances; technological change; technology subsidies; venture capital.

The study estimated the total flow of funds to small technology based firms, and the composition of that flow according to financial instruments. The relative roles of various suppliers of funds to these firms were assessed. No evidence was found of substantial market imperfections that restrict the flow of funds to small technology based firms. There was no indication that small technology based firms paid higher rates of interest or returned their unaffiliated stockholders more than other small firms. There was no indication that suppliers of funds to small technology based firms earned higher profits than could be earned by investing in listed securities. No elements of the structure of behavior in the venture capital industry were found which would enable firms in the business to charge higher rates or earn greater profits than necessary to compensate for the risks assumed.

The conclusion that there are no substantial capital market imperfections does not necessarily imply that the supply of funds to new technology based firms is in some sense ideal. Investment in small technology based firms may generate external effects so that the benefits to society from investment in these firms may not be accurately reflected in the prices those firms can get for their products and services or the rate of return which investors in such firms can expect to earn.

NBS-GCR-ETIP 76-09. **Life cycle costing in the procurement of electric ranges,** 27 pages (1976). Order from NTIS as PB253488.

Key words: electric ranges; energy efficient products; Experimental Technology Incentives Program; life cycle costing; procurement experiments.

This report documents life cycle cost procurements of electric ranges made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why electric ranges were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-10. **Life cycle costing in the procurement of refrigerator-freezers,** 40 pages (1976). Order from NTIS as PB253260.

Key words: energy efficient products; Experimental Technology Incentives Program; life cycle costing; procurement experiments; refrigerators.

This report documents life cycle cost procurements of refrigerators made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why refrigerators were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-11. **An evaluation of the Small Business Administration Innovation Loan Program,** 119 pages (1976). Order from NTIS as PB253115.

Key words: Experimental Technology Incentives Program; federal policies; innovation loans; R&D; small business; Small Business Administration; technological change.

This is an evaluation of the Innovation Loan Program (ILP), developed and administered by the Small Business Administration during 1966-70 to assist small businesses to market innovations they had developed. The agency's objective was to support new products or processes which could be expected to achieve significant societal benefits.

Approximately 90 loans totaling more than $7 million were made during the life of the program. This evaluation was limited to the 37 identifiable loans.

Borrower entities were analyzed to determine patterns of success and failure, and the merits of their innovations. Technological sophistication and social utility of the innovations were as-

sessed. Employment and tax effects of the program were measured. Borrowers were found to be typically small, newly established, undercapitalized firms with a single product. The program was adjudged a qualified success, and revival of this or a similar program is recommended.

NBS-GCR-ETIP 76-12. **An analysis of venture capital market imperfections,** 438 pages (Feb. 1976). Order from NTIS as PB254996.

Key words: capital market imperfections; federal technology policy; SBIC's; securities and tax regulation; small firm finances; technological change; technology subsidies; venture capital.

The study estimated the total flow of funds to small technology based firms, and the composition of that flow according to financial instruments. The relative roles of various suppliers of funds to these firms were assessed. No evidence was found of substantial market imperfections that restrict the flow of funds to small technology based firms. There was no indication that small technology based firms paid higher rates of interest or return their unaffiliated stockholders more than other small firms. There was no indication that suppliers of funds to small technology based firms earned higher profits than could be earned by investing in listed securities. No elements of the structure of behavior in the venture capital industry were found which would enable firms in the business to charge higher rates or earn greater profits than necessary to compensate for the risks assumed.

The conclusion that there are no substantial capital market imperfections does not necessarily imply that the supply of funds to new technology based firms is in some sense ideal. Investment in small technology based firms may generate external effects so that the benefits to society from investment in these firms may not be accurately reflected in the prices those firms can get for their products and services or the rate of return which investors in such firms can expect to earn.

NBS-GCR-ETIP 76-13. **Life cycle costing, procurement case 1, room air conditioners,** 28 pages (July 1975). Order from NTIS as PB253475.

Key words: energy efficient products; Experimental Technology Incentives Program; life cycle costing; procurement experiments; room air conditioners.

This report documents life cycle cost procurements of room air conditioners made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why room air conditioners were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-14. **Life cycle costing, procurement case 2, water heaters,** 24 pages (July 1975). Order from NTIS as PB253476.

Key words: energy efficient products; Experimental Technology Incentives Program; life cycle costing; procurement experiments; water heaters.

This report documents life cycle cost procurements of water heaters made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why room air conditioners were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-15. **Life cycle costing, procurement case 3, gas ranges,** 30 pages (Jan. 1976). Order from NTIS as PB253477.

Key words: energy efficient products; Experimental Technology Incentives Program; gas ranges; life cycle costing; procurement experiments.

This report documents life cycle cost procurements of gas ranges made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why room air conditioners were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-16. **An experiment on accelerating the writing of nuclear standards conducted for the American National Standards Institute,** N. G. Wittenbrock, 237 pages (Sept. 1975). Order from NTIS as PB256129.

Key words: administrative experiment; American National Standards Institute; Experimental Technology Incentives Program; Nuclear Regulatory Commission; standards development; technological change.

This project was an *administrative experiment,* run in cooperation with the NRC and the American National Standards Institute. Its purpose was to determine whether any or all of four changes in the method of developing nuclear standards is a desirable method for accelerating the establishment of responsible standards which are approved by ANSI and adopted by the Nuclear Regulatory Commission. Several changes in the normal way consensus standards are drafted were made to see if their development could be expedited and the information underlying them increased. It tested: (1) the use of a full-time committee chairman (versus a volunteer chairman), (2) the provision of technical editorial services for the preparation of early draft standards, (3) the provision of technical secretarial help to expedite the translation of committee discussion into draft standards, and (4) the convocation of committees for an extended period of time by paying out of pocket costs. It was hypothesized that the changes would substantially reduce the amount of time consumed by coordinating views via the mail, telephone, and through shorter meeting periods.

NBS-GCR-ETIP 76-17. **A guide for applying the concepts of life cycle costing to procurements by state and local governments,** 209 pages (1976). Order from NTIS as PB254233.

Key words: bid evaluation; Experimental Technology Incentives Program (ETIP); innovation; life cycle costing; local government; procurement policy; state government.

This guide has been developed to assist the public purchasing community to more fully understand, and use the elements of life cycle costing in the procurement process.

The guide contains chapters on concept and theory of LCC, use of LCC in equipment purchases, use of warrantees in LCC structuring LCC procurements and selected case studies plus appropriate contract clauses in equipment procurement.

The guide has application at the Federal, State and local levels of procurement activity and for industrial purchasing agents as well.

The guide was developed as part of the Experimental Technology Incentives Program's research in the use of procurement policies in providing incentives to innovation and technological change.

NBS-GCR-ETIP 76-18. **Value incentive program household goods shipping containers,** 40 pages (July 1976). Order from NTIS as PB256642.

Key words: Experimental Technology Incentives Program (ETIP); Federal Supply Service; life cycle costing; procurement policy; specifications; value.

This case study covers the use of the Value Incentive Clause by a GSA/FSS contractor to make product improvement suggestions on Household Shipping Containers. The use of this clause allows for contractors who hold FSS contracts to make suggestions to reduce the overall cost of procurement to the government and to share in the savings resulting from their suggestion. Copies of the GSA order, and the clause itself are included in addition to the specific changes proposed for the household containers. As the result of this suggestion the government will save about $7.5 million dollars over 10 years. The contractor's share of the first year's savings exceeds $150,000.

NBS-GCR-ETIP 76-19. **Life cycle costing in the procurement of window air conditioners,** 38 pages (July 1976). Order from NTIS as PB256643.

Key words: energy efficient products; Experimental Technology Incentives Program; life cycle costing; procurement experiments; window air conditioners.

This report documents life cycle cost procurements of window air conditioners made by the Federal Supply Service (FSS), General Services Administration (GSA). These procurements were part of a program instituted by FSS to apply life cycle costing techniques to its procurement process. This program was instituted in conjunction with the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards. The material contained in the report explains why refrigerators were selected for LCC, how the LCC criteria were developed, and what results were obtained. Details concerning the screening process used in selecting the products, the preparation of the invitation for bid document, the bids received, and the evaluation, analysis and award process are covered in the report.

NBS-GCR-ETIP 76-22. **Development of flame retardants for polyester/cotton blends,** R. H. Barker and M. J. Drews, 472 pages (Sept. 1976). Order from NTIS as PB257884.

Key words: antimony oxide; bromine; bromine flame retardants; calorimetry; cotton; cotton/polyester; ETIP; fabric flammability; flame retardant mechanisms; flame retardant monomers; flame retardants; hand modifiers; inherently flame retardant polyester; phosphazenes; phosphorus flame retardants; polyester; precondensates; radiation grafting.

Initial studies were carried out to determine the flame retardant characteristics of the individual polyester and cotton fibers. Since previous studies had dealt primarily with cotton and other cellulosic materials, emphasis was placed on the polyester. Structural and chemical factors affecting flammability were determined and evaluated. The interaction of the fibers was studied in both the presence and absence of flame retardants. Several specific types of phosphorus and bromine-containing materials were evaluated to determine their relative retardant efficiencies. Various methods of fixing flame retardants onto polyester were also studied with particular emphasis placed on radiation grafting techniques. Based on the results of these studies several series of model flame retardant treatments were prepared and evaluated on 50/50 blend fabrics. The results of these studies were then used as the basis for designing new flame retardant systems having a potential for commercial application. These systems include phosphonium oligomers, a bromine-containing phosphazene and brominated aromatics with a brominated acrylate binder.

NBS-GCR-ETIP 76-23. **Value incentive program computer room air conditioning units,** 35 pages (July 1976). Order from NTIS as PB258991.

Key words: computer air conditioning units; Experimental Technology Incentives Program (ETIP); Federal Supply Service; life cycle costing; procurement policy; specifications; value incentives.

This case study covers the use of the Value Incentive Clause by a GSA/FSS contractor to make product improvement suggestions on Computer Room Air Conditioning Units. The use of this clause allows for contractors who hold FSS contracts to make suggestions to reduce the overall cost of procurement to the government and to share in the savings resulting from their suggestion. Copies of the GSA order, and the clause itself are included in addition to the specific changes proposed for the computer room air conditioning units. As the result of this suggestion the government will save about $394,000 dollars over 10 years. The contractor's share of the first year's savings exceeds $7,000.

NBS-GCR-ETIP 76-24. **A framework for analyzing commodity supply restrictions,** 240 pages (1976). Order from NTIS as PB258093.

Key words: applied microeconomic framework; commodity supply crisis; econometric analysis; economic impacts; efficiency impacts; income distribution effects; policy alternatives.

Study addresses commodity supply crises due to producer country export policies, and considers the issue of resource exhaustion only as it relates to this problem. The primary concern is with *economic* impacts and policies. Crises in commodity supplies may well have political impacts, but detailed treatment of such effects is beyond the scope of the study. Possible political and diplomatic constraints on U.S. policies are considered, but the primary concern is with economic impacts.

Policies differ in their effects on the distribution of income between producers and consumers. Such effects are considered, where appropriate. Concentration is on efficiency impacts, however, and there is no attempt to address effects on the size distribution of income.

The basic analytical approach is that of the applied microeconomist working in a supply and demand framework. This framework allows the use of available qualitative economic, econometric and engineering information. There has been no use of mathematical programming or input-output techniques as it is

believed that the techniques employed are, for the purposes of this study, more productive within time and budget constraints.

U.S. Patent 3,950,995. **Ambient pressure probe,** R. D. Marshall, (Apr. 20, 1976).

Key words: ambient pressure probe; omnidirectional pressure probe; pressure probe shroud; static pressure; weatherproof pressure probe; wind field pressure measurements.

Ambient or static pressure in a fluid stream is sensed with a hollow circular cylinder placed normal to the fluid stream. A shroud is mounted on the cylinder for adjustment over a ring of ports provided in the cylinder. In this manner, the relationship between the internal pressure in the cylinder and the ambient pressure is controllable. Ideally, the internal and ambient pressures are exactly equal. Further, extension of the cylinder above and below the shroud provides symmetry for positive and negative angles of attack.

U.S. Patent 3,958,269. **Color subcarrier frequency comparator,** D. D. Davis, (May 18, 1976).

Key words: color subcarrier; frequency calibration; frequency comparator; frequency measurements; oscillator calibration; phase comparison; television receiver.

Apparatus for measuring the frequency of a reference signal which utilizes the color subcarrier signal of a television receiver as a standard frequency signal. In a first embodiment, the reference signal controls a circuit to develop bursts of a synthesized color subcarrier signal, gated at the horizontal line rate of a color television receiver. The synthesized signal is superimposed on the broadcast television signal and applied to the receiver to produce a modulation bar on the screen. Any frequency/phase difference between synthesized and broadcast color subcarrier signals will cause the modulation bar to move laterally across the screen, and/or cause the sequence of colors within the modulation bar to vary. Movement of the modulation bar is a coarse indication of frequency difference and change of the color sequence within the bar is a precise indication of phase difference.

In a second embodiment, the locally synthesized color subcarrier signal and the color subcarrier signal of the television receiver are compared in a linear phase comparator to develop a signal having an instantaneous voltage proportional to the phase difference between the two signals. The phase signal controls a generator which develops a cursor line on the screen. Movement of the line across the screen provides a coarse indication of phase difference between the subcarrier signals. The phase signal is also applied to a digital counter which affords a precise readout of the phase difference between the signals.

U.S. Patent 3,966,413. **Electrochemical chlorine flux monitor,** G. Marinenko, (June 29, 1976).

Key words: calibration cell; chlorine concentration; chlorine monitor; electrochemical calibration; internal calibration; iodine detection; potassium iodide.

This apparatus for monitoring the chlorine concentration of water has a unique internal calibration capability and a high sensitivity. A water sample is mixed with a solution of potassium iodide and the reaction produces a mole of iodine for every mole of chlorine present in the water. The mixture is passed through a detection and calibration assembly wherein the iodine is detected amperometrically by a detection cell. Calibrant (known) iodine fluxes, equivalent in effect to the unknown chlorine-produced iodine fluxes, are supplied to the detection cell during calibration runs by means of an upstream calibration cell which electrolyzes the iodide (preferably added to distilled water) to iodine at flux rates given simply by the electrolyzing currents divided by Faraday's constant. An electronics package having gain and offset controls and a concentration display is provided.

U.S. Patent 3,967,140. **Tunnel diode pulse generator,** J. R. Andrews, (June 29, 1976).

Key words: directional coupler; fast risetime; flat pulse baseline/topline; pulse generator; step waveform; tunnel diode.

A tunnel diode pulse generator is triggered through a directional coupler. The tunnel diode is coupled across one end of an output transmission line through an impedance matching network which matches the characteristic impedance of the transmission line. Triggering signals are coupled to the transmission line through the directional coupler for propagation of triggering impulses towards the tunnel diode.

U.S. Patent 3,968,363. **Radiation flux averaging device of high efficiency,** K. D. Mielenz, R. Mavrodineanu, and E. D. Cehelnik, (July 6, 1976).

Key words: averaging sphere; averaging ultraviolet and visible light; radiation converter; ultraviolet averaging sphere; ultraviolet to visible converter.

A flux averaging sphere having an improved efficiency and a high averaging and diffusing effectiveness over the visible and ultraviolet ranges. The interior surface of the sphere is coated with a white diffusing material which has a higher reflectance for visible radiation than for ultraviolet radiation. A radiation converting means is disposed inside the sphere for converting incoming ultraviolet radiation to visible radiation before reflections from the sphere wall occur. The radiation converting means is transparent to incoming visible radiation which therefore remains unaffected. The efficiency of the device is further improved by eliminating the small gap between the output area and the face of the photomultiplier tube. The sphere is formed with a tapered tubular extension at the output area and the face of the photomultiplier tube is abutted against the end of the extension thereby forming a substantially light tight seal.

U.S. Patent 3,970,862. **Polymeric sensor of vibration and dynamic pressure,** S. Edelman, S. S. Roth, and J. F. Mayo-Wells, (July 20, 1976).

Key words: dynamic pressure transducer; polymeric film transducer; sandwiched polymeric films; vibration transducer.

A transducer, and method for making it, comprising a composite film for sensing pressure comprising a pair of film sandwiches, each sandwich comprising a poled polymeric films with metallic film electrodes on opposite surfaces. One electrode does not extend quite to the end of the polymer and is considered the "hot" electrode. Two such transducer film sandwiches are cemented together with the hot electrodes in contact with each other, the center wire from a coaxial cable being in contact with and between them. The outer electrodes are electrically connected to the shield of the cable and the connection is encapsulated.

U.S. Patent 3,973,970. **Additive composition for making dental materials,** C. P. Mabie, (Aug. 10, 1976).

Key words: ammonium stabilized silica and alumina sols; colloidal alumina and silica for dental porcelain; dental porcelain; porcelain balling reduction.

Addition of ammonium stabilized colloidal silica, borax and boric acid to the distilled water in which dental porcelain is fired

greatly increases the firing range by reducing "balling" or edge rounding, and flow deformation. Greatly increased machinability and indefinitely prolonged green-biscuit strength is also obtained by the use of the present additive without deleterious effects on the porcelain.

U.S. Patent 3,975,940. **Portable tester for measuring the static coefficient of friction between a floor surface or the like and a shoe sole or heel material or the like,** R. J. Brungraber, (Aug. 24, 1976).

Key words: floor slipperiness; slipperiness tester; static coefficient of friction measurement.

A portable testing device for determining the static coefficient of friction between a floor surface and a shoe sole or heel material includes an upper, weighted strut movable within a vertical plane and a lower strut pivotably secured to the bottom portion of the upper strut. The upper strut is mounted within a bearing block which is translatably movable within a horizontal plane, and the lower strut has secured to the bottom portion thereof a yoke within which a metal shoe carrying a representative shoe sole or heel material to be tested is pivotably secured. The yoke and shoe project through the base of the device framework so as to rest upon the flooring material being tested, and a trigger is disposed near the shoe so as to be actuated thereby upon the occurrence of slip between the shoe and flooring materials. The trigger is in turn connected to a friction clutch which controls the movement of a graduated rod, which is coupled to the bearing block so as to monitor the movement thereof and upon which the static coefficient of friction data is indicated, and upon the occurrence of slip, the movement of the rod is arrested by the clutch mechanism whereby the friction coefficient may be read directly from the rod.

U.S. Patent 3,996,120. **Laser-induced photochemical enrichment of boron isotopes,** S. M. Freund and J. J. Ritter, (Dec. 7, 1976).

Key words: boron isotope separation; boron trichloride; isotope enrichment; laser isotope separation; photochemical enrichment.

A boron trichloride starting material containing both boron-10 isotopes and boron-11 isotopes is selectively enriched in one or the other of these isotopes by a laser-induced photochemical method involving the reaction of laser-excited boron trichloride with either H_2S or D_2S. The method is carried out by subjecting a low pressure gaseous mixture of boron trichloride starting material and the sulfide to infrared radiation from a carbon dioxide TE laser. The wave length of the radiation is selected so as to selectively excite one or the other of boron-10 BCl_3 molecules or boron-11 BCl_3 molecules, thereby making them preferentially more reactive with the sulfide. The laser-induced reaction produces both a boron-containing solid phase reaction product and a gaseous phase containing mostly unreacted BCl_3 and small amounts of sulfhydroboranes. Pure boron trichloride selectively enriched in one of the isotopes is recovered as the primary product of the method from the gaseous phase by a multi-step recovery procedure. Pure boron trichloride enriched in the other isotope is recovered as a secondary product of the method by the subsequent chlorination of the solid phase reaction product followed by separation of BCl_3 from the mixture of gaseous products resulting from the chlorination.

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS SP 535 Vol. 1 & Vol. 2	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE
Catalog of National Bureau of Standards Publications, 1966 - 1976.
Vol. 1 (Pt. 1 and 2) Citations and Abstracts
Vol. 2 Key Word Index (A Through L; M Through Z)

5. Publication Date 1978

6. Performing Organization Code

7. AUTHOR(S)
Betty L. Burris and Rebecca J. Morehouse, Editors

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Same as Item 9

13. Type of Report & Period Covered
Jan. 1966 - Dec. 1976

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES
Vol. 1 and 2 (1966 - 1976) have been updated by SP 305, Supplement 9.
Library of Congress Catalog Card No. 78-600145.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The published output of NBS for 1966 through 1976 is cataloged and indexed in this two-volume publication. Parts 1 and 2 of Volume 1 consist of reprints of abstracts and full citations of all published papers during the 11-year period as they originally appeared in the NBS annual publication catalogs - NBS SP 305 and its Supplements 1 through 8. Volume 2 is a consolidated permuted key word index which directs the researcher of NBS literature either to the citations and abstracts of Volume 1 or to the same information in the nine annual catalogs issued during the 11-year period. Annual supplements to SP 305 will continue to update the NBS published output; the 1977 supplement is now available as NBS SP 305, Supplement 9.

Complete catalogs available in two volumes, 2 parts each as follows:

SP 535, Volume 1 (2 parts), order as Stock No. SN003-003-02010-9, price $23.75

SP 535, Volume 2 (2 parts), order as Stock No. SN003-003-02011-7, price $21.25

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*
Catalog of NBS publications; citations and abstracts of NBS publications; NBS publications program; eleven-year key word index (1966 - 1976); index to NBS publications.

18. AVAILABILITY

☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☒ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003- See Item 16.

☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED

21. NO. OF PRINTED PAGES Vol. 1, 1908 Vol. 2, 1569

22. Price See Item 16

USCOMM-DC

☆ U. S. GOVERNMENT PRINTING OFFICE : 1979 O - 284-672

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH—The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology, and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service to subscribers each issue contains complete citations to all recent NBS publications in NBS and non-NBS media. Issued six times a year. Annual subscription: domestic $17.00; foreign $21.25. Single copy, $3.00 domestic; $3.75 foreign.

Note: The Journal was formerly published in two sections: Section A "Physics and Chemistry" and Section B "Mathematical Sciences."

DIMENSIONS/NBS

This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS. The magazine highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, it reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing.

Annual subscription: Domestic, $11.00; Foreign $13.75

NONPERIODICALS

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a world-wide program coordinated by NBS. Program under authority of National Standard Data Act (Public Law 90-396).

NOTE: At present the principal publication outlet for these data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St. N.W., Wash., D.C. 20056.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

Order **above** *NBS publications from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402*

Order **following** *NBS publications—NBSIR's and FIPS from the National Technical Information Services, Springfield, Va. 22161*

Federal Information Processing Standards Publications (FIPS PUB)—Publications in this series collectively constitute the Federal Information Processing Standards Register. Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

NBS Interagency Reports (NBSIR)—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Services (Springfield, Va. 22161) in paper copy or microfiche form.

BIBLIOGRAPHIC SUBSCRIPTION SERVICES

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau:

Cryogenic Data Center Current Awareness Service. A literature survey issued biweekly. Annual subscription: Domestic, $25.00; Foreign, $30.00.

Liquified Natural Gas. A literature survey issued quarterly. Annual subscription: $20.00.

Superconducting Devices and Materials. A literature survey issued quarterly. Annual subscription: $30.00. Send subscription orders and remittances for the preceding bibliographic services to National Bureau of Standards, Cryogenic Data Center (275.02) Boulder, Colorado 80302.