NBS SPECIAL PUBLICATION 340

NBS TECHNICAL HIGHLIGHTS 1970

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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In 1966 NBS published MEASURES FOR PROGRESS,* an authoritative history of the Bureau's first 50 years (1901-1951). Written by Dr. Rexmond C. Cochrane, MEASURES FOR PROGRESS recounts not only the scientific progress made during this period, but reflects the social environment in which the Bureau operated as well. Listed below are some of the pioneering achievements of NBS assembled from MEASURES FOR PROGRESS and updated through 1969.

- 1904 Development of First Neon Tube—Commercialized and a new industry founded about 1930.
- 1908 First Postgraduate School in Government Established—Now conducted in cooperation with universities in the Washington area.
- 1914 Precise Determination of the Faraday—A classical determination of an important physical constant that stood until a recent redetermination at NBS.
- 1915 Development of Radio Direction Finder—Now in general use by all commercial airlines.
- 1922 First AC Radio Set—Development of the first alternating current radio set was perhaps the most revolutionary development in radio; it put radio in the home.
- 1930 Measurement of Constant of Gravitation—An historic redetermination of an important constant of nature.
- 1934 Preparation of Heavy Water—Provided the experimental basis for Urey's Nobel Prize-winning work.
- 1938 The Electric Hygrometer—Greatly increased the accuracy of measurement of humidity in radio meteorography; now standard for present-day radiosondes.
- 1941 Radio Proximity (VT) Fuze for Bombs—The proximity fuze was widely used during latter part of World War II and was considered second in importance only to the atomic bomb.
- 1942 Carbon Monoxide Indicator—A sensitive colorimetric indicator of carbon monoxide, now widely used in mines, aircraft, etc.
- 1944 First Successful Guided Missile: the Bat—The only automatic, homing guided missile carried into large-scale production and used in combat during World War II.
- 1946 Electrodeless Plating of Nickel—Now the basis of multi-million dollar industries.
- 1946 Printed Circuit Techniques—First used in production of radio proximity fuzes, these techniques are now widely used in the manufacture of electronic assemblies.

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* MEASURES FOR PROGRESS by Rexmond C. Cochrane (1966). Available from the Superintendent of Documents at $5.25 a copy.

(Continued on inside of back cover)

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UNITED STATES DEPARTMENT OF COMMERCE

Maurice H. Stans, *Secretary*

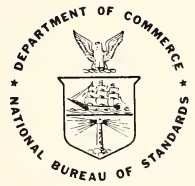
Rocco C. Siciliano, *Under Secretary*

NATIONAL BUREAU OF STANDARDS

Lewis M. Branscomb, *Director*

1970
Technical Highlights
of the
National Bureau of Standards

Annual Report, Fiscal Year 1970



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THE DIRECTOR'S STATEMENT

During the past year, as NBS reexamined its goals, organization, and programs in the light of national needs, one fact became clear: never have the skills, talents, and dedication of this fine laboratory been more critically needed. The urgent need to restore the environment, to protect the citizen from unreasonable hazards, to give the consumer a better break, and to strengthen economic productivity all place even heavier demands on U.S. science and technology. And these demands are being made at a time when many are questioning the ability of our society to use the fruits of science wisely. The focal point of this concern has been the ability of the decision-making institutions to make wise choices in an increasingly complex world.

The goal of the National Bureau of Standards—TO STRENGTHEN AND ADVANCE THE NATION'S SCIENCE AND TECHNOLOGY AND TO FACILITATE THEIR EFFECTIVE APPLICATION FOR PUBLIC BENEFIT—reflects the Bureau's dual role, both as an instrument of government and as a primary resource for the Nation's scientific and technological endeavors. Thus while NBS makes many very important contributions to the body of scientific understanding and engineering know-how, the most significant impact lies in facilitating the advance of science and its wise use by the society. In this endeavor, NBS programs serve a number of communities:

- Science and Engineering (promoting more accurate, meaningful and compatible technical data and measurements)

- Industry and Government (promoting more effective use of science and technology)

- Consumers and Sellers (promoting equity in trade and confidence in a competitive marketplace)

- Public Safety (advancing effective test methods and standards for protecting the public from hazards identified by the Congress)

The Bureau, long a central technical resource available to all Federal agencies, worked cooperatively with 23 departments and agencies during the year. Demand for NBS services continued to rise, and the urgent pressure from areas of social concern has found NBS ready to respond. Important examples of expanded activity in collaboration with other agencies include meeting National housing needs (HUD), automotive safety (DOT), crime control (Justice), noise pollution (DOT), toy and product safety (HEW and FTC), medical materials (HEW/NIH), air pollution (HEW/NAPCA), and operations research and management sciences (many agencies).

NBS also gave a high priority to legislatively assigned, socially oriented programs. One example is the flammable fabrics program, which was greatly accelerated and became productive in its efforts to insure that the public is not exposed to unreasonable risk from flammable garments or household furnishings.

Two activities of the Building Research Division deserve special mention: developing the technical basis for performance standards for construction, and helping reform the national system of building standards and regulations. At stake is the potential for expansion of an industrialized housing industry which could by 1980 double the capacity for providing new dwelling units. Progress was marked by the rapid growth of the National Conference of States on Building Codes and Standards, and the major technical support furnished by NBS to HUD's project BREAKTHROUGH.

NBS initiated a substantial research program aimed at improving the quantitative basis for air pollution measurements, based in part on the Bureau's Standards Reference Materials. NBS staff members made important contributions to many of the Government's policy studies on noise pollution during the year and set about strengthening technical capabilities in acoustics research.

Other notable contributions to technological aspects of national social problems were made in the field of mine safety (an NBS scientist was elected Chairman of the Interim Compliance Panel established by the 1969 Mine Safety Act), confidence in the fairness of

the draft lottery (NBS statisticians assured randomness in the method of ordering the birthdates), and tracking down the cause of the failure of the Apollo 13 mission to the moon (two NBS cryogenics engineers were leaders in the NASA analytical team). In these activities, as in many others, the Bureau's technical capability and reputation for independence and integrity were prime factors in our involvement.

The year also marked some major advances in measurement science. The development of a saturated absorption laser in our Boulder laboratories demonstrated that stabilized lasers can provide an improvement of a factor of perhaps a thousand in the accuracy with which a length can be defined. This work set off efforts in the laboratories of several nations to examine the desirability of replacing the current definition of the meter with a new laser standard. Exploitation of the Josephson effect in superconductivity suggested that some day it may also be possible to put electrical measurements on a fundamental atomic basis, relating differences in electrical potential to time through the frequency standard. And very accurate measurements with the NBS x-ray interferometer gave promise of linking the entire domain of x-ray measurements to the meter with greatly improved accuracy. This continued improvement in the fundamental basis for accuracy and compatibility in physical measurement is a constant NBS concern.

NBS also gave high priority attention to the domain of practical measurements that link the apex of our measurement system to the every-day needs of technical people throughout the land. In the field of precision engineering, serving both the machine measurement and machine tool industries, we found that the laser and the computer are rapidly being incorporated in the more sophisticated new commercial developments. Indeed, saturated absorption lasers may be controlling dimensions in precision production machinery before the international standards community can agree on its acceptability as a new length standard. This American gift for incorporating the results of scientific research into new products and services is the source of much of our economic strength. But such rapid advance

makes it almost impossible for NBS to satisfy once and for all the measurement needs of U.S. technology. The National basis for measurement, provided by NBS, must be superior in accuracy to the requirements of those whom NBS serves. But each new advance in basic measurements capability is quickly taken over and exploited for the benefit of all. NBS is therefore always reaching out for an ever-receding goal. This situation need not worry us, as we can measure our progress better by the rate at which the National measurement system grows and improves than by the satisfaction in reaching an accuracy goal set in earlier years.

The importance given to improving NBS work on multidimensional metrology was reflected in the merging of two divisions into a new Optical Physics Division, with a substantial expansion of research on the scientific basis for better measurement planned. This one example from the measurement research effort at NBS illustrates the dynamic nature of evolving requirements, a feature which is common to every one of the dozens of physical and engineering quantities whose central basis is provided at NBS.

NBS continued taking new steps to insure that the National measurement capability realized at NBS was readily transferable to everyone who needs assurance that their work is sufficiently accurate and compatible with that of others. The Measurement Analysis Program, which features procedures for self calibration of man-instrument-environment systems *in situ*, was extended to additional quantities. The same procedure was introduced into the services assembled under the NBS Standard Reference Materials program. NBS began to assist the users of SRMs with development of approved measurement and data analysis methods and with periodic accuracy evaluations based on measuring NBS supplied samples. Because of the health implications of reliability and accuracy in clinical measurements, this process has been given special emphasis for the biochemical SRMs, such as cholesterol. In this area NBS is working in cooperation with Federal agencies and private organizations in medicine and clinical chemistry.

This brief look at NBS—its goals, its people, its programs—reveals

a laboratory that is a broadly based National resource. Bureau services range from the most sophisticated research to improve the basis for accurate scientific measurements to work on the task of protecting people from the misuse of technology. In every case the laboratory seeks to promote the growth of the institutions needed to provide means for feedback that will insure the practical usefulness of NBS research. It is not sufficient to publish and hope that others will exploit our work; we must take steps to insure maximum application of our results for public benefit. The extensive contributions to knowledge reflected in this annual report will then be doubly valuable and responsive to the needs of the Nation.

NBS AND THE CONSUMER*

The stated purpose of the National Bureau of Standards, to ". . . promote the strength of the nation's science and technology and their effective application for public benefit, . . . " has a special meaning for the consumer in this era of rapid technological change.

As a nation, we have become increasingly dependent on technology for our comfort, convenience, and safety; yet most of the appliances and machines we buy are too complicated to fix at home; quality and dependability are not what they might be; and repair services are costly and slow. Safety has become an increasingly important factor as we harness greater power, higher voltages, and greater speed to the satisfaction of our needs.

The marketplace, too, is changing. When we buy a product we may see the salesman only once; we may never meet the store owner or the manufacturer; and we have no way of judging in advance the competence of the serviceman. Even food is prepackaged so that we can't touch it, smell it, or taste it before we take it home.

We will not return to a simpler marketplace. Today's supermarkets and mass outlets exist because they are the most efficient systems for bringing mass-produced products to a market of 200 million consumers. Nor are we likely to return to simpler products. The trend is toward greater complexity, and greater dependence of the individual upon the built-in safety and dependability of the products he buys.

And now the environment, itself, is threatened. Unless we learn to control the unwanted side effects of technology we will not only destroy our legacy of clean air and water; we may interfere with life support systems upon which our very existence depends.

The question is, how can we protect the citizen from hazards, provide greater consumer satisfaction, promote the economic strength of the nation, improve the environment, and do all these things by means which preserve free enterprise and minimize the stresses on our democratic institutions?

The National Bureau of Standards assumes its full share of responsibility in seeking answers to these questions. Without undercutting our basic and central programs of research, and without reducing our service to science, to industry, or to other government agencies, we intend to do our full share of protecting the safety of the consumer, and providing information to help him make intelligent choices in the marketplace.

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* This section, and the following sections on the Metric Study, Flammable Fabrics, Measures for Air Quality, and Building Technology, are intended as overviews rather than as detailed reports of the year's activities. Detailed accomplishments in these areas are reported in the main body of the text.

We believe we can best serve the interests of the consumer in three basic areas: measurement, product and safety standards, and information.

Measurement

As the nation's measurement laboratory, we are moving in two directions: first, to improve the accuracy of measurement; and second, to make improved measurement standards and techniques available to those who need them.

Measurement Research—Basic research to improve fundamental measurement standards may seem remote from the consumer, but in actual fact this research is essential to continued improvement of products and services. Modern communications, computers and systems for data processing and process control, medical technology, high precision manufacturing processes, and increasing numbers of products owe their existence in part to refinements in the measurement of such variables as length, time, mass, and voltage made possible by NBS and other similar organizations throughout the world.

Weights and Measures Program—But we do not stop with the development of improved measurement standards. We have a variety of programs designed to make improved measurement technology work for industry and the consumer.

For example, when you buy a pound of meat it is weighed on a scale that has been calibrated and tested by an official of your state government. Behind the official is a State Weights and Measures Laboratory; and that Laboratory is equipped with a complete set of standard weights and measures supplied by NBS.

We are now nearing the end of a program to modernize these standards. Forty states are already using the new, more accurate standards, and the last group of ten sets is now being manufactured for early distribution.

Fair Packaging—Closely related to the goal of accurate weights and measures is the goal of fair packaging. Since the Fair Packaging and Labeling Act became effective in July 1967, NBS has been working with industry to reduce the number of package sizes for such items as cereals and detergents, and to make labels more informative. The objective is to make it easier for the consumer to make intelligent comparisons of different sizes and costs when he makes a purchase. To date, 51 product categories have been standardized by voluntary agreement among the companies in the industries involved.

U.S. Metric Study—At the request of Congress, we are now carrying out a study to determine the advantages and disadvantages of increased use of the metric system in the United States. The British metrication program is proceeding; Australia and New Zealand are planning their conversion program; and Canada has declared its intention to change. This leaves the United States as the only major country not using the metric system or committed to changing. Some economists fear that the long range effect on our world trade—and therefore our prosperity—might be severe if we do not move in the direction of increased use of the metric system and international standards.

In our study we are seeking to determine for all sectors of society, including consumers, the advantages, disadvantages, costs, and benefits of alternative courses of action feasible for the United States. The present impact of increasing worldwide use of the metric system and the possible effects of any move toward increased metrication are carefully being investigated.

Standards

One of the major applications of measurement is the development of guidelines which help to standardize product design and engineering practice.

Voluntary Product Standards—The vast majority of the product standards which regulate the marketplace in the United States are voluntary standards developed largely by expert committees of standards-making organizations such as the American National Standards Institute. NBS plays an important role in these standards-making activities. At the present time we have over 400 staff members working in direct cooperation with more than 1,000 industry committees.

Mandatory Standards—At times, when the Congress decides that the public welfare is threatened, NBS becomes involved in the development of mandatory standards. We are now working to establish a technical base for standards regulating the flammability of fabrics.

Under the provisions of the Flammable Fabrics Act of 1967, the Secretary of Commerce was given the responsibility of developing mandatory flammability standards when he finds that the public may be subject to "unreasonable risk." NBS has the responsibility of providing the necessary technical information.

We are now carrying out various researches into the flammability of products, fabrics, and materials; studying the feasibility of reducing the flammability of products, fabrics, and materials; developing flammability test methods and testing devices; and developing training methods in the use of these methods and devices.

Interagency Cooperation

From time to time NBS provides expert advice, or carries out formal research programs in support of the missions of other Government Agencies.

Building Research—During the past year we have worked in close cooperation with the Department of Housing and Urban Development in support of Project BREAKTHROUGH, bringing our capabilities to bear on the problem of low cost housing. Our assignment was to develop performance statements for the housing systems selected under the program. Specifically, we are providing answers to two fundamental questions: how well does a material, component, or system perform in making a safe and healthful building; and how well does the building perform in meeting the needs of the user?

These performance statements are intended to take much of the guesswork out of the selection of designs and materials for buildings, and contribute to the improvement of building standards and codes.

Automobile Safety—Under the sponsorship of the National Highway Safety Bureau in the Department of Transportation, the Office of Vehicle Systems Research in NBS is developing precise measurements and research data upon which to base vehicle safety performance standards.

Seat belts have been evaluated from the standpoints of anchorage locations, retractor requirements, corrosion resistance, webbing strength, and low temperature performance.

Brake linings, drums, discs, and fluids have been subjected to a broad range of conditions, and their performance measured and evaluated in relation to the total system.

A comprehensive tire use survey has been completed and work is underway to develop the technical base for a uniform grading system which will enable consumers to make an informed choice in the selection of tires. Major factors which are being considered include tread wear, resistance to impact damage, and resistance to casing breakdown.

Special Programs

In addition to its assigned missions, NBS acts in support of broad objectives of the Administration, breaking new ground in areas of importance to the consumer. Two such programs are now underway.

Air Pollution—Prerequisites to a successful attack on the air pollution problem are precise information about the identity of pollutants in the air; their method of interaction; the influence of other environmental factors; and faster, more accurate methods of measuring pollution levels.

Each of these problems is fundamentally a problem of measurement, and a proper focus for NBS activity. Consequently we have initiated a new program called Measures for Air Quality to provide the measurement base needed for future programs of government and industry.

Consumer Information Series—President Nixon has placed a strong emphasis on the need for accurate information to help the consumer make intelligent choices among available products and services.

The National Bureau of Standards does not test or recommend products, but our research on measurement and standards produces information in many areas which are of potential value to the consumer. At the request of Secretary of Commerce Stans, we are initiating a new series of consumer pamphlets called the Consumer Information Series. The content of the booklets will be based on material developed in technical programs carried out by NBS, supplemented by information readily available to NBS scientists and engineers.

Since our goal will be to provide general information which the consumer can use to reach his own decisions, the material will be presented in some depth, in layman's language, with liberal use of photographs, drawings, and charts to insure communication.

Three booklets in this series have been written and will have been published by the time this Report appears. FIBERS AND FABRICS covers the commonly used natural and man-made fibers, lists the properties of the fabrics made from each fiber, and offers practical suggestions for handling and care.

TIRES, THEIR SELECTION AND CARE stresses the importance of tires in automotive handling and safety; offers practical advice for the care of tires; describes the types of tires available; and offers guidelines for the selection of tires to match the car, the driver, and the road.

ADHESIVES FOR EVERYDAY USE describes the types of adhesives which modern chemistry has made available to the home owner and hobbyist, and offers practical suggestions for their use.

Other booklets now in preparation will cover the subjects of hearing aids, flooring, plywood, care of books and documents, color harmony, seat belts, and rugs and carpets. The booklets, ranging in size from 16 to 32 pages, will be available to the public through the Government Printing Office.

METRIC STUDY

What is the present impact within the United States of increasing worldwide and domestic use of the metric system?

What would this impact be in the future, assuming that the use or nonuse of the metric system continues as at present, with no coordination among the various sectors of the society?

Alternatively, what would be the effect of a coordinated national program to increase the use of the metric system?

Briefly stated, these are the basic issues as the U.S. Metric Study enters its most searching phase, gathering data through questionnaires and special surveys.

Responsibility for the study was assigned to the National Bureau of Standards by the Secretary of Commerce after passage of Public Law 90-472. This law authorizes the Secretary to conduct a program of investigation, research, and survey in order to appraise the current situation and gage the likely effects of various alternative courses of action by the United States. According to Dr. Lewis M. Branscomb, NBS director, the survey "will present more solid data on the importance of a viable measurement system to a highly technological society than has ever been available before," regardless of the final U.S. decision on the question of metric usage.

The study is divided into three phases. The first (1969) involved planning and developing key questions to be answered by the study and identification of economic sectors to be surveyed, with attention to other areas to be investigated, such as engineering standards and history. Phase two (1970) involves gathering the data through questionnaires and special surveys. In the concluding phase (1971), data will be analyzed and a report embodying the Secretary's recommendations will be written.

Directed by Daniel V. DeSimone, the U.S. Metric Study is focused on: manufacturing industry; nonmanufacturing industry; Federal, state and local government impact; international implications; history of metric debate in the U.S.; engineering standards problems; commercial weights and measures activities; consumer attitudes and problems; educational issues; and impact on labor.

To give the study a broad base, a series of National Metric Study Conferences in the summer and fall of 1970 provided for participation of many groups and sectors of the economy in phase two of the study. Included were conferences of engineering industry and professional societies, consumer-related groups, educators, the construction industry and labor, and groups from other economic sectors.

Results of questionnaires, meetings, and interviews will become part of surveys in the following areas:

- A manufacturing survey, approved by the Bureau of the Budget, and conducted in cooperation with the American National Standards Institute and numerous other industry associations.
- A nonmanufacturing survey aimed at selected nonmanufacturing industries where the issues of the study are of sufficient concern to warrant inquiry.
- A defense study, concerned with the probable effects on national security of alternative courses of action. This study is being conducted by a special Department of Defense team and will cover all branches of the military.
- A Federal Survey, enlisting the cooperation of some 35 major agencies and departments. This survey is seeking information with respect to the probable impact that "going metric" would have on government operation and areas of responsibility.
- A special investigation of weights and measures to determine probable effects and practical difficulties associated with a shift toward greater metric usage.
- A standards survey, concerning the question of how U.S. engineering standards compare with internationally adopted standards and what impact, if any, a change in our measurement system would have on U.S. effectiveness in international standards negotiations. This survey is half completed and moving along.

Some fifty private citizens are serving on the National Metric Advisory Panel, established to assist the U.S. Metric Study in areas in which panel members are expert. The panel chairman is Louis F. Polk, president of Louis F. Polk, Inc., chairman of the ANSI metric advisory committee, president of the Polk Foundation, and a director of the Bendix Corporation.

In approaching the whole question, leaders of the study bear in mind that increased metric usage can, of course, take either or both of two distinct forms—one, by merely changing the measurement language in which an object is described, and the other by physically changing the size of the object to conform to a metric standard. The physical change, commonly described as a change in "hardware," by its nature has a much greater impact than the language change. Involved in a "hardware" change are questions of metric engineering standards, the interlocking characteristics of various segments of manufacturing industry (e.g., mating of components such as metric-sized fasteners to fit into metric-sized threaded holes), and the availability of metric-sized materials and parts called for in the specifications.

In framing survey questions for the U.S. Metric Study, certain realistic assumptions had to be made:

- In all manufactured products the use of the metric system would be increased only in new or redesigned items.
- Items in use—whether by the manufacturer, the consumer, the service shop, or the sales establishment—would not be converted to metric until they needed replacement. However, even then, such replacement would not occur if it was impractical to do so. By way of illustration, the size of electric outlets and plugs and the spacing between the screw-holes of outlet face plates would not be changed, nor would the gage of railroad tracks, although at some future date engineering handbooks would show railroad gage to be 1.435 meters instead of 4 feet 8½ inches.
- An exception to the above rule would be weighing and measuring devices and equipment used in commercial trade. Existing equipment would be changed to metric on a specified time schedule.

From the beginning, NBS realized that any governmental action with regard to increased metric usage would depend on an appraisal of the likely effects of a changeover on producers and consumers for all economic sectors as well as international considerations.

The Federal Surveys

Congress, especially noting that the system of measurement in the U.S. has an important role in military operations, made specific reference to investigating the "military advantages and disadvantages" of increased metric usage in the United States. The Department of Defense immediately undertook the task, designating the Air Force to lead the study. Synthesis of DOD results into the final NBS report is scheduled for December. NBS is coordinating a similar study involving all other Federal agencies. As with the DOD study, the object is to assess the effect of increased metric usage on such systems as transportation and communication.

Manufacturing Industry Survey

The approach decided upon was a two-part manufacturing industry survey. Part A is general in nature, with questions designed to be answered by executives familiar with overall operations of their company. These questions probe into the extent and rate of increase of current metric usage.

To arrive at a "rate," the questionnaire asks for extent of usage 10 years ago, now, and expected usage 5 years from now for the same segments. Part A then proceeds to questions relating to metric usage in export trade and foreign operations, anticipated advantages

and disadvantages if the company decided to metricate, what impact it foresees in the form of competition from imports, what changes it anticipates in its export trade, and their evaluation of the need for development of international engineering standards.

Part B of the questionnaire will yield data on the cost to industry if it were to increase metric usage on an optimum time schedule. Added manufacturing costs (basically, one-time costs) would include: development and adoption of new standards; replacement of engineering drawings; retraining of engineers, draftsmen, and operators; retooling and modification of production equipment by replacement of gages, dials, and feed-rate indicators; and increased inventories during the transition period. It already has been determined that for some manufacturing groups it would be impractical to produce hardware to metric standards. Oil well equipment, which enjoys worldwide acceptance and usage in customary units of measurement, illustrates one such industry. Rolling stock for railroads is another.

Because the determination of added costs to a company requires expensive in-depth studies, only several hundred companies are expected to respond to the cost questionnaire. To make maximum use of the small sample, the manufacturing spectrum was divided into three broad categories:

- Industries with potentially substantial cost impact, particularly where mating of parts and assembly of components is required. Automobiles and machinery are examples.
- Industries in which the cost impact would be slight, because only language changes—such as in labeling and change of dials or gages to read in metric units—are involved. These relate primarily to companies that package their product (e.g., paint, canning, pharmaceutical, refining, and milling).
- Industries for which little or no cost impact would result. Examples include cutlery, periodicals, costume jewelry, and novelties.

Nonmanufacturing Industry Survey

The diverse nonmanufacturing industry includes such categories as agriculture, forestry, fisheries, mining, construction, public utilities, wholesale and retail trade, finance, and services. There are subdivisions within each of these paralleling those described in the manufacturing survey.

The survey employs statistical techniques in developing a sample from the Standard Industrial Classification (SIC) as established by the Bureau of the Budget and used by the Bureau of the Census in its surveys. One aspect not to be overlooked is the determination

of whether the small business would face more serious dislocation than its larger competitors.

Education, Consumer, and Labor Surveys

Potential advantages of the metric system in the fields of education and science have been well understood for over a century, paving the way, for example, for the metrication of the pharmaceutical industry in the United States and for extensive, if not predominant, use of the metric system in the teaching of science courses in our secondary schools and colleges. But the bulk of our education and engineering community, serving the public and industries accustomed to the inch-pound-gallon system, has used the customary system of measurement in the instruction of our students and the training of our workers. Now the task is to see what the advantages are and what problems might develop from increasing metric usage by students, by workers, and by the general public.

A separate study for each of these groups is planned. The current studies differ from previously described surveys in that the questions will be directed for the most part to associations or professional organizations representing population segments such as the student in the school, the housewife shopping at the store or cooking in the home, and the carpenter and other skilled workers in the construction industry.

Engineering Standards Study

Two of the key questions for which this study is seeking answers are:

- To what extent are U.S. standards incompatible with international standards because of the differences in the system of measurement?
- Can we retain and promote U.S. standards internationally whether or not there is a change in our measurement system?

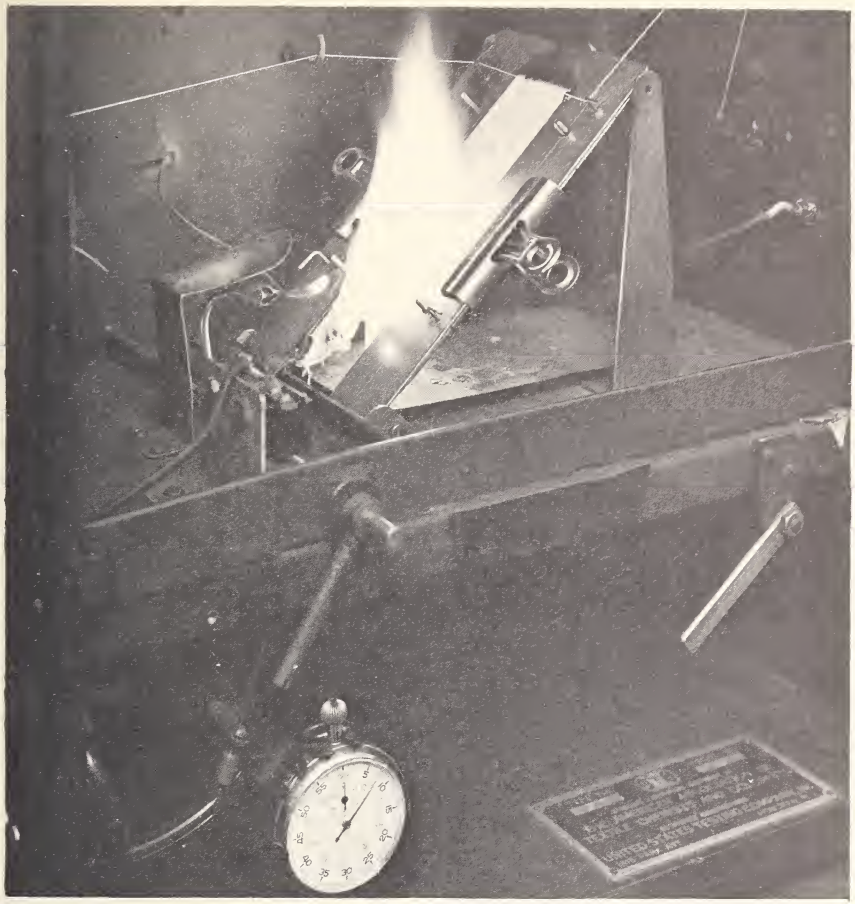
A third question concerns the extent to which private U.S. standards bodies are participating in the development of international metric engineering standards, the extent to which they should increase their participation in the light of the growth of multinational companies, and the extent to which the United States Government should encourage increased participation in international standards development if there is to be increased use of metric units.

The problem in this specialized area stems from the necessity of adapting or converting existing scales and balances in all sectors of the economy to read out in metric units, if the United States switches to their use. Grocery store scales, gasoline pumps, and heavy-duty scales used in connection with railroad freight loads and highway truck loads are the most prevalent and most obvious segments of this problem. One pertinent area that needs to be analyzed is the phasing of any coordinated effort and what part, if any, of this effort should be on a local, state-wide, or nation-wide basis. The extent and diversity of this measurement area indicate why liaison with state and local government is necessary, especially since they have laws and regulations as well as inspection systems for implementing them. The NBS study seeks to assess the potential impact in these areas.

FLAMMABLE FABRICS

Following a number of injuries and several deaths from the ignition and burning of what at that time were called "torch sweaters" in the public press, the Congress in 1953 passed a law titled the Flammable Fabrics Act. The sweaters that led to the formulation and passage of the law were highly flammable objects. A touch of a match would set them ablaze, engulfing the wearer in flames that often led to substantial serious injury and occasionally death. The 1953 law was designed to prohibit the manufacture and sale of such dangerously flammable articles of wearing apparel. It was in fact built around a test method known as CS–191–53, which required the measurement of the time to ignite and burn a six inch long and two inch wide strip of fabric held in a suitable holder, upon application for one second of a standardized small igniting flame, approximating a match. If the time-to-ignite-and-burn was less than three and one half seconds for an ordinary fabric, or less than four seconds for a raised-surface fabric (such as velvet, terry cloth, or brushed rayon) the material was deemed too flammable for public use and could not be sold for use in apparel. This was one of the first consumer protection laws passed in recent years, the model for which was the Pure Food and Drugs Act of approximately seventy years ago.

As time passed, it became apparent that while this Flammable Fabrics Act protected the consumer from such highly flammable articles of apparel as the "torch sweaters," against which it was primarily designed, people were still dying in significant numbers from burning fabrics. By 1967 the matter had become of sufficient



Standard test apparatus used in determining flammability of fabrics.

concern that the Congress held hearings on amendments to the Flammable Fabrics Act. It was estimated at that time that 150,000 to 250,000 people a year were injured from the burning of clothing, and that some 2,000 to 3,000 deaths occurred. These injuries and deaths were about 60 percent of all those due to the burning of textile products, with the other 40 percent being caused by the burning of interior furnishings such as bedding, upholstered furniture, rugs, drapes, etc. It became clear that while the 1953 act protected the consumer from such items as "torch sweaters," flammable fabrics were still a source of danger, and the Congress set out to try to remedy the situation.

They did this by passing major amendments to the 1953 act, and on December 14, 1967, there was signed into law by President Lyndon Baines Johnson the "Flammable Fabrics Act Amendments of 1967 (PL 90-189)." The Act as so amended is that referred to when the "Flammable Fabrics Act" is mentioned.

This law had some sweeping provisions. While retaining the provisions of the 1953 law for the flammability of apparel fabrics permitted for sale (i.e., the compliance with CS–191–53) it gave the Secretary of Commerce new powers and authorities to change those provisions and to set standards for interior furnishings when he finds it necessary to do so to protect the public.

The amendments make the Flammable Fabrics Act a milestone in consumer protection legislation, for in it the Congress delegated to the Secretary of Commerce the responsibility to determine when a new standard was needed. That is to say, the Congress did not of itself decide that a new standard was needed, but left that decision up to the Secretary of Commerce. There are, however, several key phrases in the language. First, the Secretary of Commerce must find that the public is subject to "unreasonable risk" before proposing a standard, and the term "unreasonable risk" is undefined. Second, any standard the Secretary proposes must be "reasonable, technologically practicable, and appropriate." Clearly all these undefined terms are necessary to prevent arbitrary action on the part of the Secretary of Commerce.

However, the law states that the Secretary may base his actions on investigations or research. By investigations is meant the investigation of accident cases and the collection of accident statistics, and by research is meant laboratory studies. This gives the Secretary some flexibility in his actions.

In order to fulfill his responsibilities, the act authorizes the Secretary of Commerce to carry out certain activities, specifically detailed in Section 14 of the Flammable Fabrics Act. One of these activities is to be carried out in cooperation with the Secretary of Health, Education and Welfare—investigating the deaths, injuries, and economic losses resulting from burning of fabrics. Specifically, the law states, "The Secretary of Health, Education, and Welfare in cooperation with the Secretary of Commerce shall conduct a continuing study and investigation of the deaths, injuries, and economic losses resulting from accidental burning of products, fabrics, or related materials. The Secretary of Health, Education, and Welfare shall submit annually a report to the President and to the Congress containing the results of the study and investigation."

The law, with some specificity, also details activities the Secretary of Commerce is authorized to carry out in his own department. As spelled out in the law, these are:

"(1) conduct research into the flammability of products, fabrics, and materials;

"(2) conduct feasibility studies on reduction of flammability of products, fabrics, and materials;

"(3) develop flammability test methods and testing devices; and

"(4) offer appropriate training in the use of the flammability test methods and testing devices.

The Secretary shall annually report the results of these activities to the Congress."

These last activities were delegated by the Secretary to the National Bureau of Standards by Departmental Order in 1968. The highlights of the program carried out in the past year under this delegation are given on pages __ to __ of this report.

When the Flammable Fabrics Act is viewed in respect to other consumer protection laws, it has at least two unique aspects. First, as previously mentioned, it gives the Secretary of Commerce the authority to decide when "unreasonable risk" exists, next to propose a standard to correct the existance of this unreasonable risk, and then to issue a final standard. In response to specific language in the Act, a set of procedures has been evolved by the Department of Commerce. In brief, these are:

(1) A notice shall be published by the Secretary whenever he finds that there may be unreasonable risk. Public comments on this finding are invited.

(2) Upon review of the comments, the Secretary may decide that there is no unreasonable risk, and withdraw the finding, or he may decide that there is unreasonable risk and publish a *proposed* standard to solve this unreasonable risk. Again he invites public comments on this proposed standard.

(3) After consideration of the comments, the Secretary may withdraw the proposed standard, or modify it as appropriate and consult with the National Advisory Committee for the Flammable Fabrics Act, as required therein.

(4) Only then may the Secretary publish it in its final form. It becomes law one year after such publication.

The National Bureau of Standards provides all the technical input necessary to carry out the actions designated above.

A second form of uniqueness of the Flammable Fabrics Act is that four Executive Departments are involved in its implementation. The Department of Commerce, as discussed, has primary responsibility for determining when a need exists and for developing the standards to meet that need. The technical work necessary in this effort is carried out by NBS. The Department of Health, Education, and Welfare has the responsibility to collect data from investigations of burn injury cases to permit the Secretary of Commerce to carry out his duties. The Federal Trade Commission has the responsibility to enforce the Standards promulgated by the Secretary of Commerce, and the Treasury Department has the responsibility of regulating imports on the basis of the standards developed by the Department of Commerce.

Because of these aspects of the Flammable Fabrics Act, it represents a unique effort in consumer protection legislation, and one in which the National Bureau of Standards is playing an important role.

MEASURES FOR AIR QUALITY

The abatement of air pollution depends to an important degree upon our ability to measure the pollutants in air. While substantial efforts have been made by various groups to develop methods of measurement, these efforts have for the most part fallen short of present requirements. The procedures that have been developed often cannot realize their potential because of the nonavailability of calibrating methods. Future needs in air pollution instrumentation are for greater speed and freedom from interferences.

The National Bureau of Standards' role in this problem includes development of standard reference materials and devices for the calibration of existing and future measurement instruments and the concentrated advancement of measurement science in those areas of direct relevance to air pollution problems. In order to achieve these ends and to assist National Air Pollution Control Administration in fulfilling its obligations, NBS has instituted the Measures for Air Quality program (MAQ).

The technical activities of the MAQ program are Bureauwide, but the MAQ office (manager, deputy, and a secretary) is located in the Institute for Materials Research and reports through the IMR office. This office coordinates and manages all activities related to air pollution at NBS. The technical projects of the MAQ program, most of which are partly funded through the MAQ office, are performed in the technical divisions, under their line supervision, but the MAQ office reviews (and reports) progress to assure that these projects stay relevant to air pollution goals, and to coordinate the activities in different divisions. This office also manages other facets of the program such as liaison with NAPCA, seminars by outside air pollution experts, industrial research associates, an MAQ newsletter, and travel to air pollution meetings.

Standard Reference Materials—The only pollutant measurements that are independent of the method of measurement are those for which Standard Reference Materials exist. Such major important pollutants as O_3, SO_2, NO_2, and particulate matter have resisted efforts to contain them in dilute (parts per million) mixture with air because of their inherent instability or reactivity. Thus, Standard Reference Materials for these substances are not available. NAPCA is supporting work at NBS in the development of standard reference "devices" for O_3, SO_2, and NO_2. The concept is to create a device from which a certified number of molecules of, say, SO_2 is delivered

to an analytical instrument upon application of a prescribed stimulus. NBS will be supporting the development of new concepts in standard reference devices such as molecular complexes of NO_2 and of SO_2, and the development of a standard reference material of an aerosol which may be characterized by means of light scattering properties.

Analytical Methods for Gases—The wet chemical methods currently in use are often too slow and nonspecific for today's needs. The assertion in the recent Nader Report that the technology of air quality instrumentation has stood still for fifteen years may be overstated, but rapid, interference-free, physical methods have not been sufficiently developed for gaseous pollutants. A reliable method for the measurement of CO below 5 parts per million does not exist. Of a number of commercial instruments for the measurement of SO_2, response times vary from 1.5–26.5 minutes and accuracies are severely limited by the lack of a calibration method. Instruments for continuous and rapid measurement of NO in stack gases, for the measurement of H_2S, formaldehyde, ethylene, ammonia, boron, lead, and for the determination of carcinogenic polynuclear aromatic hydrocarbons do not exist.

The MAQ Program will support projects in electron energy loss spectrometry, far infrared spectroscopy, atomic emission detectors for gases, and attenuation of tuned laser beams by specific pollutants, with the objective of developing specific, rapid optical methods for measurement of gaseous pollutants.

Particulate Matter—The nature of particulate matter dispersed in air is perhaps the most poorly understood aspect of pollution analysis. Less than half of the mass of particulates has been accounted for in typical urban samples. The problem has been approached in specialized ways without sufficient attention having been given to a total approach to the particulate measurement problem.

In the MAQ Program total analysis of the particulate problem will be undertaken. A sampling station will be set up on NBS grounds to gain experience in collection and analysis of real samples. Next, we plan to obtain a large, homogeneous sample of urban particulate matter for dissemination as a research material. The research program on measurement methods will be applied wherever possible to this material and the results made publicly available.

The measurement methods to be applied to particulate matter include the following:

(1) Wet Chemical Analysis
(2) Neutron Activation Analysis for Trace Metals
(3) Laser Stimulated Emission Spectroscopy
(4) Electron Microscopy of Particulates
(5) X-ray Crystallography of Particulates

(6) Size Distribution by Mie Scattering
(7) Development of Particulate Aerosol SRM
(8) Measurement of Carcinogens in Particulates

Other Measurement Studies—Certain fundamental aspects of modeling will be studied, such as the location of air pollution monitoring stations for most meaningful measurement of urban ambient pollution. The thermodynamic properties of high temperature air perturbed by NO, CO, CO_2, and H_2O, a question of considerable basic importance to the control of NO formed in fossil fuel burning, are to be calculated. There will be efforts expended in the measurement of the kinetics of atmospheric processes such as the reactions of singlet oxygen, oxygen atoms, and ozone, and of the excited states of sulfur dioxide to provide information for atmospheric modeling. Our activity will extend to the assessment of the efficiency of air filtering devices relevant to indoor pollution problems. Investigations are being made into the need for information in the form of handbooks for workers in air pollution.

Relationships with NAPCA—The primary responsibility for air pollution research is held by the National Air Pollution Control Administration. The NBS involvement has been encouraged by NAPCA which funds a number of projects in calibration devices and in atmospheric modeling. In its role as the agency primarily responsible for the development of measurement science, the NBS welcomes the opportunity to apply its expertise in this field to such national problems as air pollution. NBS will continue to solicit the recommendations of NAPCA officials as well as those of officials of other Federal, state, and municipal agencies as well as the technological community in general.

BUILDING TECHNOLOGY

In the 1968 Housing Act, Congress called for 26 million new housing units to be built over a 10-year period, or an average annual production rate of 2.6 million units. Yet the nation today is producing at a rate of less than 1.5 million units, and to make matters worse, units lost to deterioration and demolition in many urban areas outnumber newly constructed units.

Beyond the crisis in housing, the building industry in general (all building types) is hampered by its own fragmentation, a lack of adequate coordination, and a continuing reliance on handcraft techniques. Commensurate with national needs for greater housing production and a heightened general building capability, the Building Research Division (BRD) has marshalled intensive efforts in both housing and building technologies.

Technological measurements and standards are at the interface between science and its application to the needs of our society. In

such areas of investigation as structures, interior environments, durability of materials, fire safety, standards and codes, systems engineering, building economics, and the sensory environment, the BRD endeavors to create the basic knowledge required for the development of engineering standards and the *measurements* related to them. The objective is to develop the technical base and evaluative procedures essential to the fostering of innovation in the building industry.

The BRD program has been designed to promote the concept of performance as the basis for measurement in the building industry. Performance statements which both invite technological innovation and seek the accommodation of the user's functional and ambient needs, by their very nature, must carefully describe measurement methods.

Performance makes possible the stating of those building attributes necessary to satisfy the needs of the building's users without regard to the specific materials, components, or systems to be employed. It is a concept which stresses the performance of whole structures and total environments.

The program of the BRD is structured to provide service to other Federal agencies, the design professions, the building industry in general, state and local governments, and the public.

It serves the design professions and the building industry through the dissemination of research findings. BRD professional staff also serve on committees of the American Society for Testing and Materials, the American National Standards Institute, and numerous other standards-generating organizations.

The Research Associate Plan has proven to be a successful method for the building industry and BRD to join forces. The Bureau's facilities and resources are used by the associates and all results of their research are in the public domain.

Besides furnishing direct laboratory and field support to state and local governments, BRD research provides the necessary technical input to building codes in the form of test methods and performance criteria. Close cooperation is maintained with the National Conference of States on Building Codes and Standards, a group organized to help solve building and code problems; the BRD, in fact, serves NCSBCS as executive secretary.

The public is served indirectly by all BRD activities and by the Division's performance (user's needs) orientation, and directly by BRD's participation in the NBS consumers' publication series.

The BRD supplies support to some 35 Federal agencies. An important function of the BRD program is performing research, including a limited amount of material testing, for branches of the Federal government. The Departments of Defense, Housing and

Urban Development; Health, Education, and Welfare; Post Office; and General Services Administration support projects that in many cases mean savings of millions of dollars to the taxpayer. Consultation and advice are also available to solve unique building problems that arise in these departments.

A notable example of interdepartmental cooperation is seen in the BRD participation in the Operation BREAKTHROUGH program of the Department of Housing and Urban Development. The HUD program is intended to solve the housing crisis through volume production.

BRD's performance orientation in recent years made possible the rapid development of the "Guide Criteria for the Design and Evaluation of Operation BREAKTHROUGH Housing," which is being used for the development and testing of 22 housing systems HUD has selected under the program. The development of the criteria not

Secretary George Romney of the U.S. Department of Housing and Urban Development (left) and Secretary Maurice H. Stans of the U.S. Department of Commerce sign an agreement authorizing use of technological resources of NBS in broad HUD housing programs. Observing are HUD Assistant Secretary for Research and Technology, Harold B. Finger (left) and Dr. Lewis M. Branscomb, NBS Director.

only constituted a benchmark achievement—it was hailed by the BRD Chief, Dr. James R. Wright, as "a milestone in the NBS–HUD relationship and in BRD history"—but underscored what was already known: the art of making performance statements is clearly in a fledgling state in terms of both user needs determination and performance testing.

Central to the performance approach is the identification of significant user requirements and criteria by which the satisfaction of those requirements can be measured.

Objective *and* subjective investigations must be made to determine true performance levels to replace empirically or arbitrarily established "numbers." Long-needed research and extensive involvement of the so called soft-science disciplines is required and the Division is shaping its team toward this end.

A multidisciplinary BREAKTHROUGH team was assembled in the fall of 1969 by Division management. The team not only articulated performance requirements, criteria, and test methods for housing systems but on the basis of these criteria is managing the evaluation and testing of completed BREAKTHROUGH prototypes, subsystems, and components.

In addition to the preparation of the guide criteria, several companion documents were prepared. A study of the climatological characteristics of 11 BREAKTHROUGH sites was carried out as well as a survey of the existing building regulations and building permit procedures at the sites, both of which resulted in NBS reports to HUD. A Testing and Analysis document was prepared for use in planning the measurement of aspects necessary to assure safe, healthful, and comfortable housing.

Also undertaken were research projects that will establish the relative performance of the first generation of BREAKTHROUGH housing. Finally, BRD will develop technical standards and assist HUD in the analysis, selection, and evaluation of various energy systems to be installed at the several BREAKTHROUGH sites. The data gained will determine how independent systems compare with conventional multiple-energy systems in such performance categories as cost and reliability.

Beyond the development of performance criteria and measurement techniques, some acceptance system has to exist for the effective transfer of the most advanced information to the real world of building construction. In this connection, BRD staff over the year directed the administration of the National Conference of States on Building Codes and Standards. Staff participated in hearings and meetings, transmitted research results from NBS, and maintained a central repository for informtion on state activities providing for more uniform standards and codes.

The third annual meeting of the Conference drew representatives from 34 states and territories, from local and state governments, and from industry associations. The Conference approved programs for achieving a common code framework, improved standards, laboratory accreditation, innovation evaluation, educational standardization, and computer utilization.

While developing long-range programs, the BRD maintained a quick-response service to satisfy the queries and consultative needs of both government and private industry. Teams from the BRD also responded promptly to two natural disasters, traveling to the ravaged area of Hurricane Camile in August, 1969, and to tornado-stricken Lubbock, Texas, in May, 1970, to gather data on the performance of buildings under extreme wind, surge, and hail loadings.

The BRD has underway a full-scale research project on the effects of wind on buildings. Conducted in cooperation with the Environmental Data Services of ESSA, the study's preliminary results indicate that the effects of gusts on buildings are far greater than has been heretofore suggested by wind tunnel experimentation. The Lubbock tornado was accompanied by a hailstorm with hailstones of three-inch size, and the resultant building damage was of interest to another ongoing BRD research project involving the hail resistance of building materials. The project uses a hail gun which discharges ice spheres at speeds corresponding to those experienced in hailstorms to test hail resistance of various materials.

The BRD deals essentially in producing information, in supplying information to government construction agencies and the private building industry, and also in bringing information on the needs of both government and industry—and on the results of research conducted elsewhere in the world—to the cognizance of Division personnel. In the latter connection, exchange programs are underway with the U.S.S.R. and France. An exchange of visits with the Soviet Union has taken place with the aim of exchanging information on what the two nations are accomplishing in the industrialization of the building process. The exchange with France involves that nation's Centre Scientifique et Technique due Batiment, the French equivalent of the Building Research Division.

The Division over the year advanced basic knowledge in housing and building technologies, widened its disciplinary base, strengthened its general research capability, and provided research and consultative services. Perhaps the most noteworthy contribution of the Division has been the implementation of the performance concept in HUD's Operation BREAKTHROUGH program—a program which is expected to generate the means to better house millions of Americans now living in substandard housing.

INSTITUTE FOR BASIC STANDARDS

The primary responsibility of the Institute for Basic Standards (IBS) is to provide the central basis for a complete and consistent national system of physical measurement, coordinating that system with those of other nations, and furnishing the essential services leading to accurate and uniform physical measurements throughout the United States. The IBS staff of 900 includes 528 scientists and engineers, 200 at the Ph.D. level, in facilities at Gaithersburg, Maryland, and Boulder, Colorado. In addition to these primary locations, specialized activities are carried out at Fort Collins, Colorado; Arcata, California; Maui, Hawaii; and an abandoned gold mine in the Colorado Rockies. The broad nature of the IBS responsibility requires work at many levels of technical sophistication; however, the critical contributions in measurement generally lie at the frontiers of science and engineering.

PHYSICAL QUANTITIES

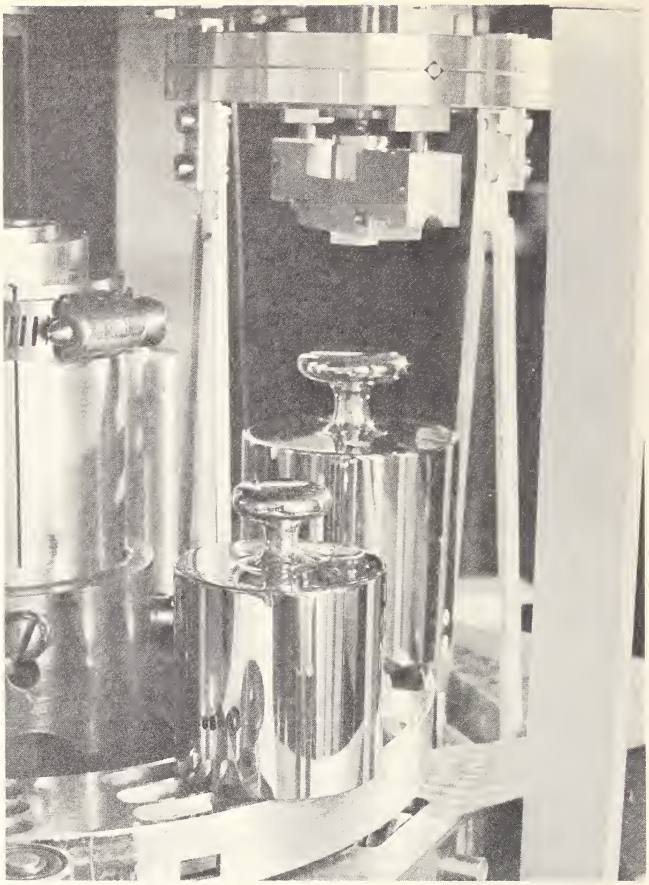
The international system of measurement (SI) is based upon six quantities: mass, length, time, temperature, electric current, and luminous intensity. All other physical quantities can be derived from these six. The United States and most other nations base their measurement systems upon these six units. Since it is impractical to make all measurements directly in terms of base units, standards for other physical quantities have been developed that are consistent with these basic quantities.

In a high technology society, the needs for better standards and means of measurement—more precise, stable, and easily disseminated—increase continually. Some of the current research in this area is described below.

International Base Units

Mass

Standard Balance for BIPM—NBS recently presented to representatives of the International Bureau of Weights and Measures (BIPM), located in Sevres, France, a unique and extraordinarily precise balance for calibrating mass standards. The balance is the first nonsymmetrical instrument to provide mass data to a precision of a few

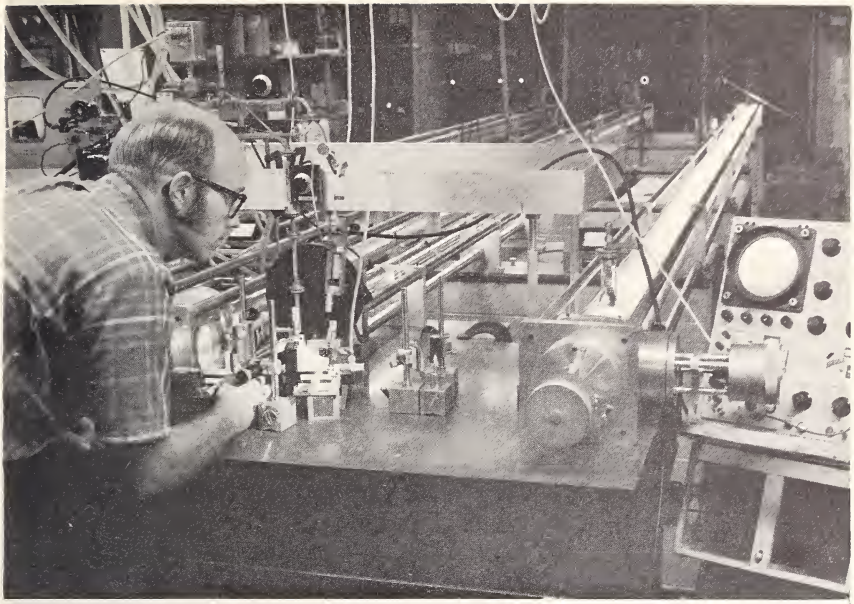


A portion of the 1-kilogram balance that provides a precision of a few parts per billion.

parts in a billion. An NBS data analysis study played an important part in the work. The study indicated that buoyant effects of air on balance configurations out of buoyant equilibrium could not be handled adequately. Subsequently a technique was devised to maintain the balance in near perfect equilibrium regardless of the load.

The high precision performance of the instrument is mainly due to a novel arrestment system in which all knives and flats remain in contact under constant load throughout the weighing cycle. The arm length is quite short—only two inches. To achieve reproducibility of a part in a billion requires that the arm length be constant to a part in a billion during the measurement interval. A part in a billion of the two-inch arm length is a distance shorter than one atomic diameter, and the "constant load" arrestment system holds the effective arm length constant to about this amount.

Two additional balances of this advanced designed are now under construction.



Absolute measurement of the frequency of laser radiation. Attempting to measure the frequency of the He-Ne laser (about 88 THz) by generating harmonics of two other lasers and mixing their radiation with klystron radiation. Combined radiation is focused on a tungsten catwhisker diode employed for frequency detection.

Time and Frequency

Laser Saturated Absorption of Methane—The technique of stabilizing a 3.39 micrometer helium-neon laser by saturated absorption of methane is now generally recognized to be of great importance in the fields of length and frequency standards. *Frequency stability* of one part in 10^{14} has now been achieved using this technique, which is comparable to the stability of the hydrogen maser. Techniques are now being developed to improve the *accuracy* (now better than one part in 10^{11}). In this respect, saturation has been achieved with the absorption cell external to the cavity, which eliminates some frequency-pulling effects. An important contribution to the measurement accuracy of the saturated-absorption technique results from the stability of the line center despite absorber pressure variations. The 3.39 micrometer line of methane will be proposed this fall to the International Committee for the Definition of the Meter for consideration as a new length standard. The wavelength is now being measured at NBS with respect to the present length standard, the Kr^{86} 605.7 nanometer line. Progress being made in measuring frequencies in the near infrared indicates the fascinating possibility of soon being able to measure the frequency of this 3.39 micrometer transition. When this is possible, the same transition of methane may give a more accurately measureable and reproducible standard of frequency, as well as length, than any other source.

Absolute Measurement of Laser Radiation Frequency—Considerable

progress has been made to extend measurement of frequency toward the visible region of the spectrum. The highest frequency measured to date is the 10.6 micrometer CO_2 transition (28.3 THz). The measurement was accomplished through a process of harmonic mixing of known laser and klystron frequencies, leading to the unknown laser frequency being referred to the NBS atomic frequency standard. The power necessary for mixing was attained with special compound laser interferometers; conventional tungsten catwhisker diodes were used for frequency detection. Diode coupling was improved by applying long antenna theory. NBS measurements have concentrated to date on CW lasers, with about 8 meters of active discharge.

Television Time-Dissemination System—A television time synchronization technique is now operational for long-term steering of the WWV, WWVB and WWVL broadcasts from Ft. Collins, Colorado relative to the NBS Time-Scale system located in Boulder, Colorado. Measurement precision on a day-to-day basis is better than 0.5 microsecond. An important side benefit of this operational system is the ability to use the three cesium standards at Ft. Collins as a backup timekeeping system for the Time-Scale system in Boulder. Wide interest in the basic technique has been shown by many users; for example, the Air Force is implementing an operational TV-synchronization system for some of their own units. As a result of such interest, the monthly Time and Frequency Bulletin began publishing measurements made at NBS of specific synchronization pulses as received from all three major television networks. Using this information, along with known propagation delays of the television signals, a user anywhere in the U.S. that has access to the same live network-TV program as measured each day in Boulder may relate his local clock to the NBS Time Scale with an equipment investment of only a few hundred dollars.

Expanding upon this basic TV-synchronization technique, a prototype system for disseminating an hours/minutes/seconds time code on line 10 of the TV vertical interval (black bar between frames) has been constructed and tested using the facilities of Channel 7 in Denver, Colorado, and Channel 5 in Cheyenne, Wyoming. The receiver, consisting of an inexpensive television set and the necessary decoding electronics, costs about $1000 and visually displays the hours/minutes/seconds reading on the face of the TV set. A second line of numbers in the visual display gives the time difference between a local clock pulse in the user's laboratory and a reference mark in the time code that is derived from a cesium clock at the originating TV station. This time-difference display can have a resolution of 100 nanoseconds or 1 nanosecond at the option of the user.

Two encoding systems have recently been installed at television stations in Washington, D.C., and Los Angeles, California, to permit

Conventional TV receiver and associated decoder displays time-of-day on picture-tube face in hours, minutes, seconds format on top line and time difference on the bottom line.

further evaluation of the technique jointly by NBS and the U.S. Naval Observatory as well as other interested users in these areas. Preliminary results indicate these systems are capable of better than 10-nanosecond stability for time synchronization and long-term frequency stability equal to that of the cesium standard at the TV station.

WWVH Relocation—Standard frequency and time signals have been broadcasted from radio station WWVH on Maui, Hawaii, since 1948, as an aid to a large number of users in the Pacific area. These users include ship operators, various Department of Defense units, rocket and satellite tracking facilities, and university and Government groups studying seismology and oceanography. A gradual deterioration of the WWVH facility has been caused by shoreline erosion, the corrosive environment, and normal aging of the electronic equipment. A 1.2 million dollar allocation was received from Congress to relocate and upgrade the WWVH facility. A leased site was obtained from the U.S. Navy's Pacific Missile Range facility on Kauai, Hawaii. Physical improvement of the site has begun; the transmitters and most other electronics have been ordered; and the antenna-system construction is nearly completed. The new station is expected to be on the air April 1, 1971. In addition to having new, improved electronic equipment, the relocated WWVH will add a 20-

MHz transmission to its format and will increase radiated power from 2 kW to 10 kW on all frequencies except 2.5 MHz. A more efficient antenna-radiation pattern will also contribute to increased coverage and reception reliability throughout the Pacific region.

Development of New Atomic Frequency Standards—Work on new types of frequency standards at NBS has, in the recent past, been confined to the development of two experimental hydrogen masers. Because of this experience and a critical appraisal of hydrogen-maser performance achieved in a variety of other laboratories throughout the world, it now appears that maser accuracy performance is limited by wall-shift effects to a few parts in 10^{13}. Since this accuracy accomplishment is also projected for the better-understood cesium-beam standards within the next year or so, direct work on hydrogen masers has been terminated in favor of a different approach, which appears to offer a potential accuracy *and* stability of near 1×10^{-14}.

This new approach, the hydrogen-storage-beam technique, seeks to combine the advantages of both the cesium-beam and hydrogen-maser techniques while eliminating most of their disadvantages. It is an extension of Professor Ramsey's experiments of about ten years ago in which a beam of cesium atoms was detected after being stored in a "bounce box" or storage chamber located between the two deflecting magnets of the device. When employed with atomic hydrogen, this approach is expected to yield the very narrow resonance-linewidth characteristic of the hydrogen maser while substantially reducing problems of cavity pulling and storage-bulb wall shifts. An initial version of a hydrogen-storage-beam tube has been designed using some existing maser parts and should soon be ready for testing.

NBS Time Scale Improvement—Two commercial cesium-beam clocks have been added to the NBS atomic Time Scale facility making a total of four. In addition, the use of TV-synchronization pulses on a routine, operational basis to compare this time scale with three other cesium clocks at the Ft. Collins radio stations (WWV, WWVB, and WWVL) permits the Ft. Collins ensemble to be used as a backup timing system, if necessary. A new computer program provides near-optimum precision timing from the available ensemble of cesium clocks. This program has the facility to allow the number of clocks included in the time scale to be changed with only insigificant short-term transient effects in the overall Time Scale. The present precision of time prediction over a one-day interval is now 7 nanoseconds rms.

Automation of the time-scale operations is continuing. An on-line computer system that will automatically perform all necessary clock intercomparisons, perform related computations, and generate a correction signal to control the outputs of the working clocks at selected times is near completion.

The time coordination between NBS and the U.S. Naval Observatory, which was initiated in October 1968, has proceeded smoothly. Coordination is now accomplished using Loran-C transmission data as measured in Boulder and periodic portable-clock measurements with rms precisions of about 1 microsecond and 0.1 microsecond, respectively. The time difference between the UTS(USNO) and the UTC(NBS) times scales has been well within the mutually-agreed-upon tolerance of 5 microseconds.

Progress on New NBS Frequency Standard—The present NBS Frequency Standard, NBS–III is undergoing major modifications to improve both its stability and absolute accuracy. Upon completion, this cesium-beam standard will be designated NBS–V. The stability of the new standard is expected to be about 1×10^{-13} for one-second averaging times as a result of employing a refined, computer-optimized beam-optics system for higher beam signal-to-noise ratio. The accuracy capability will be improved to near 2×10^{-13} by operating the standard as a double-beam system. Alternate operation with the beam traveling in opposite directions allows a simple, quick, and very precise determination of any residual cavity phase-shift error. This technique and the addition of an improved microwave-cavity structure should also eliminate the small changes of phase shift with time as previously observed.

Temperature

Improved He^3 and He^4 Vapor Pressure Measurements Using a Capacitance Diaphragm Manometer—Very accurate vapor pressure measurements for both He^3 and He^4 can now be made by using a capacitance diaphragm gage operated at cryogenic temperatures. This method allows vapor pressure readings without the uncertainty introduced by thermomolecular pressure gradients (thermal transpiration). Using a specially designed capacitance bridge with high stability, a resolution of about 10^{-5} mm of Hg is obtained at pressures lower than 10 mm Hg. Preliminary He^4 measurements have been compared with acoustical thermometer values, and differences up to 8 millikelvins have been noted.

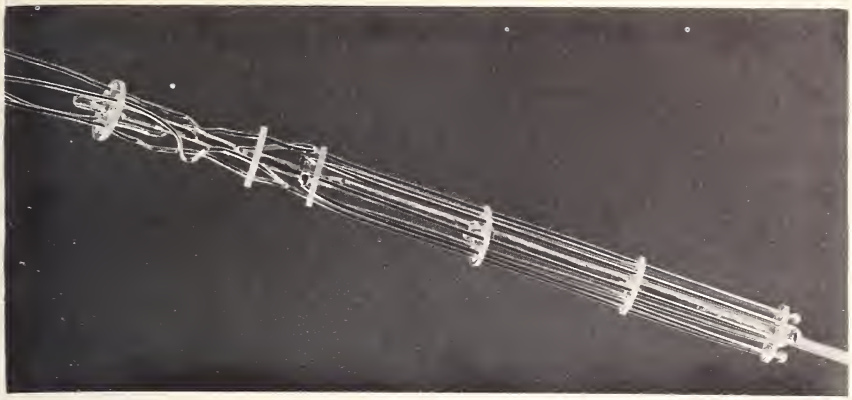
Low Gravity Thermometry—An instrumentation system has been developed to detect the presence of either liquid or gaseous hydrogen as well as measuring temperature in a spacecraft cryogenic propellant tank under near-zero gravity conditions. The measurement system employs a thin-film carbon sensor having a fast response time to measure temperature and to indicate either the presence or absence of liquid hydrogen on the sensor surface. The carbon thin-film sensor provides a relatively high voltage signal for temperature measurement. An analysis of the sensor thermal response has been developed and this analysis corresponds well with the experimental results.

Drop-tower tests were conducted to evaluate sensor performance under short-term, low-gravity conditions. Results of these tests indicate the usefulness of the measurement system for the intended purpose and points up the possibility of more extensive use of carbon or metallic thin films in thermometry and heat transfer studies.

Thermometry Fixed Points—The International Practical Temperature Scale (IPTS–68) from 13.81 to 903.89 K is based upon nine fixed points and the use of platinum resistance thermometers as interpolating devices. NBS is investigating the reproducibility of the fixed points presently in use, attempting to realize the other (IPTS–68) defined fixed points, and investigating possible alternative points. Under closely controlled conditions, the triple-point temperatures of thirteen water cells were found to agree within 0.0001 K; older cells (15 years) are at the lower half of this "range of spread". The range of freezing plateau temperatures over a 1.5 hour period (10 to 25 percent solid) of seven nominally 99.9999 percent tin samples was about 0.0001 K and that of three nominally 99.999 percent samples also 0.0001 K; the average plateau temepratures of the two groups of samples differed by about 0.0006 K. The triple-point temperature of argon—a possible replacement for the oxygen boiling point as a fixed point—was investigated; tests on two commercially built argon cells exhibit average freezing plateaus (over a four hour period) that agree within 0.0005 K. NBS had six mercury cells constructed and tested; these exhibited freezing plateaus that were consistent within 0.0001 K.

Platinum Resistance Thermometer Development for 630 to 1064°C—Nine high-temperature platinum resistance thermometers and eight standard platinum-10 percent rhodium versus platinum thermocouples were intercompared over the temperature range 630.74 to 1064.43°C. The group of thermometers consisted of three made at NBS and two each from three commercial suppliers. The thermocouple wires were obtained from four major U.S. refiners of platinum metals. Both the thermometers and thermocouples were calibrated at the freezing points of antimony about (630.75 °C, silver (961.93 °C), and gold (1064.43 °C), and were then intercompared in a special copper block comparator at 50 °C intervals from 650 to 1000 °C. It was found that the uncertainty in the determination of a value of temperature on IPTS–68 with a single resistance thermometer was about one-third the uncertainty usually attributed (0.2 °C) to a determination with a single thermocouple. It is expected that these results will furnish a basis for future improvement of the practical temperature scale by replacing thermocouples with platinum resistance thermometers.

Platinum Resistance Thermometer Development—Extended high temperature aging data have been accumulated on six different experi-



A "birdcage" resistor (about 40 mm long by 5 mm diameter) used in high temperature platinum resistance thermometers. The resistor wires are supported on silica or synthetic sapphire disks and a central platinum rod or tube. Four platinum leads are attached to the ends of the resistor wire.

mental platinum resistance thermometers for periods of up to 1900 hours. One thermometer, A–1, has shown a drift rate in its resistance at the triple-point of water of 5 ppm in 90 hours over a test period of 1800 hours of exposure to 1050 °C. Other thermometers have exhibited a drift rate of 1 ppm per hour (at the H_2O triple point) of exposure at 1050 °C, which has been typical of most high-temperature platinum resistance thermometers. Two factors are believed to contribute to the improved stability of thermometer A–1: the design of the resistor's supporting structure, and an overnight preliminary heat treatment in air at about 1400 °C before the resistor is encapsulated. This design may be expected to provide improved thermometer performance because the activated portion of the resistor contacts only high-purity platinum, thus reducing the possibility of chemical contamination, and the supporting structure has the same thermal expansion as the resistor. Aging studies are being continued and presently indicate that materials other than platinum merit consideration for precise resistance thermometry in the range 630 to 1064 °C.

Automation of Pyrometer Calibrations—An automatic digital recording system for pyrometric calibrations has been developed and incorporated into the routine calibration program. The system consists of a programmable input scanner, a precision digital voltmeter, an intercoupler and a teletypewriter with paper tape punch. At the operator's command, pyrometric measurements are recorded with a teletypewriter and simultaneously punched on paper tape. The tape data thus produced are then transmitted by telephone to a computer for automatic analysis and data reduction. The computer returns a finished calibration document that includes a statistical analysis and interpolation tables. The overall uncertainty of the system, in terms of the recorded voltage measurements, is 0.01 percent or 5 μV, which-

ever is greater; the system makes it possible for one person rather than the customary two to calibrate an optical pyrometer with no reduction in precision. In addition, since all data recording, handling, and calculating are done by automatic machine methods, the calibrations can be performed with less chance of error, less fatigue, and in less time than when using the older "potentiometer-notebook" method.

Fundamental Physical Constants

Measurement of Atomic Spacings—The distance between atoms in a crystal can now be measured with great accuracy by a technique first demonstrated at NBS. To accomplish these measurements, one portion of a perfect silicon crystal is moved very slowly and uniformly relative to another portion of the same crystal. When the crystal portions are perfectly alined, an effect is achieved similar to that observed if one picket fence is moved in front of another. When the pickets are lined up, light passes through, when they are staggered, it does not. In the case of the silicon crystals, the rows of atoms act like pickets in a fence, and x rays passing through the crystal change in intensity as the rows of atoms pass each other.

A laser beam is reflected from a pair of mirrors attached to these same crystals. These mirrors form an interferometer, and light reflected between the mirrors shows maxima and minima as the mirrors are moved. Since the laser wavelength can be accurately measured, it is possible by these experiments to obtain the distance between atoms to an accuracy of about a part per million. The results of this work have several important applications: (1) x-ray wavelengths have long been measured in terms of the X-unit, whose value in terms of the meter has not been known to sufficient precision. That unit will now be known to a part per million. (2) Avogadro's constant, the number of atoms in the given mass of an element, has been known only to a part per 20,000. It will now be possible to approach a part per million accuracy. (3) The fine structure constant is now uncertain by a part in 70,000. Experiments now underway at NBS utilize the measurement of the silicon atom spacing to improve our knowledge of this number.

Proton Magnetic Moment—A new measurement of the proton magnetic moment in nuclear magnetons has recently been completed. Great care was taken in checking for possible small systematic errors in the result. The achieved accuracy of six parts per million is equal to that of a recent Russian measurement made by a quite different method and is much better than that of other previous measurements. The new measurements indicate that the values of the proton moment, proton mass, Avagadro's number, and the Faraday given in recent adjustments of the fundamental constants of physics are substantially in error.

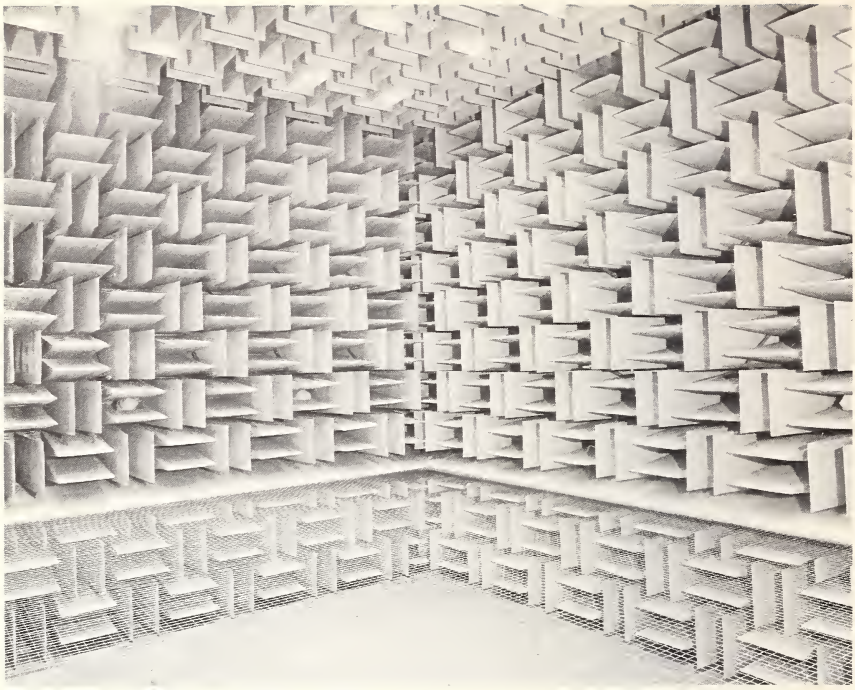
High Precision Measurement of Angles—A new device developed at NBS now makes it possible to measure angles with an accuracy of one millionth of a degree by means of the wavelength of laser light. The angle measurement device makes use of these very stable, accurately known (part per billion) wavelengths to measure the movement of a retroreflecting mirror. This mirror is attached to a table whose turning is measured. The first application of this instrument will be to the very precise measurement of gamma-ray wavelengths.

Reverberation Room—One of the highly specialized test chambers of the Sound Laboratory Building is the massive 15,000 ft^3 shell-within-shell type structure called the reverberation chamber. The 1.2 million pound chamber that floats on helical coil steel springs will be used in studies of the properties and behavior of various types of sound fields and their influence on the measurement of such acoustical parameters as sound power radiation, sound absorption, and transmission.

In connection with such studies, a large three-bladed rotating vane of unique design was recently installed in the chamber for the purpose of continuously varying the sound field in a controllable and systematic way. The vane, centrally suspended from the chamber ceiling, consists basically of a motor-driven mechanism that slowly and silently rotates a shaft supporting three 7 × 10 ft sound reflecting panels, symmetrically oriented and obliquely angled with respect to the shaft.

The vane system is thought to be the most versatile in existence. It has provisions for variable speed of rotation, adjustable sweep volume, variable angle of blade tilt, variable height adjustment, and provision for the simple installation of blades of different sizes and shape including cylindrical and conical reflectors. With this system it will be possible to conduct a systematic study of the effects of vane parameters on the statistics of reverberant sound fields and possibly to find an optimum design for the nonadjustable vanes used in routine acoustical testing.

Anechoic Chamber Completed—A large anechoic chamber with especially good sound-absorbing characteristics at low audio frequencies has recently been added to the facilities of the Sound Laboratory. All six inner surfaces of the chamber are lined with Fiberglas wedges. The chamber, which has free-field dimensions of 33 ft × 22 ft × 22 ft, will be used for the calibration of microphones and sound sources (including loudspeakers), measurement of the noise output of devices, the study of radiation patterns of sound sources, subjective investigations of sound fields (including loudness, noisiness, and localization) and experiments in the scattering of sound.



The anechoic chamber, used in a variety of sound measurement and calibration studies, has been completed.

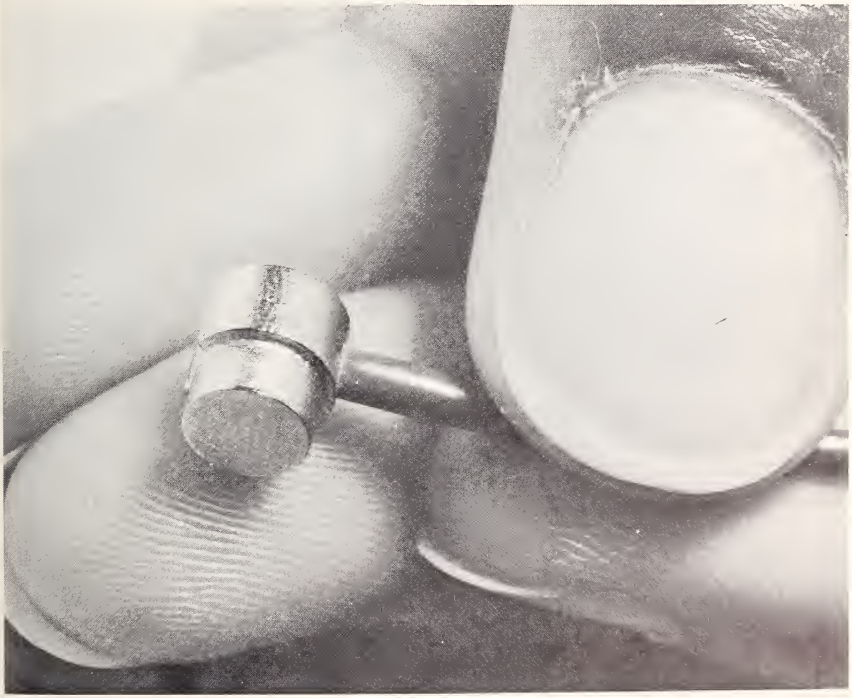
Access to the room is by means of a horizontal, interlaced, steel-cable net located five feet above the tips of the floor wedges and supported by heavy I-beams. Double-wall construction and steel spring mounts serve to isolate the anechoic chamber from external sources of airborne noise and vibration.

New Type Wedges for Anechoic Chambers—A novel type of Fiberglas wedge structure that absorbs more than 99 percent of the normal-incident sound energy in the audio frequency range above 43 Hz and more than 99.75 percent above 75 Hz has been devised by NBS for installation in the anechoic chamber of the Sound Laboratory. The wedge design previously used proved to be unsatisfactory because of a recent change by the manufacturer in the ratio of flow resistance to density in the material. The new wedge structure, which is 70 inches long, consists of a 55-inch tapered portion with a density of 3 lb-ft^3, an 11-inch base with a density of 1 lb/ft^3, and a 4-inch air space. The region behind the tapered portion of the wedge acts like the volume element of a Helmholtz resonator and enhances the sound absorbing characteristics at low frequencies. Measurements leading to the new design were performed in the NBS 32-foot plane-wave tube.

Low Frequency Vibration Calibration Service—An electrodynamic vibration generator was developed in collaboration with the Department of the Navy that produces sinusoidal motion of high quality for

calibration of vibration pickups over a frequency range from 1.5 to 50 Hz. The maximum acceleration level of 0.3 m/sec^2 peak (approximately 3 g) is limited by a double-amplitude displacement of 4.5 cm (approximately 1.75 inches). The generator uses two air bearings to guide the moving element; the first restricts lateral motion and the second minimizes rotational motion. A servo-accelerometer used as an internal vibration sensor, is calibrated by optical methods, and the calibration verified by other independent techniques. Special methods were devised to measure harmonic distortion and voltage levels at these infrasonic frequencies. A calibration service is expected to be available for this frequency range in late 1970.

High Frequency Piezoelectric Accelerometers—A miniature piezoelectric accelerometer having a mounted resonance frequency greater than 200 kHz has been designed and constructed. Cemented ceramic piezoelectric accelerometers are used in studies regarding the motion of high-frequency vibration generators, and for the analysis of mechanical vibrations in structures. It is advantageous for such accelerometers to be light weight while maintaining a reasonable sensitivity. The accelerometer developed at NBS has a sensitivity of 0.02 mV/m/sec^2 (about 0.2 mV/g) and a mass of approximately 1 gram. The base is made of Al_2O_3 ceramic that provides a very stiff mounting surface. The overall size of the units is approximately the

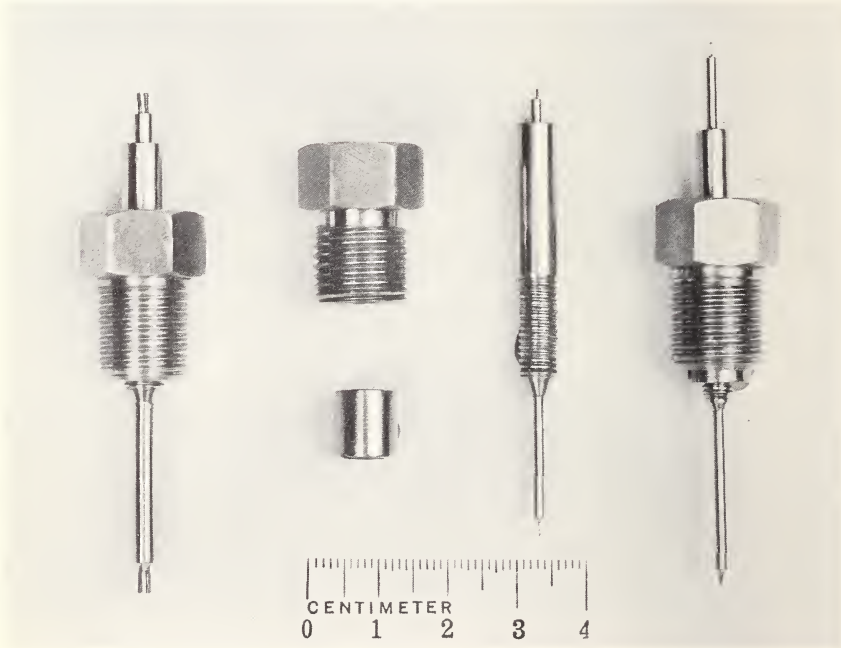


Miniature piezoelectric accelerometer. Cable is integrally attached to metalized Al_2O_3 base. Overall weight of accelerometer is approximately 1 gram.

same as a small pencil eraser, and the accelerometer has an internal capacitance of about 600 pF compared with 11.5 pF for commercial devices of similar size.

Temperature Dependence of the Bismuth I-II Tranistion Pressure—Since the pioneering work of P. W. Bridgman the phase transition of bismuth (Bi) at about 25 kbar has been one of the most important fixed points on the pressure scale. This point was recently redetermined at NBS with a specially designed very-high-pressure piston gage. These measurements were made at 25 °C. To utilize the 25 °C value at other temperatures a very careful determination of the temperature dependence of this transition pressure has also been made. Such a determination was necessary because of the wide variety of temperature coefficients reported in the literature. The new determination is supplemented by a careful analysis of the uncertainty of the derived value.

High-Pressure Electrical Feedthrough—Work at high hydrostatic pressures frequently requires electrical leads into or out of the high pressure apparatus. The leads may carry either dc voltages or signals with frequencies of up to several MHz. To solve many of the problems previously encountered in this area, a group of very simple and reliable electrical feedthroughs has been developed. The feedthroughs have been tested in more than one hundred runs at pressures of up to 25 kbar (360,000 psi) with no failures. Feedthroughs for pressures

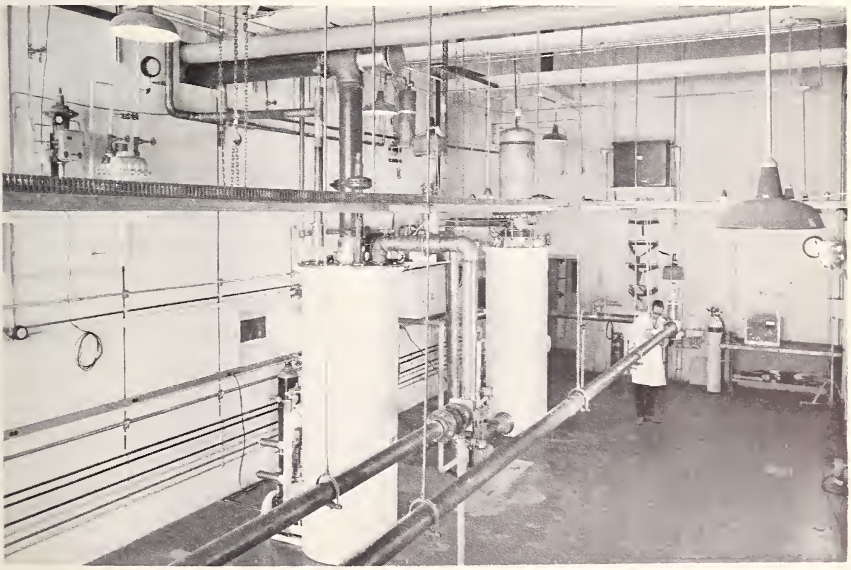


Electrical feedthroughs have been developed for use in pressure apparatus at pressures up to 360,000 psi.

to 14 kbar (200,000 psi) can be screwed into standard high-pressure fittings. Their insulation resistance of more than 2000 M Ω between the leads and the outside sheath makes them especially valuable for use with managanin or strain gages. Other types, based on the same fabrication principles, are used at frequencies up to 30 MHz for nuclear quadrupole and ultrasonic measurements.

Fluids for High Pressures—Density and bulk modulus have been determined for mixtures of aviation instrument oil and iso-pentane at pressures up to 26 kbar. The mixtures are particularly useful as pressure transmitting fluids, whereas the individual components have unfavorable characteristics under pressure. From ultrasonic measurements made on the compressed fluid samples, data for the ratio of specific heats as a function of pressure and a qualitative measure of the viscosities were obtained. These measurements were made in an apparatus designed at NBS for the compression of fluids to more than 40 kbar.

Cryogenic Flow Research—A facility for the study of cryogenic flowmetering is now complete and operational and has been utilized to evaluate seven positive-displacement-type cryogenic flowmeters currently used in commerce. These meters, representing four different manufacturers, have been evaluated for precision and accuracy using liquid nitrogen over a range of temperatures from 71 K to 90 K and from saturation to 0.9 meganewtons per square meter (132 psi). Results of these meter evaluations will furnish guidelines for type approval and code requirements and provide information for the



Facility for the evaluation of commercial flowmeters and the development of new cryogenic flowmetering systems.

development of new flowmetering measurement systems. The program was established under sponsorship of NBS and the Compressed Gas Association. The joint sponsorship by CGA provides international support for the program as this trade organization represents not only six of the largest cryogenic producers in the United States but also producers in England, France, and Germany.

Equations for Thermal Transpiration in High Vacuum—Temperature gradients in low-pressure systems induce gradients in gas molecule concentration and in pressure. A knowledge of the corrections due to temperature gradients is crucial to measurement accuracy in operating systems. Earlier studies by Reynolds, Maxwell, and Knudsen showed that the gas pressures, P_1 and P_2, at the ends of a capillary tube connecting two separate chambers maintained at temperatures T_1 and T_2, repectively, are related by $P_1/P_2=\sqrt{T_1/T_2}=R_K$. Subsequently, more accurate measurements have shown deviations from Knudsen's limiting value, R_K, of greater than 20 percent of the value of R_K. No theory fully accounted for the anomalous Knudsen limiting value. Now, concepts of nonequilibrium thermodynamics and statistical mechanics have been used to derive a general expression for the thermal transpiration ratio, R, which embodies the type of molecular scattering from the surfaces as well as the nature of the gas. The result is that $R/R_K= (T_2/T_1)\ \epsilon\ (\sigma, \lambda)$, where σ represents the degree of specular to diffuse scattering and λ is the mean free path. The general expression has been evaluated for a cylindrical tube at high vacuum to give results in agreement with experimental values.

Mechanical Compliance of Single-Edge-Notch Specimens—Improvement of design criteria for high-strength materials, particularly metals, depends on a better understanding of their fracture properties. Compliance measurement is a technique frequently used in attemtping to isolate the causes of brittle fracture experimentally. The single-edge-notch compliance specimen is well suited to plate or sheet materials, and two sizes of these were measured: a long specimen to make comparisons with theoretical stress function solutions, and a short one similar to the size that has been widely used in the determination of long-term, environmental effects (principally radiation) on the crack-toughness properties of materials.

Load-displacement (compliance) results obtained with the long specimen were in good agreement with the theoretical solutions and earlier experimental work. The data for the short specimen reflected a strong dependence upon the point of attachment of the extensometer; poorer agreement between predicted and observed extensions is probably due to the points of load application being nearer the notch in this shorter length specimen.

Dynamic Load Errors in Testing Machines—Tests to determine the strength of materials are made at various rates of load application.

Testing machines used to make these tests, however, are generally calibrated under static load conditions. Errors due to the lag of the load-indicating mechanism also may affect the apparent dynamic test results. To determine the magnitude of these dynamic errors, a procedure was developed for comparing the loads indicated by the testing machine and, independently, by a load cell. Results obtained with the new procedure revealed that the dynamic error was proportional to the rate of load application, and that correction factors could be found for use with individual testing machines.

Dynamic Response of a Load Cell Element—Errors of unkown magnitude are introduced when a rapidly changing force is measured with an instrument that has been calibrated under static loading conditions. To help determine these errors, a method was developed for determining the dynamic characteristics of a prototype load cell element subjected to sinusoidal forces by a piezoelectric shaker. Small accelerometers were used to measure the motion of the ends of the element being driven near its resonant frequency. A simple viscoelastic model was assumed for the element, and relaxation times on the order of 10^{-7} second were measured.

Roughness Induced Transition—A rough surface usually induces earlier transition to turbulent flow. Although a great deal of engineering data on such behavior has been established, a fundamental understanding of this behavior has been lacking. An experimental investigation, supported by the National Aeronautics and Space Administration, of the effect of single two-dimensional roughness elements on the transition to turbulent flow in boundary layers has been carried out at NBS using a four and one-half foot wind tunnel. Emphasis was given to the measurement of mean velocity distributions, and in particular to the behavior of disturbances—their intensity, growth, and decay in the immediate downstream vicinity of the roughness. Their behavior was examined in the light of stability theory, which revealed that the earlier transition to turbulent flow induced by single two-dimensional roughness elements is due to the destabilizing influence of the distorted flow created by the roughness. In addition to the understanding of the basic mechanism, these results will also be useful in connection with closely related problems encountered in aerodynamic and hydrodynamic testing.

Electrical Quantities—DC and Low Frequency

Precise EMF's and the Microwave Josephson Effect—In the "ac Josephson effect" a microwave frequency is converted to a dc voltage by a quantum process in a junction of special construction operating at a temperature of 2 kelvins. Voltages above 16 mV have been achieved in single junctions. A low-level potentiometer, operating in the range 0-10 mV, has been constructed for the accurate measurement

Comparing the voltage produced by a Josephson junction when exposed to microwave frequency to that of a standard cell.

of these voltages in terms of the emf of a standard cell. In this potentiometer, a pair of interchangeable 10-element Hamon networks provide a 100/1 ratio accurate to better than a part in 10^8. A 6-decade current divider is used to achieve approximate balance against the standard cell emf. Precise balance—to better than a part in 10^7—is accomplished by adjustment of the microwave frequency. In a series of measurements with a number of junctions, over a period of months, voltages from 2.5 to 10 mV have been measured. The observed frequency/step-voltage ratio has in every instance been the same within 1 part in 10^6. It is anticiapted that after further refinement of the measuring process, the effect will be useful in monitoring the stability of the national unit of voltage as maintained with standard cells.

Development of a resistive voltage-ratio standard—Resistive voltage dividers having discrete ratios from 1/1 to 1000/1 are an important link in the transfer of accurate dc voltages from the standard cell voltage level to the one kilovolt level and higher. For many years, these dividers have been calibrated by comparison with a ratio standard that could be self-calibrated by a bootstrap technique. The accuracy to which the ratios of this standard were known is of the order of 5 ppm of ratio.

A new ratio standard designed and constructed at NBS incorporates an additional measurement technique based on the series-parallel principle to establish the values of its ratios. The standard is provided with its own measuring network and the entire system is housed in a temperature-controlled dry air enclosure. The values

of its ratios are known to an accuracy of 0.2 ppm. Several features were included in the design of the ratio standard to permit operation at 100 Hz and below.

Measurement of Transformer Ratios—A new method for the calibration of isolated decade inductive dividers and other precise ratio transformers has been developed. The method employs a reciprocal transformer-type network whose terminal characteristics can be fully measured. The transformers can be calibrated either in the voltage or current mode. With this new method the inductive divider ratios can be measured to $\pm 2 \times 10^{-9}$ and $\pm 5 \times 10^{-9}$ accuracy (with respect to input) for the in-phase and quadrature components, respectively. By calibrating inductive dividers in both voltage and current modes, it has been demonstrated that well-designed units are reciprocal within a few parts in 10^9.

Comparator for Thermal Voltage Converters—Coaxial ac-dc transfer standards of the thermal converter type measure ac voltages in terms of dc reference voltages. A compact, inexpensive comparator has been developed to intercompare these converters with an accuracy of better than 10 ppm at audio frequencies. With the new comparator the relative ac-dc differences of adjacent ranges of converters can be determined quickly and easily in the user's laboratory to step up and down the voltage scale. Only a single range need be calibrated at NBS as a reference, and recalibration is not necessary unless the intercomparisons show changes. Thus the high accuracy of these converters can be established and maintained at a very low cost in time and equipment.

Improved Accuracy in Resistance Measurements at the One-Ohm Level—An entirely new measurement system for calibrating Thomas-type one-ohm Standard Resistors has been devised and placed in successful operation. The new system uses a dc current comparator and is capable of measuring resistors with a total uncertainty of 0.08 part per million, which is based on a three-standard-deviation limit for random errors of 0.05 and an allowance of 0.03 part per million for systematic errors due to possible uncorrected effects of temperature and pressure. This ten-fold improvement over the previous uncertainty of 1.0 part per million has been achieved at reduced power dissipation, now 0.01 watt per resistor.

Environmental factors are controlled more rigidly in the new system (temperature is held to 25.000 ± .003°C) and the Standard Resistors are never touched or moved by the operator during test. Inasmuch as all other resistance measurements at the National Bureau of Standards, from 10^{-4} to 10^{14} ohms, stem from this one-ohm base, an accuracy improvement here will affect the accuracy of all other resistance measurements.

High Voltage Pulse Measurements From High Speed, Fringe Pattern Photographs—A novel photographic technique has been developed for measurement of short-duration, high-voltage pulses (peak magnitude $\approx$ 100 kV). The pulse magnitude is measured directly from detailed two-dimensional fringe patterns produced under pulse conditions by the Kerr effect and photographed at high speed using a pulsed, expanded laser beam. In contrast to earlier fringe-pattern results obtained using high direct voltages, the present patterns are produced by voltage pulses with durations so short ($\sim$ 5 μs) that space charge distortion of the inter-electrode field is effectively precluded. The pulse magnitude may therefore be determined directly from the photograph, by counting the numerous dark fringes that map the distorted electric field at the sides of the electrodes of a calibrated Kerr-cell. Advantages afforded by this optical approach to voltage measurement include the following: (1) Since precision electrical metering equipment is not employed, the measuring system is not subject to electrical interference effects. (2) This approach makes feasible high-resolution (to 1% or better) measurements of steeply rising submicrosecond high voltage pulses. Because of the frequency response and deflection limitations of photodectors and oscilloscopes, accurate measurements of such pulses are extremely difficult, if not impossible, using conventional pulse voltage divider or Kerr system techniques. (3) It enables detection and measurement of fringing end field effects that often cause troublesome errors in conventional Kerr system pulse measurements. (4) It allows experimental study of the effects of design changes on the ideal electric field distribution without complications added by space charge distortion.

Calibration of Kerr Cells for Measurement of Pulsed High Voltages—Several Kerr cells have been calibrated for Kerr system measurement of pulse voltages peaking as high as 300 kV. By use of the electro-optical field mapping technique developed last year, the calibrations were achieved by reference to accurate high direct voltage measurements. Until now, calibrations of high-voltage pulse measuring dividers and Kerr cells have been extrapolated from low-voltage measurements. After calibration, Kerr cell measurements agreed with simultaneous calibrated divider results to within 1 percent to the 300 kV level.

Electrical Quantities—Radio Frequency

Comparison of Near- and Far-Field Determination of (JPL) Antenna Patterns—To support the deep space program as well as lunar missions, the Jet Propulsion Laboratory required an accurate calibration of standard-gain horns to be used with their 210 ft dish antenna at Goldstone, California.

To meet this need, a system was devised to calibrate the horns by

measuring the near-field distribution in a plane area in front of the horns. These data are then mathematically transformed to arrive at far-field antenna-gain patterns of high accuracy and great detail. The end result is a superior measurement with reduced cost.

Electromagnetic Radiation Hazards—An analysis of nonionizing radiation hazards shows that accepted hazards-measurement standards have little or no meaning in near fields, despite the fact that a large fraction of hazards occur, and many biological experiments are carried out, in near fields. Studies indicate that under very general conditions, electric-energy density in body tissues should be a good measure of hazard. A detailed analysis of both hazard measures and complications of their measurement parameter has been carried out. Several immediately useful outputs of this effort include a calibration method for electromagnetic-hazard meters that uses near-zone antenna-measurement techniques to eliminate the need for high-power rf sources; a microwave exposure chamber designed for the USAF School of Aerospace Medicine at San Antonio, Texas; and a prototype EM-hazard meter using a new type of field sensor.

This sensor is composed of a set of three orthogonal dipoles with diode detectors placed between the arms of each dipole. The detected signals from the diodes are transmitted over high-resistance plastic lines to a remote instrument that meters the levels. These lines produce very little distortion of the field being measured and have very little interaction with the dipoles. The full potential of this instrumentation has not yet been realized. Its outstanding characteristics are very wide frequency and dynamic range, ability to measure both peak- and average-field levels, and capability to measure accurately fields of arbitrary polarization with multipath or reactive components. For the first time, this meter and sensor combination make it possible to quantify accurately hazardous EM radiation from commercial microwave ovens, radar equipment, and antennas.

Bio-Electronic Transducer Research—An ultra-sensitive microphotometer was constructed to measure the speed of red-blood-cell flow in the surface capillaries of the lung as viewed through a window in the chest. These data, plus a measurement of cell color changes, give information about the oxygen-absorption mechanism and should provide a quantitative measurement of the effects of air pollutants on lung performance.

In this same area of research, a special ultrasonic transit-time measuring unit was constructed that permits an accurate, continuous measurement of left-ventricle diameter in the hearts of dogs. Further development in this area will be directed toward similar measurements in humans, with the goal of quantifying heart condition and performance on a routine, painless basis.

Pulse and Time Domain—New techniques for measuring pulses

with time durations between one picosecond and one second are being developed. Experimental and theoretical studies have been performed on coaxial transmission lines (TEM mode) whose losses were attributed to metal skin effect, simple Debye dielectric relaxation, or to semi-solid dielectric structures. Time- and frequency-domain measurements were made on a 213-meter (700-foot) superconductive coaxial line. A generalized theory was derived for electron-beam deflection in traveling-wave cathode-ray oscilloscopes. The theory is applicable to fast- or slow-wave deflection structures and includes the deflection-structure circuit properties and the electron-beam dynamics. Electronic systems were developed to acquire and process pulse-measurement data from sampling-oscilloscope systems. Many present-day commercial electronics systems and equipment (e.g. pulse generators, radar, computers) employ pulses having rise times of only a few picoseconds.

Matrix Diode Mixer—Many precision electromagnetic-measurement systems require frequency conversion to permit a single frequency-reference standard to be used over a large portion of the EM spectrum. The diode mixer generally is the weakest link in such systems. To overcome this problem a matrix-diode principle has been employed that uses from 16 to 24 hot-carrier diodes in a balanced configuration to provide a more linear conversion range with substantially lower noise figure. At 2.4 GHz, the mixer can accept a +10 dBm signal without compression while maintaining a 4 dB noise figure.

Decade Inductive Voltage Dividers for 100 kHz—Uncertainties of less than 0.5 part per million have been obtained in a 2-stage, guarded, inductive voltage divider. This single-decade divider yields this accuracy at frequencies to 100 kHz. High accuracy was achieved by employing an excitation winding wound on an additional core, and by using the center conductor of a coaxial cable as the principal winding conductor. Near-perfect guarding of each divider-section winding was achieved by applying guard potentials derived from a tap on the excitation winding to corresponding points on the shield of the coaxial cable section. The shield is continuous only within a section. The NBS divider design overcomes the two major limitations on accuracy at high frequencies that are inherent in other available inductive voltage dividers; namely, (1) excitation current and (2) current from stray admittances between sections of the winding that cause voltage drops in the leakage inductances of the sections. The device should be of value as a standard for calibrating other dividers, as an instrument for measuring voltage ratio and attenuation, and as ratio arms in bridges used for impedance measurements.

Precision Directional Couplers—New coaxial directional couplers have been developed for rf power measurement in the frequency range 2 to 3000 MHz. The couplers are used as stable, precision dividers and allow the measurement of high-power levels (e.g., 1 kW)

using low-level (10 mW) power meters. One coupler spans the 2 to 50 MHz frequency range with 50-db directivity and ± 0.2-dB maximum variation in coupling. A second coupler covers the 300 to 3000 MHz range with coupling flatness of ± 0.05 dB (1%), 40 dB or greater directivity, and maximum SWR of 1.02. Employing a variable slot-length feature, the coupler can be quickly adjusted to a quarter wavelength at any frequency within its band. Prior to this development, 3 or 4 couplers were required to span the decade band, which introduced coupling variations as large as 1.5 dB. The new coupler also is useful as an accurate, variable attenuator having a known attenuation curve. A third coupler is under development to span the 50 to 300 MHz frequency range.

Noise Calibration above 60 MHz—The first noise calibration service above 60 MHz for coaxial noise generators has been initiated. This new capability, between 2.60 and 3.96 GHz, can accommodate thermal-, gas-discharge-, and shot-noise generators with coaxial connectors. With appropriate adapters, uniconductor waveguide generators can also be calibrated.

New Thermal Voltage Converters—Higher accuracy measurements of rf voltage are now possible in the 1000 MHz range following the recent development of new thermal voltage converters (TVC's). A set of three TVC's covers the voltage range from 0.25 to 7 volts with an uncertainty limit of 1 percent. Formerly, this limit was 7 percent. Each converter employs a built-in tee connector to minimize voltage-reference-plane error. These units will be useful in calibrating rf voltmeters, receivers, oscilloscopes, and a variety of other equipment used in industrial and military applications.

Pulse Rise-Time Calibration Service—A pulse rise-time calibration service has been initiated using a commercial sampling oscilloscope as the working standard. Evaluation of the oscilloscope in the frequency domain allowed calculation of its time-domain response. Amplitude-response data were obtained at up to 18 GHz while the phase response was measured at up to 11 GHz. The new calibration service is intended mainly to accommodate tunnel-diode step generators and 2-port passive devices. The rise-time range extends from 20 picoseconds or less to approximately 1 microsecond. Uncertainty limits are 30 percent and 2 percent, respectively.

Photometric and Radiometric Quantities

Interlaboratory Comparison of Spectral Irradiance Standards—The radiometric community obtains most of their standards of spectral irradiance from commercial and Department of Defense laboratories whose standards are traceable to NBS. At times large differences between calibrations performed at these laboratories have been noticed. To determine the extent and source of these differences, an

interlaboratory comparison of spectral irradiance calibrations at the U.S. Army Metrology and Calibration Center, Redstone Arsenal; Eppley Laboratory, Inc.; Optronic Laboratories, Inc.; and the NBS was undertaken. Extensive measurements were made at each laboratory at a number of wavelengths between 0.25 μm and 2.4 μm on three, 1000-watt tungsten-halogen irradiance lamps. The results of this "round-robin" revealed differences between laboratory calibrations as high as 5 percent and differences between the laboratories and NBS as high as 3 percent, with little dependence on wavelength. The repeatability of a single laboratory participating in this intercomparison corresponded to a standard deviation varying from 0.5 to 1.0 percent, and the lamps used had an indicated drift throughout the test of about 0.5 percent. The observed laboratory differences have motivated efforts to reexamine and modify calibration procedures. The laboratory intercomparisons, including additional laboratories, will be continued on a regularly scheduled basis and are expected to improve the consistency and accuracy of spectral irradiance standards in the U.S.

Uncertainty of Spectral Radiance Calibrations of Tungsten Strip Lamps—The accuracy of tungsten strip lamps calibrated by an optical pyrometer determination of brightness temperature, published spectral emissivities of tungsten, and calculated spectral transmittances of the lamp window is usually unknown, primarily because of the uncertainty of how well the emissivities and transmittances used correspond to those of the lamp. To indicate the possible magnitude of error, this type of calibration has been performed on about 25 lamps for which spectral radiance values had been measured directly by comparison to a blackbody from 800 to 210 nm. The results of the investigation have indicated the emissivities that should be used and the errors in spectral radiance to be expected. From 650 to 300 nm emissivities published by Larrabee and from 650 to 800 nm those published by DeVos are preferred. From 300 to 225 nm, emissivities obtained as part of this investigation resulted in smaller errors than those of DeVos. Using the above emissivities, about 90 percent of the lamps tested had errors not exceeding 2 percent down to 300 nm and 6 percent down to 225 nm. The remainder of the lamps had errors as large as 6 percent at 300 nm and 20 percent at 225 nm.

Reflectance Standards for the Ultraviolet to Infrared—Eighty-three reflectance standards have been prepared and calibrated for use in the measurement of normal, spectral reflectance (0-10° irradiation, 0-10° viewing) over the wavelength range of 0.25 to 30 μm with an uncertainty varying from 0.1 to 1.0 percent. The standards are opaque, high-vacuum evaporated aluminum and gold mirrors, which have been aged for over a year (to minimize reflectance changes

caused by further aging). A Strong reflectometer in conjunction with a prism spectrometer for the wavelength range from 0.25 to 5 μm and a fast scanning Michelson interferometer spectrometer for the range from 5 to 30 μm were employed for the measurements. The standards are available in four sizes: 0.875 in diam, 1.125 in diam, 1.5 × 1.5 in, and 3 × 4 in, and may be purchased from the Office of Standard Reference Materials at NBS.

New Camera Test Method—A precise method of locating the axial focus of a camera objective lens mounted in a camera body has been developed. An optically flat, first surface mirror is placed in the film plane and the camera is mounted in a modified Twyman-Green interferometer with laser illumination. An interferogram is obtained that indicates the focal error and which can be used to evaluate the quality of the lens.

Theory of Microdensitometry—All measurements of the fine structure of photographic images depend on the measurement of the optical densities of microscopic areas of such images. Serious discrepancies between such measurements in various laboratories have been traced to the effects of partial coherence of the light passing through the instruments used for these measurements. A rigorous analysis has established the physical conditions required for the linear operation of microdensitometers. The findings of this analysis will also contribute substantially to an understanding of the operation of setting a microscope crosshair on the scale marks on a length standard, such as a meter bar.

New Approaches to Lens Evaluation—A new technique of lens evaluation, based on the use of a shearing interferometer developed at NBS, has been subjected to rigorous theoretical analysis and preliminary tests. A digital computer is used to compute the pupil function and transfer function of the lens from the information contained in the interferogram.

Another new technique, recently developed, utilizes an autocorrelator to measure the modulation transfer function of a lens rapidly and accurately. The technique should also be useful in other optical and photographic correlation studies.

Theory of Resolving Power—The quality of most cameras and other optical instruments is judged primarily by their resolving power as measured with a high-contrast three-bar test target. The theory of the formation of optical images of such objects has recently been reformulated, taking partial coherence into account. During the course of this work it was shown that considerable differences in resolving power can be attributed to differences in coherence of light propagated from the target to the objective of the camera or other optical instrument. This research should result in the specification of more reproducible and meaningful test methods.

Thirty-Meter Laser Interferometer—For the last year a 30-meter Fabry-Perot interferometer, located in an unused gold mine near Boulder, has been used as a geophysical strainmeter. The instrument uses two lasers oscillating at 3.39 micrometers. One laser is locked to a transition in methane, and the other is locked to a fringe of the interferometer. The ends of the Fabry-Perot cavity are anchored in the rock of the mine, so that the change in the beat frequency between the two lasers is a direct measurement of the change in the strain of the rock. The ultimate sensitivity of the system has not yet been reached, but strain fluctuations of the order of two parts in 10^{13} per unit bandwidth can now be measured. The instrument is being used to study various problems of geophysical and astrophysical interest, including the possible detection of gravitational waves from pulsars.

Biological Magnetism—Magnetic fields of 10^{-10} tesla or less are associated with the human heart beat and fields of 10^{-13} tesla are associated with the alpha-rhythm currents in the brain. These and other small biological fields can be detected with superconducting quantum-flux sensors. Work on these superconducting magnetometers was initiated by scientists of Philco-Ford Corporation and is being continued at NBS, Boulder. A compact portable instrument built at Boulder has a sensitivity of 10^{-13} tesla or better (10 to 100 times better than the best presently-available instruments). Magnetocardiograms taken with the newest magnetometer are comparable to good electrocardiograms in quality. This suggests new medical diagnostic procedures using magnetometers as passive, nonintrusive monitors of biological processes. Other applications include studies of paleomagnetism and magnetic anomaly detection.

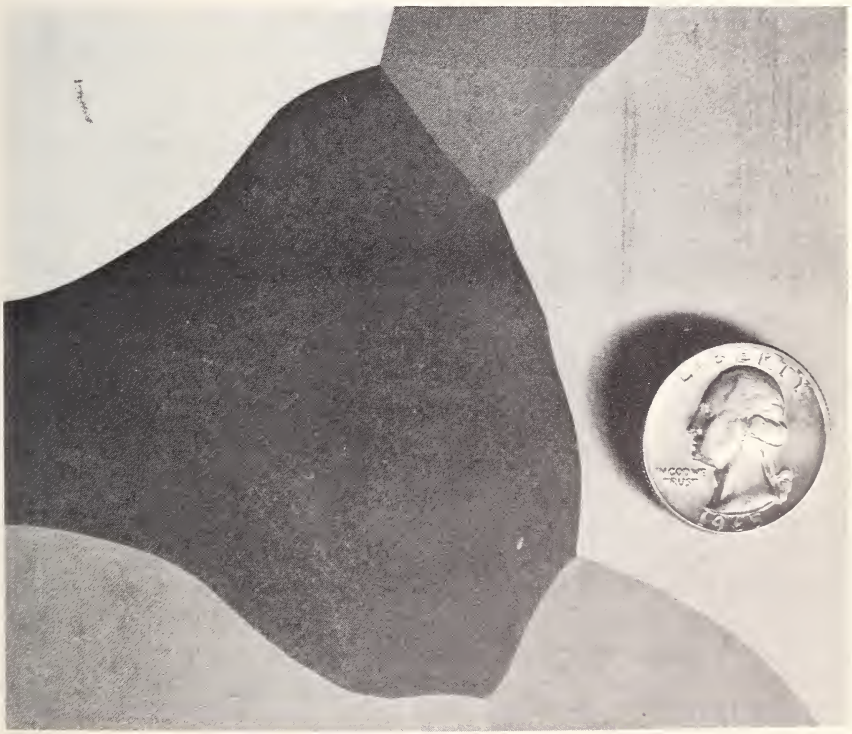
Superconducting Quantum Interference Devices—A relatively simple technique has been developed for fabricating controlled weak electrical contacts (Dayem microbridges) between superconducting thin films of niobium. The electrical properties of these microbridges are controlled by quantum-mechanical interference, a phenomenon that forms the basis of a new generation of very sensitive instruments such as magnetometers, galvanometers, infrared detectors, and millikelvin thermometers. The niobium microbridges, in contrast to their predecessors, are expected to possess the ruggedness and longevity required of instruments operated in field conditions.

New Hypo Test Method—Residual hypo is one of the critical factors determining the archival permanence of films. A new method which has been developed for measuring the amount of hypo remaining in film after washing has several advantages over previous ones: it is nondestructive, employs no highly poisonous chemical, and is simpler and quicker. In this method, a piece of chromatographic

paper saturated with an ammonia solution is placed on the emulsion to be tested. The hypo dissolves and is absorbed in the paper. When the paper is treated with a silver nitrate solution, silver sulfide forms in an amount proportional to the concentration of hypo. The dark-colored sulfide can be determined quantitatively by measuring light transmitted through the paper. The paper may be applied to the film at a processing site and then be sent to another laboratory for evaluation without sending the film. Whereas previous methods determined the average hypo concentration over a square inch of film, the new method reveals the variation in concentration over the surface. Judgment of the archival suitability of film can now be based on the maximum hypo concentration rather than an average. Measurement of the distribution of residual hypo also should be particularly useful to designers of film-washing equipment.

REFERENCE MATERIALS

Preparation and Characterization of Standard Reference Metals— Present and future needs for high-speed ground transportation, more efficient power distribution, and aerospace applications have created



The giant grain size of this aluminum sample is a prominent feature of the ultra-pure, accurately characterized metal produced for international comparisons.

a demand for a standardized metal that may be used in cryoconductor research. A Research Material, ultra-purity aluminum, which satisfies this need has been prepared, fabricated into special shapes, and made available.

Standardized specimens may also be used to calibrate physical apparatus, such as thermal conductivity cryostats, where absolute measurements are difficult. Measurements have been completed between 4 and 300 K on a NATO-AGARD stainless steel, iron, and gold. These metals were selected to obtain highly reproducible specimens of low, medium, and high conductivity, respectively. The well-characterized specimens have conductivities known to an accuracy of 1 percent.

Standardization of Copper—With the international trade in ultra-purity metals increasing significantly, there is a need for standardization of analytical chemical methods. This may be accomplished by the production and distribution of homogenous specimens of certain materials so that the results from laboratories of different nations using different methods may be intercompared. Over 200 carefully prepared specimens of copper in different shapes were produced, fabricated, and distributed to representatives of 12 different nations that are members of the Organization for Economic Cooperation and Development.

PHYSICAL PROPERTIES

Approximately half of the activity within the Institute for Basic Standards is related to the measurement of physical properties of well-defined substances. The rapid growth of the physical sciences has provided scientists with many new techniques for measuring "old" physical properties and has made accessible many new ones. With new techniques it has been possible to increase the precision of measurement, provide the scientific community with a greater range of reference data, and characterize certain processes more fully. Examples of these activities, drawn from current work, are given below.

Nuclear Properties

Angular Momentum Assignments of Slow Neutron Resonances—In order to demonstrate a new method for determining the angular momentum of slow neutron resonances, the NBS mobile He^3 refrigerator, which provided a highly polarized target of holmium-165, was used in conjunction with a neutron beam at the Atomic Energy Research Establishment, Harwell (England) Electron Linear Accelerator. High resolution total neutron cross sections of both polarized and unpolarized holmium-165 were measured with *unpolarized* neutrons over the energy range 12 eV to 2–3 keV. These measure-

ments will yield angular momentum assignments of many of the resonances covered in this energy region. Previous measurements made on holmium-165 at Brookhaven National Laboratory (U.S.A.) and Dubna (Russia), using *both* a polarized target and a polarized neutron beam, covered only the energy region below 100 eV.

Atomic and Molecular Properties

Autoionizing Transitions in Lithium Vapor—A modified heat pipe oven utilizing thin aluminum films as windows has been developed as a metal vapor absorption cell. Using the continuum radiated by the 180 MeV electron synchrotron as a background light source, new structure in the absorption spectrum of lithium vapor has been observed in the wavelength range 230 to 170 Å. Series have been observed converging to the $1s2s(^{1,3}S)$, and $1s2p(^{1,3}P)$ limits in Li II.

The experimentally observed positions of members of the $1s2s(^{3}S)np$ series with n = 2,3,4,5 confirm energies for these levels predicted theoretically at NBS. Configuration interaction between series members has been observed, perturbing both the strength and energy position of the levels. An experiment is now in progress to determine the photoabsorption cross section profile of these excitations.

Atomic Spectra—New measurements and analyses of a number of atomic spectra were carried out. The results of such work are useful for plasma physics, physical chemistry, solid state physics, astrophysics, laser research, as well as for atomic and molecular physics. New energy levels were found in seventeen different atoms or atomic ions, six of these being previously unknown spectra. Work on the spectra of several rare-earth elements was continued; compilation of the energy levels of both the lanthanide and actinide atoms and ions was begun.

A New Transition Probability Scale for Fe I—Astronomers are dependent upon laboratory values of atomic transition probabilities for their determination of the abundances of elements in the sun and stars. Many laboratory results have disagreed violently, especially for the metals (for example, there still exists an unresolved discrepancy of a factor of 10,000 for Ti II). Measurements of many Fe I transition probabilities have been performed with a wall-stabilized arc and a delayed coincidence lifetime apparatus, leading to a new set of data, consistent with all other recent measurements. This set ties together these previously unrelated measurements, and differs from the older, widely used data by factors up to 30. On the basis of these new results, astronomers now believe that there is about 10 times more iron in the sun than previously assumed. The new values for the iron transition probabilities also resolve a long standing

inconsistency between the iron abundance in the corona and the photosphere. On the basis of the new data, these solar regions now appear to have the same iron abundance.

Exploitation of Systematic Trends for the Determination of New Oscillator Strengths—Recently detected systematic trends among atomic oscillator strengths along isoelectronic sequences have been utilized for the determination of new numerical data and for the evaluation of the reliability of existing material. About 100 well-established systematic trends were found for the lighter elements from a critical, detailed study of the literature. About 1500 new oscillator strengths could be interpolated from the graphs, mainly for the higher stages of ionization. The new data are estimated to be accurate to about 20 percent or better.

Study of Decaying Arc Plasma—Electric arcs have been widely used as sources for the experimental determination of atomic constants and high temperature properties of gases. The interpretation of most such measurements depends upon the arc plasma being in local thermodynamic equilibrium, a condition difficult to verify experimentally. A spectrometric investigation of decaying arc plasmas has been undertaken to develop experimental means for determining the degree of equilibrium existing in arcs. For this study, the supply of electric power to high current (10 to 100 A) argon arcs is suddenly removed and the time behavior of selected spectral features is recorded. The results support a two-temperature plasma model in which the temperature of free electrons decays within a microsecond to a value several hundred degrees below the temperature of the heavier atoms and ions after which both temperatures decay slowly, typically with a time constant of 100 microseconds.

Theoretical Atomic Structure Calculations—A general computer program to calculate superposition of configuration (SOC) wavefunctions for atoms is being used to study various problems in atomic physics. Experience indicates that this program is capable of yielding atomic properties with an accuracy comparable to present day experimental techniques. Two such properties in particular have been studied recently: electron affinities and f-values. Electron affinities have been calculated for the lighter alkali- and alkaline-earth elements, and for helium, neon and argon. In the latter case the calculations actually give the positions of the negative ion resonance states seen in electron scattering experiments. The SOC program has been used to determine the f-value behavior for selected transitions along isoelectronic sequences (the boron and beryllium sequences) as well as the f-value distribution in perturbed spectral series of selected elements (aluminum and beryllium). In both cases the effects of configuration interaction have been found, in general, to have a profound effect on the oscillator strengths.

Dye Laser Stabilization—The full potential of the laser as a tool for precision measurement depends on the stability and the selectivity of the optical cavity. A typical gas laser, for example, operates on a specific atomic transition. The selectivity of the cavity can be made so high that laser operation can be confined to a very narrow portion of the linewidth. Reproducibility of the laser wavelength can be high if the mirrors which constitute the cavity are mechanically stabilized. A different sort of selection and stabilization is required for a dye laser, which has the property of being continuously tunable over a wide frequency range. A dispersing element is used in place of one of the cavity mirrors to achieve tunability. Cavities of this sort are inherently less stable and less selective. A JILA Visiting Fellow has developed a technique for using a birefringent filter within the cavity to specify and control the frequency at which laser action occurs. An electric field, applied transverse to the laser axis, controls and varies the transmission frequency of the filter and hence of the laser. Laser emission lines have been produced with widths of less than 0.5 picometer (0.005 Å) and tunable over a range of scores of nanometers. The device has immediate and important applications in high resolution studies of spectral absorptions and nonlinear processes.

Reactions Involving Negative Ions in Oxygen—A study has been made of the reaction $O_2^- + 2O_2 \rightarrow O_4^- + O_2$ at pressures and temperatures characteristic of the ionosphere. When low energy electrons are released in oxygen gas they attach to make O_2^-. The O_2^- further reacts with the oxygen to make O_4^-. Measurements have been of the rate of the O_2^- to O_4^- reaction and equilibrium ratio of the two ion types for the temperature range 280 K to 312 K at gas density of 3×10^{16} molecules per cubic centimeter. O_4^- is observed to react rapidly with CO_2 and H_2O contaminants.

Microwave Spectra of Molecules with Astrophysical Significance—The $5_{2,3} \leftarrow 6_{1,6}$ transition in $H_2{}^{16}O$ has been observed by radio astronomers from several sources in the galaxy. The detection of $H_2{}^{18}O$ in these same sources would confirm the $H_2{}^{16}O$ assignment as well as provide inforamtion on the $^{18}O/^{16}O$ galactic abundance and the H_2O emission excitation mechanism. Before an astronomical search can be made, it is necessary to have a laboratory measurement of the transition. Such a measurement has been made, giving a value for the $5_{2,3} \rightarrow 6_{1,6}$ transition frequency in $H_2{}^{18}O$ at 5625.147 ± 0.015 MHz.

Since absorption by the formaldehyde molecule in the galaxy has been detected, speculation exists about the occurrence of similar molecules. The new species thioformaldehyde, H_2CS, has been generated and its microwave spectrum observed. A prediction of the $1_1 \rightarrow 1_{10}$ transition frequency (1046.48 ± 0.002 MHz) has been made with precision sufficient for an astronomical search.

High Resolution Infrared Spectra of Unstable Molecular Species in the Gas Phase—Although infrared studies of free radicals or unstable molecules trapped in rare gas matrices at very low temperatures have been highly successful, little work has been done on the gas phase spectra of such molecules and virtually none at high resolution where individual rotation-vibration lines can be measured. Thioformaldehyde (H_2CS), a short lived species first identified at NBS, is produced in a flow system by reacting the fluorine atoms, produced by an rf discharge through SF_6, with dimethyl disulfide. Sufficient concentrations have been produced in a 40-meter optical path to observe three infrared bands with better than 0.05 cm^{-1} resolution. When combined with microwave data, this work has made it possible to determine all the significant ground state rotational constants with a high degree of accuracy. In addition this study yields vibrational frequencies unperturbed by solvent effects (as in the case of matrix techniques) and thereby contributes to an understanding of the vibrational force field in the molecule. Thioformaldehyde has been postulated to be one of the molecular species in interstellar space. If so, then this study will aid astrophysicists in identifying the spectral lines and estimating the concentration of this molecular species.

The Precise Calculation of Rotational Spectra—By correctly including the effects of centrifugal distortion in rotational energy level calculations for molecules, it is now possible to compute their microwave spectra within experimental accuracy. The model consists of fifteen parameters and has been tested on ten different molecular species with equal success in all cases. The full exploitation of the statistics of the least squares analysis gives a prediction of unmeasured transitions within reliable uncertainty limits. Such predictions are extremely useful in sorting out the spectra of complex mixtures of substances. A major consequence of this study has been the development of methods for detecting errors in the assignment of microwave spectra, and errors have been found in the published spectra of three of the 10 molecular species tested. In special cases (XYX bent molecules) knowledge of the centrifugal distortion constants has provided insight into the description of intramolecular forces.

The Electronic Spectrum of AlN—Seven years ago Prof. Robert E. Mulliken pointed out that the molecular orbitals for molecules having the same number of valence electrons as C_2 and BN are not well understood. In an attempt to shed some light on this problem, AlN has been observed spectroscopically in the gas phase for the first time. The observed transition has been shown to be $^3\Pi$–$^3\Pi$. Both electronic states of this transition have spin-orbit coupling characteristics intermediate between Hund's case (a) and case (b). Their energy levels did not fit a simple algebraic expression, so the rotational constants

B and D and the spin-orbit coupling constant A were obtained by least squares analysis involving the diagonalization of the appropriate spin rotational Hamiltonian matrices. Predissociation occurs in both electronic states of this transition, as shown by the abrupt cutoff of lines in the bands, and by the slight broadening of all lines in the transition. Therefore the lower state of this observed transition is not the ground state of the molecule; the ground state is still unknown.

Minima in Generalized Oscillator Strengths—A characteristic of electron impact excitation of low-lying Rydberg electronic states is a minimum in the generalized oscillator strength as a function of K, the momentum transfer. This characteristic was used to probe the Rydberg character of four transitions in C_2H_4. Three of the transitions have long been identified as Rydberg and are found to exhibit the characteristic minimum. The fourth transition is normally termed a valence excitation, and a theoretical calculation using Hartree-Fock molecular orbitals had predicted no minimum. For an energy loss of 8.0 eV, which is identified with the valence transition, a definite minimum is observed. Speculation of the source of this anomaly centers on a type of valence-Rydberg mixing that can occur in many molecules. It is believed that the presence or absence of minima in generalized oscillator strength curves can be used to probe the aspect of the character of the excited state.

Solid State Properties

Development of a Highly Sensitive Vibrating Sample Magnetometer—In order to make precise magnetization measurements on small samples at very low temperatures and in high magnetic fields, a high-sensitivity vibrating-sample magnetometer has been developed. This device has been made extremely compact by the use of a piezoelectric element as the vibrator. A constant amplitude of vibration is obtained by controlling the applied voltage to the element. This is done by monitoring the signal from a small spherical yttrium iron garnet (YIG) sample mounted midway on the element and having separate pick up coils. YIG was chosen as a reference since its magnetization in a fixed applied field is essentially independent of temperature below 10 K. The smallest detectable signal of this system is 10^{-6} emu.

$DyPO_4$: A Three-Dimensional Ising Antiferromagnet—Although the Ising model has been used successfully for one- and two-dimensional systems, no substantial test of it has been made for a three-dimensional system. To make such a test, the magnetic susceptibility, heat capacity, and optical absorption spectrum of $DyPO_4$ have been measured as a function of temperature and magnetic field. The results provide excellent agreement with the exact series expansions based on the three-dimensional Ising model for the diamond lattice.

Motion of Point Defects in a Crystalline Lattice—The thermally activated diffusive motion of simple point defects has been studied by means of detailed molecular dynamical calculations. This work was carried out in collaboration with the Theoretical Physics Division of the U. K. Atomic Energy Research Establishment, Harwell, England. The results show the mechanisms of defect motion in atomic detail that are generally not observable either in laboratory experiments or statistical theories. Of special interest is the conclusion that the energy of defect motion under dynamical conditions may be quite different from that obtained under static conditions, in contrast to usual assumptions. This study has suggested and stimulated related investigations involving motion of the atoms—polymorphic phase transition, phenomena of melting, Debye-Waller factor, etc.—both at the NBS and elsewhere.

Field Emission Energy Distribution Studies—The adaptation of a Kuyatt-Simpson type 135° spherical deflection analyzer to field emission has extended the accessible energy range by many electron volts both above and below the Fermi surface. Total energy distribution over six to eight orders of magnitude in current are routinely obtained with resolution of at least 20 meV.

Energy distribution from the low index planes of tungsten have revealed marked "surface band structure" effects, which are dramatically altered upon chemisorption, depending upon the nature of the atom or molecule being adsorbed. New structure after adsorption has been interpreted in terms of the energy levels of the surface complex. Also, with proper signal averaging, energy distributions throughout a wide range of field and temperature have been compiled, shedding light on the fundamental problem of an electron tunneling through or escaping over a barrier.

Thermodynamic and Transport Properties

Simple Equation of State for High Temperature Gases—An equation of state for high temperature gases was developed phenomenologically. The relatively simple equation, based upon considerations of pair-wise molecular interactions, has been applied to argon and nitrogen. At temperatures above two times the critical temperature, this equation was found to be a considerable improvement over other simple equations, such as the Redlich-Kwong equation. Furthermore, the agreement with experiment tends to improve with increasing temperature. The equation has no arbitrary adjustable parameters of its own, being completely and unambiguously determined by the pair potentials of the molecules.

The Solubility of Liquids in Compressed Gases—The phase equilibrium between a gas and a condensed material has been studied theoretically. An analytic relation was derived in terms of the molecular

interactions for the solubility of the condensed phase in the gas that is valid up to high pressures, pressures where the gas density is approaching the density of a liquid. It has been shown for the first time that at high pressures the solubility of any condensed material in any gas is sharply reduced. The analysis also corrected some widely held but erroneous conclusions on the size of the effect of the solubility of mercury on pressure measurements in a gas in contact with the mercury. The effect is now shown to be considerably smaller than was previously estimated. As a result, a large uncertainty could be removed from a number of PVT measurements reported by workers in various laboratories.

Densities and Compressibilities of Oxygen in the Critical Region—The determination of an accurate equation of state for simple fluids has defied both empirical and theoretical efforts for many decades. A partial solution to this problem has recently been achieved with a scaling-law equation of state that may be asymptotically valid for all simple fluids near their critical points. To further test the correctness of scaling-law predictions, density versus height profiles were measured for oxygen in the critical region using capacitance techniques. This method provides a direct determination of the isothermal compressibility with a sensitivity that is several orders of magnitude better than that obtained from conventional PVT measurements. These measurements provide the most precise and comprehensive tests to date of the scaling-law equation of state and are in excellent agreement with analysis of thermodynamic data for other fluids.

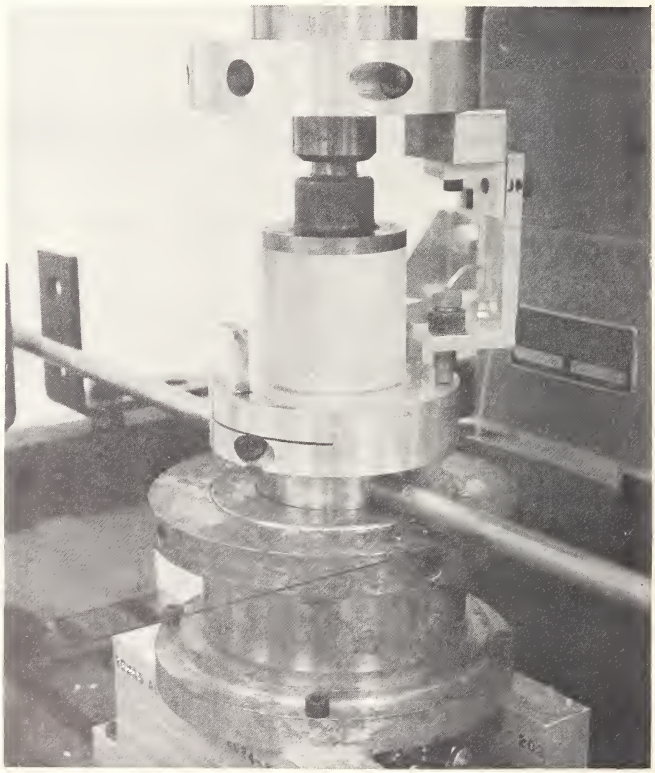
Vapor Pressure, PVT and Specific-Heat Measurements on Gaseous and Liquid Fluorine—Fluorine is one of the most reactive oxidizers known and its use with hydrogen provides the highest specific impulse of any stable oxidizer-fuel combination. Accurate thermodynamic-property data on both substances are required for the design of efficient rocket-propulsion systems, but few physical-property measurements have been made on compressed fluorine because of its extreme reactivity and toxicity. After solving the compatibility problems associated with handling this substance, accurate vapor pressures, densities and specific heats were measured at temperatures down to the triple point (53.5 K) and pressures to 21 MN/m^2 (3100 psi). The volumetric and thermal measurements are being used with ideal gas-spectroscopic measurements to provide the most accurate and extensive thermodynamic property data in existence for this substance.

Wide-Range Dielectric-Constant Measurements on Gaseous and Liquid Oxygen—A stable oxygen-compatible capacitor has been developed for accurate low-frequency dielectric-constant measurements on compressed fluids. Wide-range dielectric-constant measurements were performed on gaseous and liquid oxygen at temperatures down

to the triple point (54.35 K) and pressures to 35 meganewtons per square meter (5000 psi). The dielectric-constant measurements were combined with previous density measurements to determine the density and temperature dependence of the molecular polarizability for this substance. Measurement precision and the range of variables covered far exceeds that of most previous investigations of the electromagnetic properties of fluids. Standard-reference-quality data on this physical property are useful both for practical densitometry and for providing basic knowledge on molecular interactions.

Finite Deformations of Elastic Materials—The classical theory of finite deformations of elastic materials arises from the assumption that the stress at any point in an elastic body is determined by the strain at that point, and that derivatives of the strain do not directly affect the stress. There is essentially no evidence to justify this assumption with the exception of experiments confined to small deformations for which linear theory is adequate.

Predicting the stress produced by an inhomogeneous deformation from data of homogeneous deformations for which the strain is constant throughout the material would constitute a test of the assump-



Rubber sample mounted in torsion apparatus. A measured twist is applied to the top of the sample, and an air bearing at the bottom permits measurement of torque and force.

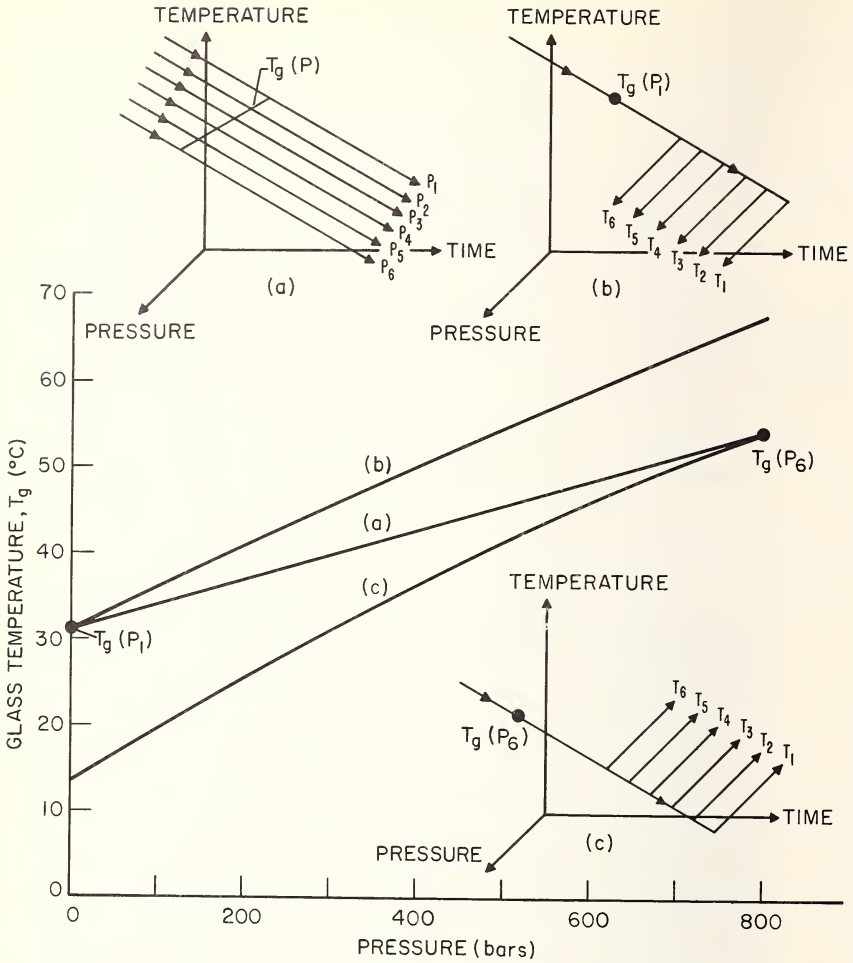
tion. The data in the literature are too inaccurate to make this test. Alternatively, twisting cylinders of the same material with different diameters, and observing whether the stresses scale as predicted by the classical theory, is a test which is particularly simple and accurate. An apparatus for this experiment was constructed by modifying a commercial milling machine. The torque and forces normal to the end surfaces of cylinders of natural rubber were measured as a function of the angle of twist. The small cylinders were cut from larger cylinders to insure that the tests were on identical material. Plots of reduced torque and of a reduced normal force versus a reduced twist for the different sized cylinders coincide to within 1 percent. Even this discrepancy can be accounted for by the inaccuracy in measuring the radii of the rubber cylinders. This result confirms the assumption of the classical theory.

The Dependence of Specific Volume of a Glass on Temperature and Pressure Histories—PVT measurements on poly(vinyl acetate) were undertaken to study the influence of certain thermodynamic histories used to form the glass on its physical properties. For example, the pressure dependence of the apparent glass transition temperature, T_g, for three different histories is shown on page 64. These curves were obtained from the intersections of the liquid and glass equations of state, the latter obtained from the histories shown schematically in the drawing:

(a) isobaric (constant pressure) cooling repeated at different pressures, (b) isobaric cooling at atmospheric pressure (P_1) followed by isothermal (constant temperature) pressure changes well below T_g, and (c) isobaric cooling at $P_6 = 800$ bars (1 bar = 10^5 newtons per square meter $\approx$ 1 atm) again followed by isothermal measurements well below T_g. All measurements were initiated in the liquid region, in which the material is in a true thermodynamic equilibrium state, and the glass formed at a constant rate of cooling of 5 °C per hour. In the glassy region further changes in temperature or pressure may be considered as isochronal (at equal times) because no significant mechanical relaxations can occur during the experimental times used. The curves illustrate the differences in the values of the glass transition temperatures (and, accordingly, other related properties, including hardness) resulting from different histories with the same rate of cooling used to form the glass.

Optical Properties

Construction of an Accurate Absolute Polarimeter—A photoelectric azimuthal polarimeter has been constructed to measure the angle through which plane polarized light is rotated as it passes through a quartz plate. A statistical study of measurements made with this instrument indicates a standard deviation for one measurement of



Pressure dependance of the glass transition temperature of poly (vinyl acetate) for three different histories (a), (b), (c), used to form the glass.

0.0014 degree for angles up to 40°. Comparison of measurements made on a quartz plate which had been measured at NPL in England and PTB in Germany showed a complete agreement within the standard deviation of the measurements.

This instrument will be used to calibrate the optical rotation of quartz plates which are used to check the accuracy of instruments in industrial laboratories as well as at U.S. Customs duty stations. This type of calibration has large financial implications for the sugar industry because the duty imposed on imported sugar is assessed on the basis of the optical rotatory power of a solution of the sugar.

APPLIED MATHEMATICS

The Institute for Basic Standards conducts a program in applied mathematics and statistics to meet varied needs in the development

of new measurement techniques and in the evaluation of the results of measurement. The level of the mathematics involved makes it essential to conduct fundamental mathematics research on a fairly broad scale.

Computer Algorithms and Programs—The error and probability functions together with their related functions arise frequently in scientific and statistical calculations. A number of algorithms for the computation of these functions were examined thoroughly, revealing a variety of weaknesses. The best of the methods have been combined in an ANSI FORTRAN program for computing the functions to the fullest possible accuracy over their entire ranges. Methods of computation, test data, critical results and check values have been documented in detail. The computer program is readily adaptable to the various computers in use, and has served as a test case in detecting software and hardware errors.

Numerical Analysis—The Bureau's computer program for the exact solution of linear systems and the inversion of matrices was prepared in various FORTRAN versions (depending upon whether or not special features of a particular computer were to be utilized). In addition, a FORTRAN program to find the rank and a complete set of independent vectors of any set of integral vectors was completed, using the same number-theoretic method. These programs have been distributed to a large number of requesters, and are functioning in many institutions.

A FORTRAN program for determining the invariant factors of an integral matrix was prepared. It has already found statistical application, having been used to show that certain block designs are not isomorphic, and is expected to find many other applications.

Numerical Studies of Partial Differential Equations—A high-order Taylor series expansion in the time variable was developed for the Vlasov equation describing the dynamics of a one-dimensional plasma. This method has the advantages of high speed of solution and of permitting the explicit calculation of error bounds. Comparison of the results with those from other methods revealed that reproducibility of the electric field, frequently used as a criterion for numerical stability, is wholly inadequate, numerically unstable computer runs giving substantially the same values of the electric field as do stable runs. The same can be said of criteria based on conservation of momentum and energy. These findings illustrate that numerical studies of processes that are highly dependent on kinetic effects in plasma must be carefully examined to insure that the results obtained are numerically accurate.

Acoustic Propagation in Heat-Conducting Media—Theoretical investigations have been made of acoustic propagation in both viscous and inviscid heat-conducting media. The principal new finding is that

certain solutions of the underlying fourth-order partial differential equation are not stable. (In viscous fluids the instability does not occur if the viscosity exceeds a certain critical value that depends on the ratio of the specific heats and the Prandtl number.) Thus the customary mathematical "model" is not adequate to rule out such physically meaningless modes of propagation.

Combined Index to Statistics Journals—In collaboration with the Harry Diamond Laboratories and the National Research Institute for the Mathematical Sciences, South Africa, the Statistical Engineering Laboratory prepared a combined author and permuted index for seven statistics journals. Over 5000 articles appearing in the following journals were indexed: *Annals of Mathematical Statistics*, *Biometrics*, *Biometrika*, *Journal of the American Statistical Association*, *Journal of the Royal Statistical Society*, *Series B*, *South African Statistical Journal*, *Technometrics*. The articles indexed are those appearing since the most recent cumulative index was published for the first six named journals, while for *Technometrics* all articles during the period 1959–1969 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. The author index is similar to a conventional author index.

Biomedical Image and Language Pattern Processing—Computer algorithms developed in previous phases of this work can segment a digitized image into distinguishable "objects" and determine the "inside-outside" relationships among these objects. In the present phase these algorithms were imbedded in more sophisticated analysis procedures. The latter were applied to serial sections of a "double neuron," recorded using a programmable microscope connected to a computer. The resultant abstract versions of the sections were "stacked" to produce a 3-dimensional representation of the original specimen. This representation was found to be quite acceptably realistic, verifying that the type of "measurement" implict in such algorithmic methods does succeed in capturing those properties useful to the biomedical scientist in analyzing the microscope images he studies. A similarly successful reconstruction was made of an optical intensity photograph of two chromosomes.

OMNITAB II—As part of the continuing program to maintain and update OMNITAB, fifty-five new instructions were added to the system and some major revisions were added to the system and some major revisions were made in existing instructions. These included fourteen for magnetic tape operations, nine for thermodynamics, six for complex arithmetic, three for matrix and array operations, seven for printing and nine for statistical analysis. Two of the instructions

for statistical analysis, ONEWAY and CORRELATION, provide an automatic printing of a comprehensive set of results in a readable form. Both the automatic printing and storage of the curve fitting instructions is vastly improved. In particular, the automatic printing gives four plots on a single page of the standardized residuals to enable the user to assess the adequacy of his model.

TECHNICAL ASSISTANCE TO OTHERS

Advisory and Consulting Services

Capacity Concept for Runway and Final-Approach Path Airspace—The present measure of airport capacity is based on a "tolerable average delay level" plus an assumption of highly random arrival-times for aircraft. In an FAA-requested study, the Bureau developed an alternative "maximum throughput rate" capacity concept, and rigorously established its representability by a simple mathematical formula. Because the formula explicitly combines the various parameters influencing capacity (e.g. traffic mix of aircraft types, runway occupancy time for each type, in-air separation standards), it is useful for studying "what if?" questions concerning capacity (such as the effect of a shift toward more use by large, fast planes), as well as in analyzing the relative effectiveness for capacity enlargement of runway improvements versus improvements permitting smaller in-air separations.

Improved Methods for Designing Sorting Systems—In the course of technical contract-monitoring assistance to the Post Office Department, two significant additions to mathematical techniques for the optimal design of sorting systems and operations were developed. While the need for such systems can arise in an information-processing context, or say in sorting produce by size, the most familiar example is the sorting of mail addressed to numerous destinations, each receiving a known average fraction of the total. Such sorting is not done all at once, but rather in progressively finer steps that are related by obvious logical constraints, e.g. if one step is to sort state X's mail by city, and another is to sort by state all mail to the region which contains state X, then the second-mentioned step must precede the first-mentioned. One Bureau contribution, extending previous work dealing with only two or three levels of sorting, determines the delay-minimizing sequence in which such a process should be performed when only a single sorting device is to be used, executing the steps one by one. The other contribution determines both what the individual sorting steps should be (what category should be split into which subcategories) and which of a set of sorting devices should be assigned to each step, given each device's

NBS provided the random tables and random calendars used in the draft lottery for men born in 1951.

error rate (where the objective is minimum overall error rate) or speed (where the objective is minimum overall delay).

Random Calendars for Use in Draft Lottery—At the request of the Selective Service System, NBS provided sets of 25 "random calendars" and 25 "random permutations" for use in the draft lottery conducted July 1, 1970. The sets were derived from tables published by Moses and Oakford, and tested for randomness according to the criteria established by Moses and Oakford. One of the random calendars and two of the random permutations were used to randomize the order in which dates and numbers were inserted into capsules, and the order in which capsules were loaded into two drums, in preparation for the draft drawing. In the final drawing a birthdate drawn from the calendar drum was associated with a number drawn from the second drum, establishing the order in which men born in 1951 will be called for induction.

Photoabsorption and Ionization Data for NASA—During the past year the JILA Information Analysis Center has begun a collaborative program with the NASA Manned Spacecraft Center to compile and critically evaluate photoabsorption and photoionization cross section data for atoms and simple molecules. These data are of importance in interpreting satellite, rocket and ground observation of radiation from planetary atmospheres and other hot radiating astrophysical objects.

Apollo-13 Investigation—Two members of the Cryogenics Division worked as part of a six-man Board of Consultants to help establish the sequence of events leading to the Apollo-13 explosion. They were asked to assist NASA's investigating team to ensure scientific objectivity, critically review the analyses made by NASA personnel, and contribute their own expertise in the field of cryogenics. The detailed study allowed the team to identify the most probable cause of failure and to establish a basis for redesign.

During the technical analysis of data telemetered from the spacecraft, accurate knowledge of the thermophysical properties of oxygen became exceedingly important. The carefully determined data on oxygen properties generated and supplied by NBS enabled the investigators to determine the nature of the explosion and the quantities of material involved.

Conferences and Symposia

Thermometry and Pyrometry Measurement Seminar—The seminar was held March 23–26, 1970 and was attended by 20 individuals (6 from DOD standards laboratories, 1 from a U.S. Government laboratory and the remaining 13 from industrial laboratories). Both lecture and laboratory sessions were employed.

High-Frequency and Microwave Noise Seminar—The High-Frequency and Microwave Noise Seminar was held April 27–May 1, 1970. Formal attendance from industry, government, the military, and two foreign countries was 30. The job orientation of the attendees was equally divided among standards laboratories, telecommunications, and radio astronomy. Over 500 pages of material were written specifically for this seminar, over 100 pages of material were released for the first time, and over 100 pages of reprints of NBS work were distributed to the attendees. The seminar treated the topics of measurement instruments, noise sources, and applications of noise technique.

Field-Strength and Antenna-Measurements Seminar—A four-day seminar held in April, 1970, was oversubscribed in March. Forty-six applicants attended from government and industry. Four came from foreign countries.

The seminar was balanced between precision-measurement practice and theory. Included among the many topics were lectures on the state-of-the-art of vector angular spectra, far-field computations from near-field data, and electromagnetic-radiation-hazards quantification.

Applied Superconductivity Conference—A three-day conference was held June 15–17, 1970, at the University of Colorado, Boulder, under joint sponsorship with the Office of Naval Research, American Physical Society and IEEE Magnetics Group. More than 300 scientists

heard over 70 invited and contributed papers covering recent developments in applied superconductivity. The one-day overlapping session, June 17, with the Cryogenic Engineering Conference was extremely well received and the plenary session was attended by over 800 scientists and engineers.

OSO Satellite Workshop—During the weeks of August 4–15, 1969, NASA and the Joint Institute for Laboratory Astrophysics sponsored a workshop to clarify and evaluate the current status of knowledge of the outer solar atmosphere. It was held at the JILA facility in Boulder, Colorado, and included principal investigators and collaborators for experiments on Orbiting Solar Observatories-III, -IV, and -V, as well as theorists and ground-based solar observers. The emphasis at this workshop was on how the physical properties—density, temperature, magnetic field, and velocity fields—of the outer solar atmosphere may be derived from existing data and what future satellite experiments are needed to obtain a complete description of the outer atmosphere.

Antenna Guy Lines—The replacement of steel guys, which now support large antenna towers, with glass-reinforced plastic (GRP) rod and rope is under consideration by several agencies which have responsibilities for tower maintenance. These GRP materials may be preferable to steel cable and rope because of their nonconducting properties (eliminating the need for large ceramic compression insulators), light weight, and low installation and maintenance cost.

However, limited field experiences with GRP guys have indicated several problem areas which merit further study before large-scale replacements can be justified. Representatives of the Army, Navy, Air Force, Coast Guard, and USIA met with NBS personnel in a working conference on November 4, 1970, to discuss these problem areas. As a result, a jointly sponsored project was established at NBS to evaluate the suitability of GRP materials for guy-line applications. Among the characteristics to be evaluated in this two-year effort are: size effects, long-term strength, Aeolian vibration effects, long-term storage characteristics, low temperature flexibility, and gripping techniques.

Precision Force Measurement—A two-day seminar on precision force measurement was held at NBS on April 6 and 7, 1970. The seminar included ten talks describing state-of-the-art force measurement systems, calibration methods, data handling techniques, NBS services and proposed changes, and a history of the field. The 20 attendees were also given an opportunity to observe and participate in NBS calibration procedures.

INSTITUTE FOR MATERIALS RESEARCH

Emphasis in the Institute for Materials Research (IMR) is o materials measurement methodology with particular concern for th characterization of materials. This emphasis supports the unique mission to develop standards of measurement for the commercial, industrial, and educational communities of the Nation and to provide research and consulting services to other Government agencies. About 25 percent of IMR's work is for other Government agencies.

STANDARD REFERENCE MATERIALS

Since the turn of the century, the NBS Standard Reference Materials (SRM) Program has provided the Nation's scientific and industrial laboratories with a means for calibrating their methods and instruments on site. The program has recently increased in size and broadened in scope to include standards certified for physical properties and engineering type standards in addition to the original standards certified for chemical composition.

The SRM effort, initiated in 1906, made the United States the first country with a program of this kind. Currently, more than 725 different SRM's are available or nearing completion. In the latter category are a new series of low alloy steels for calibration of optical emission and x-ray spectrometers, gases certified for their hydrocarbon and carbon monoxide contents, iron carbide in ferrite, austenite in steel, and activity standards for ion-selective electrodes. These are in addition to the 670 SRM's previously available and to the new thermogravimetric, molecular weight, organic dielectric constant, thermal expansion, calorimetric, and gold coating thickness standards made available for the first time this year.

In all 45 new SRM's and 22 renewals were certified and 14 were discontinued this year. New SRM's are prepared in response to recognized national needs and for newly developed industrial technologies. The renewals are prepared to supply the requirements of industries that rely heavily on SRM's and to supply the standards specified in codes or specifications of national standards writing bodies. As the need for some SRM's diminishes or new SRM's are produced that better serve the overall interests of the Nation's science and technology, certain SRM's are discontinued.

At the end of the year, 701 different items were in stock in 42 distinct categories and 66 subcategories totaling 396,618 units. Work is in progress to produce 193 new and renewal SRM's and is centered

in 134 projects. Sales to over 8,000 customers during the fiscal year accounted for 32,943 units and totaled $1,176,599.

The following examples were selected from the 45 new SRM's completed and certified during fiscal 1970 by 12 technical divisions of NBS:

Glass Viscosity Standard—A homogeneous borosilicate glass, SRM 717, completes a series of three viscosity SRM's for the types of glasses most widely used in industry. The other two SRM's in the series are soda-lime-silica glass and lead-silica glass.

The new SRM not only offers another viscosity standard to the glass industry for calibration and standardization of instruments used to measure properties of glass at elevated temperatures, but also a type of glass used in the electrical industry as a sealing glass. This glass has the desired electrical and dilation properties and adequate chemical durability to perform as a sealing glass. It is suitable for "kovar" seals having a linear coefficient of thermal expansion of about $51.5 \times 10^{-7}/°C$.

Viscosity measurements were made between the temperatures 470 and 1460 °C or from $\log_{10}$ viscosity values ranging from 15.0 to 2.0. These data, together with data submitted by four cooperating research laboratories, were tabulated in a certificate of viscosity values. Measurements were made by the rotating cylinder, fiber elongation, beam-bending, and parallel-plate methods.

The softening, annealing, and strain points of the new standard glass have also been determined by each laboratory according to ASTM Methods of Test and are reported on the certificate.

Ferrous Material Standards—Five white chill-cast iron SRM's were certified by NBS. The compositions of two of these, SRM's 1143 and 1144, were specially designed for production control of blast furnace iron. The others, SRM's 1147, 1148, and 1149, simulate important gray iron structure by means of rapid chill-casting and the addition of powerful carbide stabilizers.

These new SRM's were prepared and issued to meet a serious shortage of standards for production control and customer acceptance in the cast iron industry. They are designed primarily for calibration in optical emission and x-ray spectrometric methods of analysis.

The certification and issuance of these white iron standards is the culmination of a cooperative program between industry and NBS that included planning, preparation, homogeneity testing, and analysis. The material for the standards was melted and cast at the American Cast Iron Pipe Company, Birmingham, Ala. Homogeneity testing was performed by the American Cast Iron Pipe Company, Ford Motor Company, International Nickel Company, and U.S. Pipe and Foundry Corporation, which are members of the Ductile Iron Society.

A new high-silicon steel standard, SRM 1134, was issued by NBS primarily for application in optical emission and x-ray spectrometric methods of analysis. The high-silicon steels are widely used in transformers and dynamos where the electrical properties that have been imparted by the high-silicon content are of paramount importance. With numerous and increasing specialized applications of these high-silicon alloys, the tolerances for variation in behavior and properties (and therefore the chemistry) have become severe. The Armco Steel Corporation, in a cooperative program with NBS, produced the material for this standard and carried out fabrication procedures to provide material of the highest possible homogeneity. Extensive testing was conducted at NBS, including metallographic examinations as well as analyses by chemical, optical emission, and x-ray spectrometric methods. The testing revealed the material to be of high homogeneity. The Applied Research Laboratories of the United States Steel Corporation, in addition to the Armco Research Laboratory, cooperated with NBS in the analytical program for certification.

A new stainless steel standard, SRM 1155, was issued primarily for the calibration of optical emission and x-ray spectroscopic methods of analysis. It was prepared from an AISI type 316 stainless steel, one of the most important grades of austenitic stainless steels for high temperature applications. The material for the standard was prepared at the Duquesne Works of the United States Steel Corporation, Pittsburgh, Pa., in the form of rounds 12.7 cm (5 in) in diameter and 91 cm (36 in) long. These were later cut at NBS to a diameter of 6.4 cm (2.5 in) and the remaining cores then forge rolled to oversize rods 3.2 cm (1.25 in) in diameter at the Naval Research Laboratory and finally centerless ground to size at NBS. Homogeneity testing and analyses for provisional certification were performed at NBS.

Work neared completion on a new series of five alloy SRM's to be designated the 1200 series, which will replace the eight SRM's in the 1100 series for which the supply for most is exhausted. Through cooperative effort within the iron and steel industry, particularly through ASTM Committees E–2 on Emission Spectroscopy and E–3 on Chemical Analysis of Metals, the compositions were planned so that the new series will provide a graded concentration range for 40 elements. A grant from the American Iron and Steel Institute was of material assistance in purchase and preparation of the necessary stock of material. Each material will be issued as: (1) disks for optical emission and x-ray spectroscopy, (2) rods for determination of gas content, (3) smaller rods for microchemical methods such as electron probe microanalysis, and (4) chips for chemical methods of analysis.

Linear Thermal Expansion Standard—NBS has certified copper as the first of a series of thermal expansion SRM's. The complete series will cover the temperature range from 20 to 1900 K and have

coefficients of thermal expansion in the 0.5 to 25 $\times 10^{-6}$/ K range.

SRM 736, certified over the temperature range 20–800 K should be of particular interest to laboratories making measurements using relative methods of expansion measurements such as push-rod dilatometers.

Laboratories that measure thermal expansion have a definite need for reliable and accurate standards. Experience has shown that it is not uncommon for variations among laboratories using push-rod dilatometers to be of the order of a few hundred parts per million in $\Delta L/L$. Homogeneity of this material has been established by extensive testing at NBS so that it is suitable for interlaboratory comparisons.

Gold Coating Thickness—Twelve gold coating weight SRM's were announced by NBS, comprised of three series of four standards each of gold on a Fe-Ni-Co glass sealing alloy (SRM's 1371 through 1374), on a copper clad, glass epoxy laminate (SRM's 2301 through 2304), and on copper (SRM's 2311 through 2314), respectively. Each series has nominal coating weights of 1.5, 3, 6, and 14 mg/cm^2, equivalent to 30, 60, 120, and 280 microinch thicknesses of pure gold. The sealing alloy conforming to ASTM designation F15: 53 percent iron, 29 percent nickel, and 17 percent cobalt, is commonly used for making hermetic seals to glass in electronic applications. The second series is coated on a laminate that consists of 33 to 38 μm (1.3 to 1.4 mil) of copper on glass epoxy sheet, equivalent to ASTM grade 10. The third series is coated on pure copper.

Trace Element Glass Standards—Melts of glass containing 61 elements added at a nominal 500, 50, 1 and 0.02 ppm level were prepared and certified as SRM's for the calibration of a variety of instrumental methods at the trace level, and for the development and standardization of test methods involving chemistry for the determination of trace levels of the elements in a glass matrix with a nominal composition of 72 percent SiO_2, 12 percent CaO, 14 percent Na_2O, and 2 percent Al_2O_3 by weight. The overall homogeneity of each concentration has been checked for 20 or more elements. The SRM's should be useful for development and standardization of new test methods in the fields of radiochemical analysis, isotopic dilution analysis, activation analysis, atomic absorption, emission and flame spectrometry, and in spectrophotometry.

The provisional certificate for these SRM's was issued with 40 elements yet to be completely measured and certified. The analytical work and competences used in the certification represent possibly the most complex ever done at NBS involving to date more than 11,000 man-hours at NBS and 3,000 to 4,000 man-hours at cooperating laboratories.

Austenite in Steel—Standards with certified amounts of retained austenite in ferrous materials are desired because the amount of

austenite present critically affects metallurgical properties. The accuracy of x-ray diffraction intensity measurement of retained austenite decreases significantly as the amount of austenite present in the material decreases. Therefore, NBS is developing a series of standards containing from 1 to 25 percent austenite for use in the calibration of x-ray diffraction equipment for this use. A method of producing satisfactory standards from metal powders has been developed and the first group of compacts of nominally 4 percent retained austenite are ready for issue.

Iron Carbide in Ferrite—One of a series of four new SRM's consisting of spheroidized iron carbide in ferrite has been developed and will be ready for issuance shortly. Designated SRM 493, Iron Carbide in Ferrite, this SRM contains 14 percent Fe_3C. SRM 493 can be used in conjunction with retained austenite standards now being developed to calibrate x-ray diffraction and Mössbauer equipment, thus providing for accurate determinations of the austenite and carbide content of steels. These are two of most important microstructural constituents in steel.

Thermal Analysis Materials—Two materials, quartz and potassium nitrate, were certified as SRM's for use in thermal analysis. The phase transition temperature for quartz, SRM 775, is approximately 575°C and for potassium nitrate, SRM 756, approximately 130°C. The transition temperatures given on the certificates are the means of the values obtained on several differential thermal analysis (DTA) instruments. Generally, the differential temperature curve value is somewhat higher than the adiabatic value and will vary in a complex manner for different equipment and heating rates.

Quartz and potassium nitrate are the first two materials to be made available as SRM's from a group of compounds screened by the Standard Committee of the International Conference on Thermal Analysis (ICTA). It is anticipated that with additional cooperation from the newly formed ASTM provisional committee on thermal analysis, further progress will be made in screening and supplying materials suitable for DTA and differential scanning calorimeter standards covering subambient to very high operating temperatures.

The ICTA Committee on Standardization recommended the use of these materials as DTA SRM's. In addition to the determinations made at NBS, cooperative work and values on one or both of these SRM's were furnished by the Department of Chemistry, University of Akron, Akron, Ohio, and by the Ontario Research Foundation, Sheridan Park, Ontario, Canada.

Dielectric Constant Standards—The dielectric constant of most materials is commonly defined as the ratio of the capacitance of a capacitor immersed in the medium in question to that in vacuum. Because most test capacitors are nonideal, they must be calibrated for

accurate work using air and one or more materials of known dielectric constant.

Two compounds, 1,2-dichloroethane, SRM 1512, and nitrobenzene, SRM 1513, were certified as dielectric constant standards. These SRM's, together with SRM 1511, cyclohexane, complete the series of three dielectric constant standards now available. The dielectric constants for each of these materials were measured at 20, 25, and 30°C. Calculated values can be used from 10 to 40 °C without introducing appreciable error. These SRM's are useful for the determination of the geometric capacitance of two-terminal dielectric constant cells and for checking the linearity of the geometric capacitance of the three-terminal, or absolute, cells.

Heat Source Calorimetry Standards—Three new SRM's—1651, 1652, and 1653—certified as gasless heat-source materials, are now available.

The certified heating values were determined calorimetrically by comparison with electrical energy measured in terms of the national standards of resistance, voltage, and time using a specially designed electrical heater and a small calorimeter submerged in an isothermal calorimeter jacket. The values were obtained when no air, oxygen, or nitrogen was in contact with the sample. For users to reproduce these values, air should be excluded or purged from the reaction vessel with an inert gas.

These SRM's were prepared from barium chromate and zirconium; the agglomerate was dried, screened, and separated into small units for safety in handling.

The barium chromate-zirconium mixture is thermodynamically unstable, the components reacting to produce the desired heat.

Instructions for safe handling of these SRM's are given on each certificate.

Polyethylene Standards—For several years, two polystyrene SRM's have been available for polymer characterization work, one of narrow molecular weight distribution (SRM 705) and the other of broad molecular weight distribution (SRM 706). Now there are also available a linear polyethylene SRM 1475 (whole polymer) and a branched polyethylene SRM 1476 (whole polymer).

The molecular weight distribution of the linear polyethylene has been carefully determined so that the material may be used to calibrate gel permeation chromatography instruments over a wide molecular weight range. This SRM is also certified for the limiting viscosity number (intrinsic viscosity) at 130 °C in three solvents; 1-chloronaphthalene, 1,2,4-trichlorobenzene, and decahydronaphthalene. The ASTM melt-flow rate and the density are also certified. SRM 1475 should be particularly useful in the calibration of instruments employed in the molecular weight determinations of polyolefins such as

the gel-permeation chromatograph, and should also find use as a well-characterized material for scientific investigation.

SRM 1476 Branched Polyethylene is certified for limiting viscosity number at 130°C using the same three solvents, and for the ASTM melt-flow rate (melt index) and density. This SRM will be useful in several areas of polymer research such as dilute solution studies, polymer rheology, and polymer crystal physics.

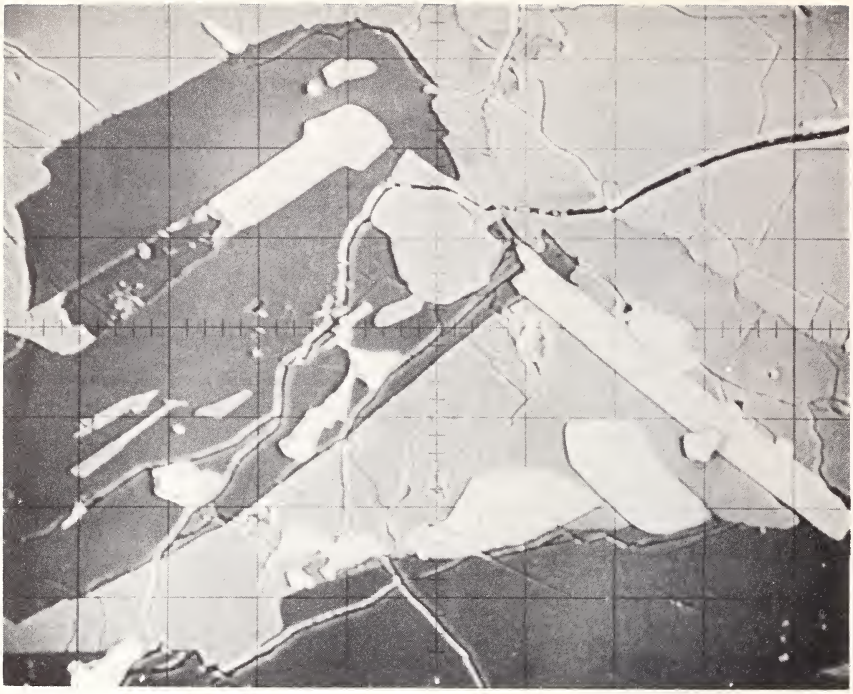
Activity Standards for Ion-Selective Electrodes—The recent rapid development of ion-selective electrodes along with many new applications has produced a demand for a suitable means of standardizing these electrodes and related measuring systems. The first in a series of Standard Reference Materials, NaCl and KCl, have been procured and certified for conventional single ionic activities, Na^+, Cl^- and K^+ based on the Stokes-Robinson hydration theory. These materials will soon be issued as SRM's that will enable researchers thoughout the world to standardize their instruments on a common, conventional ionic activity scale. Partial support for this program has been obtained from the Scientific Apparatus Makers Association.

RESEARCH TO IMPROVE MEASUREMENTS ON MATERIALS

Microstandards—The calibration of analytical mass spectrometers has been extended to measure samples from one billionth to one trillionth of one gram. This is done by loading the element of interest onto homogeneous ion exchange beads. The "weighing" of the bead is then done by microscopically measuring its diameter, the mass being obtained from the calculated volume and known density. The versatility of the technique has been established; elements such as lead, sodium, calcium, chromium, and uranium have been loaded onto beads. While the original work was done with synthetic organic cation exchange beads that are spherical, it is now possible to use small cubes, such as synthetic inorganic zeolite materials, by measuring the size of an edge of a single crysta'

Multi-element Analyses of Lunar Minerals by the Electron Probe Microanalyzer—The number of elements that can be determined simultaneously in the electron probe microanalyzer is normally equal to that of the x-ray spectrometers of the instrument (2-4 in commercial instruments). This limitation is a serious drawback in the investigation of complex specimens such as the lunar rocks, which are composed of many minerals, each of which contains several elements.

A lithium-drifted silicon x-ray detector that operates on the basis of pulse-energy dispersion, and which permits the simultaneous measurement of several elements, has been installed in an electron microprobe. By combining the output of this detector with the signals from the three crystal spectrometers provided with the instrument, a method was developed that permits the simultaneous quantitative determina-



Sector (0.20 × 0.25 mm) of a polished lunar rock from flight Apollo 12 containing four different silicates, two oxydic phases free of silica, one sulfide, and one metallic phase. The image shown is a target current scan obtained with the electron probe microanalyzer.

tion of seven elements. This method permitted, in one operation, a complete quantitative analysis of each of the minerals present in rock specimens from flights Apollo 11 and 12. Such multiple determinations were performed on more than a hundred grains of lunar specimens. The analyses were made in cooperation with the Goddard Manned Spaceflight Center, NASA, which plans to install similar equipment and to use the method developed at NBS-IMR in future investigations.

Liquid Chromatography—Liquid chromatography is a well known and thoroughly established method of performing chemical separations. Its theoretical basis and experimental limitations have been inadequately understood until recent developments have shown that the improper choosing of flow conditions can cause profound deteriorations in the sharpness of the separations. With properly designed apparatus and sensitive detectors it is possible to carry out much faster separations on samples weighing one microgram and less. These methods have been applied to achieve the first successful high resolution chromatography of bilirubin using gel permeation chromatography. Applications to the measurement of airborne carcinogens are being studied intensively.

Determination of Trace Amounts of Carbon in Metals by Photon Activation Analysis—Photon activation analysis has been applied to the determination of carbon in a variety of pure metals. Samples are irradiated in the bremsstrahlung beam produced from electrons accelerated to 35 MeV, inducing the reaction $^{12}C(\lambda,n)^{11}C$. Separation of the carbon activity is based on traditional high temperature combustion methods. The intrinsic sensitivity for the production of ^{11}C coupled with the absence of reagent and equipment blanks and the possibility in some cases of etching the sample after irradiation but before separation and counting allows determination at levels of below 10^{-7} gram of carbon.

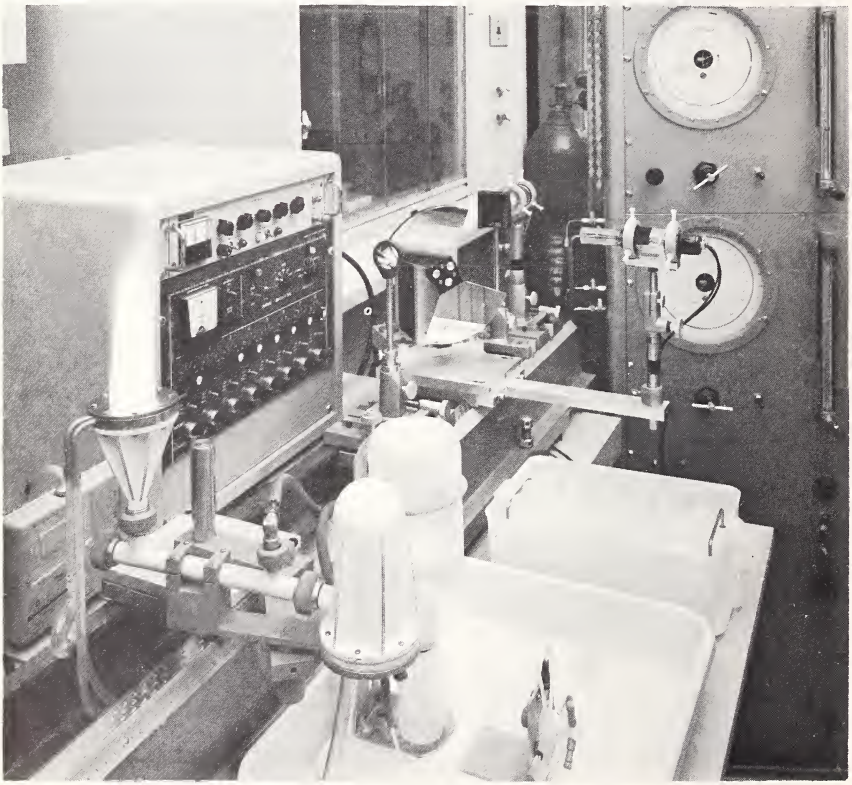
Characterization of the NBS Reactor for Neutron Activation Analysis—Extensive experiments have been carried out to characterize the new NBS 10-megawatt research reactor for use as an intense source of neutrons for activation analysis. The parameters of absolute neutron flux, neutron energy distribution, and variation of the neutron flux within the sample irradiation area were determined for each of the four pneumatic tubes and the manual access vertical thimble that make up the present operational irradiation facilities. In addition, temperature and pressure measurements were made on a variety of sample materials to establish usable operating parameters. At present, many types of samples can be safely irradiated for 8 hours at a neutron flux of 5×10^{13} $n \cdot cm^{-2} \cdot s^{-1}$ in the pneumatic tube facilities, and for weeks or months in the manual access facility at a neutron flux of 1.1×10^{14} $n \cdot cm^{-2} s^{-1}$.

Assay of Rubidium Chloride—A high accuracy method for the assay of rubidium in rubidium chloride has been developed. The method is a combination of gravimetry in which most of the rubidium is precipitated and weighed as rubidium perchlorate and the soluble rubidium from the precipitation is determined by isotope dilution mass spectrometry. The method has been shown to be capable of assaying RbCl to $\pm$ 0.02 percent at the 95 percent confidence level and has been applied to the assay of SRM 727, Rubidium Chloride, which was found to be 99.90 $\pm$ 0.02 percent RbCl.

Stable Isotopic Dilution Capability Established—IMR has established the capability for the determination of trace level impurities by stable isotope dilution analysis using thermal ionization mass spectrometry. This technique, in which natural isotopic ratios are altered by the addition of a known amount of a separated isotope and then measured by mass spectrometry, is capable of high accuracy trace determinations. It has the great advantage of not requiring quantitative separation of the element to be determined. Copper, silver, lead, thallium, rubidium, potassium, uranium, boron, and nickel have been determined in a number of SRM's including glass and steel standards with standard deviations of less that $\pm$ 1 percent even at

the parts per billion level. For example, in the 0.02 ppm Trace Elements in Glass SRM, uranium was found to be 71.7 ppb with a standard deviation of 0.5 ppb and thallium was found to be 8.2 ppb with a standard deviation of 0.1 ppb.

Multichannel Simultaneous Flame Emission and Atomic Absorption Spectophotometer—A flexible multichannel flame spectrophotometer was designed and built to extend the measuring capabilities of analytical methods in which a combustion flame is used to emit or absorb specific radiations. This instrument is composed of a 1 meter spectrometer with its multichannel phototube housing, the appropriate electronic components for scanning, and ac and dc signal measurement with integration and printout and a punch tape arrangement for computer calculations. A unique feature of the measurement system is an NBS designed burner and sprayer made of pure alumina with a water cooled tantalum flame plate, which provides an unusually stable flame and hence improved precision of measurement. The instrument can be used as a scanning monochromator, a spectrograph, or a multichannel spectrometer by appropriate arrangement at the focal plane of the spectrometer. At the present time, the instrument



Multichannel simultaneous flame emission and atomic absorption spectrophotometer.

is used for the simultaneous determination of Na, K, Ca, and Mg in biological fluids using Li as an internal standard. The instrument provides the full advantages of specificity, sensitivity, speed, and economy of sample in simultaneously obtaining data suitable for rapid computer evaluation.

Determination of the Structure of Surfaces—Mössbauer effect spectroscopy has been used to measure the chemical structure of very thin layers of iron bearing materials. The technique utilizes the fact that the 14.4-keV nuclear level exhibiting the Mössbauer effect is highly connected. By detecting 8-keV conversion electrons, only those that can pass out of the material are detected. Since the range is on the order of 1000 Å it is opssible to detect a signal from a layer as thin as 50 Å. This technique has been used to measure very thin films of conversion products on iron metal surfaces. Other applications are the analysis of iron-bearing particulate matter for air and water studies, and the fabrication of a resonant detector that can significantly enhance the sensitivity of Mossbauer spectroscopy.

Computer Analysis of Nuclear Magnetic Resonance Spectra—A versatile new computer program has been written for the analysis of nuclear magnetic resonance (NMR). It allows the fitting of spectral parameters, using an iterative method, to larger spin systems than could previously be accommodated. This is accomplished by using magnetic equivalence factoring that allows the three spins of a methyl group, for example, to be replaced by a complex particle of spin 3/2. The NMR parameters of molecules such as $CH_3CH_2SiF_3$, $CH_3CH_2GeH_3$, and $[(CH_3)_2CH]_3P$ have been found by the use of the program. The usefulness of the NMR method for characterization of molecular species is thus considerably enhanced, since a large group of molecules whose spectra could not be analyzed successfully in the past may now be included.

A noniterative version of the same program has been used to help analyze the spectrum of isotopically enriched diborane, $^{11}B_2H_6$. The results of the computation for the first time provide a fully adequate explanation for the observed NMR spectrum, and, in addition, provide the first known estimate for the magnitude of a B-B nuclear spin-coupling constant.

Characterization and Use of High Energy Photon Sources—The operational characteristics of rare gas resonance lamps, which deliver monochromatic radiation in the energy range 8.4 to 21.2 eV, have been investigated in detail. These titanium gettered lamps, which have a high spectral purity and long lifetimes, were designed at the Bureau and are now used in many laboratories around the world, not only for photolytic studies but also as a mass spectrometric ionization source and as an energy source for photoelectron spectroscopy.

These lamps, which essentially bridge the energy gap between

classical photochemical light sources and soft x rays, have been used at NBS to elucidate modes of deposition of high energy radiation in matter. This kind of information has been derived, in part, from accurate measurements of extinction coefficients and ionization efficiencies for a large number of organic and inorganic compounds. In addition, the modes of decomposition of these molecules and their ions over a wide energy range have been determined. Comparison of these results with those obtained in the gamma-ray radiolysis furnishes information about the nature of the activated species formed in gamma-irradiated materials. This work was sponsored by the AEC.

Gas Chromatography with Aqueous Solvents—Aqueous electrolyte solutions have been shown to have interesting possibilities as gas chromatographic substrates, as with such solutions it is possible to bring chemical selectivity into the separation process. The possibilities have been demonstrated using aqueous silver nitrate solutions in the highly specific separations of various olefins from each other and from their deuterated isomers. The applicability of such columns for pollution analysis is being explored.

Bond Dissociation Energies from the Fluorescence Appearance Threshold—Bond dissociation energies can be obtained by measuring the threshold energies of incident photons that produce electronically excited fragments from parent compounds. This technique, used successfully to obtain hitherto unknown bond energies such as $D(H-NCO)$, $D(HN-CO)$, $D(NC-N_3)$, and $D(CH_2—N_2)$, has a unique advantage over that of appearance potential of fragment ions: it is not required to know the ionization potential of fragment radicals of interest.

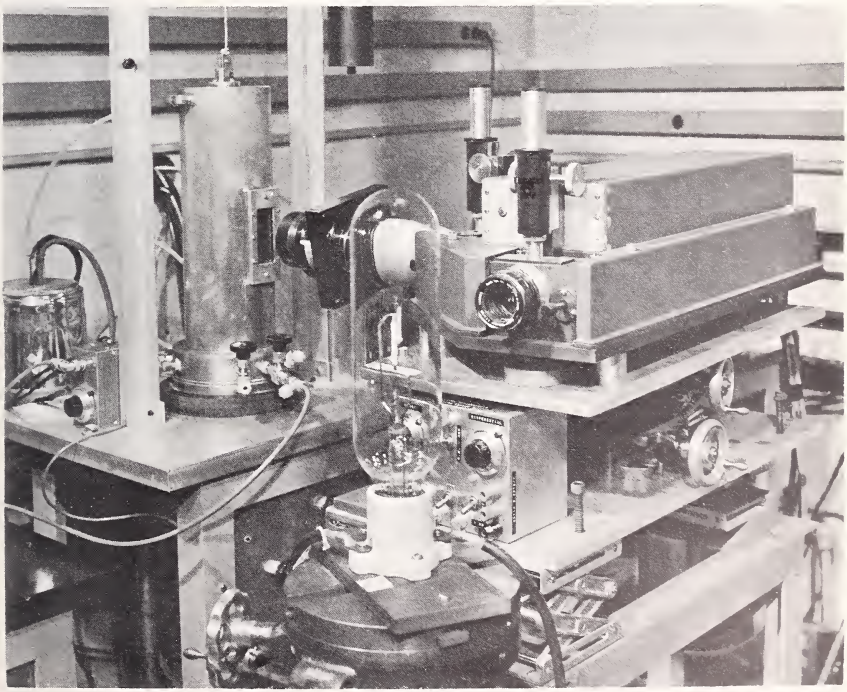
Organic Dye Laser as a Detector Absorption—An organic dye laser normally emits in a broad continuum approximately 100 Å wide. Insertion into the optical cavity of trace impurities, which absorb within the broad band of the laser emission, quenches the laser emission at the absorption wavelengths. The sensitivity of this detection device is at least two orders of magnitude greater than that using conventional photographic absorption techniques. The detailed mechanism for this enhancement in sensitivity is not clear. This technique has been used to detect I_2 and Na.

Slit Correction Program for Small-Angle X-Ray Scattering—The interpretation of small-angle x-ray scattering data is complicated by the necessity of correcting for the effect of the finite length of the instrumental slits. Procedures for applying the correction assume various simplified functional forms for either the scattering curve or the slit weighting function. The extent of the error introduced by the inadequacy of the functional forms employed is difficult to assess. A procedure for applying the slit correction which is free of these simplifying assumptions has been developed. The procedure is implemented in a computer program incorporating a back-check, in which

the corrected scattering curve is back-transformed for comparison with the original data.

Quartz Thermometry for Calorimetry—Investigations have been made of quartz crystal oscillator thermometers with digital output for use in measuring small temperature changes in calorimetry near room temperature. By the following two improvements, temperature changes can be measured in well designed calorimeters with an imprecision of ± 6 microdegrees. (1) Improving the reference crystal stability and temperature coefficient *or* using the NBS in-house frequency standard with a stability of 1 part in 10^{10} per day. (Recently direct counting of the probe oscillator frequency has also become commercially available with this degree of stability of the time base.) (2) Using a sensor crystal probe with only a thin copper capsule as an enclosure, or a copper capsule with a second thin metal sheath. The latter change improves the speed of response as well as the stability of the sensor. Further studies are being made on the long term (months) stability of the probe sensor-probe oscillator system so as to evaluate the reliability of the temperature measurement (as distinguished from the temperature difference measurement discussed here).

High Speed Measurement of Thermophysical Properties—Accurate measurement of thermophysical properties at temperatures above



The experiment chamber and the pyrometer used in the high-speed measurement of thermophysical properties.

2500 K had been hindered in the past by the difficulties resulting from excessive heat losses, chemical reactions, evaporation, loss of mechanical strength, etc. The recent development of a high-speed method enables the measurement of properties (specific heat, electrical resistivity, thermal radiation properties) of electrically conducting substances at high temperatures with an accuracy that surpasses any other known method. An additional advantage of this technique is that it allows the simultaneous measurement of several properties. Duration of an individual experiment in which the specimen is heated from room temperature to its melting point is less than one second. Temperature measurements are made with a millisecond resolution photoelectric pyrometer, and experimental quantities are recorded with a high-speed digital data acquisition system that has a full-scale resolution of one part in 8000. The time resolution of the entire system is 0.4 ms. Experiments were conducted on molybdenum and tantalum from 2000 K to their melting points. The high-speed technique is expected to be very valuable in measuring properties of refractory metals and their alloys and other substances with high melting points which find applications in various fields related to space, nuclear energy, etc.

EDTA Analysis Using Coulometrically Generated Zinc Ion—Electrogenerated zinc ion can be very conveniently used as a reagent for complexmetric coulometry. A new coulometric method was developed for Ethylenediamine Tetraacetic Acid (EDTA) analysis that makes use of amperometric end-point detection under conditions where the indicator signal is proportional to the uncomplexed zinc ion concentration.

Preliminary results indicate a highly reproducible titration of disodium EDTA with an assay of 99.936_3 percent and a standard deviation of a single determination of 0.002_2 percent. This titration provides the basis for a novel determination of the stoichiometry of various semiconductor materials such as gallium arsenide. The stoichiometry of semiconductors is of vital interest to the electronics industry because of the dependence of electrical properties on small deviations in stoichiometry. At present there are no satisfactory methods for this purpose at the required degrees of accuracy and precision.

DETERMINATION OF DATA REQUIRED BY THE MEASUREMENT SYSTEM

Properties of Materials

Ultra Pure Chemical Reagents—The very limited availability of pure chemical reagents, especially of corrosive acids, has been a long standing source of frustration to analytical chemists interested in trace analysis. A major source of difficulty is the fact that most con-

tainers are slowly attacked and dissolved by the reagents. Teflon should be an especially inert material for this purpose but in the course of manufacturing it tends to become contaminated by small particles. To illustrate, nitric acid is capable of diffusing into the container, attacking the particles, and the back diffusion carries the dissolved particles as contaminants. The leaching of Teflon by hot concentrated nitric acid, and then by steam, offers considerable promise for container purification, especially if coupled to subsequent storage of the acids at −50 °C.

Inositol Hexasulfate—*myo*-Inositol, a member of a family of substances having a cyclohexane ring with a hydroxyl group attached to each carbon atom, withstands dehydration by sulfuric acid. This behavior is markedly different from that of alditols and sugars, substances not possessing cyclohexane rings but otherwise closely related in composition to inositols. IMR chemists have found that the *myo*-inositol is converted into a hexasulfate, and this highly acidic product can be isolated as the crystalline hexapotassium salt. A very convenient procedure has been developed and patented for preparing the hexasulfate, a product of special interest because of its similarity to phytic acid, the hexaphosphoric acid derivative of inositol, a substance of widespread natural occurrence.

Analysis of Skew Conformations of Cyclic Molecules by Proton Magnetic Resonance—Although there is considerable interest in understanding the relative importance of chair and nonchair conformations of molecules that contain six-membered rings, little proton resonance data exists for unequivocal examples of nonchair conformations that can serve as a reference for conformational equilibria. Certain rigid carbohydrate molecules can be most useful in this regard. An NMR study of 3-*O*-benzoyl-1, 2, 4-*O*-benzylidene-α-D-ribopyranose has defined the degree of applicability of previously developed relationships between coupling constants and dihedral angles with the locked, skew conformation of this compound. Spectral assignments were confirmed by frequency-swept spin-decoupling experiments, and by studies of the effect of change of solvent on chemical shifts. The NMR spectrum was analyzed by an iterative, least-squares method, and the geminal, vicinal, and long-range coupling-constants obtained have been correlated with the stereochemical relationships. The mean deviation of the vicinal, proton-proton, dihedral angles calculated and those measured from a molecular model was 11°.

Application of the Reduced Cell Concept to Triclinic Crystals—The theory of reduced cells as developed at NBS is the basis for computer programs used to analyze all the 1100 triclinic crystals studied by x-ray diffraction before 1966. The results of these analyses will appear in the compliation, "Crystal Data."

Of the seven crystal systems, the triclinic is the only one without

a unique symmetry element. There is always a question of whether the crystal in fact lacks symmetry elements or whether the scientists failed to detect the true symmetry of the crystal. The possible higher symmetries are determined from special metric relationships between the unit cell constants as determined by the characteristic dot products of the reduced cell matrix. Not only is the possibility of higher symmetry determined, but also the system which the crystal may have. Approximately 20 percent of the crystals studied show relationships that indicate they may have higher symmetry. The most common possibility is C centered monoclinic.

In many cases where specialized metric relationships have been found, twinning is known to occur.

Photoionization of Halogen Molecules—Previous measurements by electron impact, photoionization, and photoelectron spectroscopy of molecular ionization thresholds for fluorine, chlorine, bromine, and iodine have failed to take into account the effect of hot bands due to ionization of vibrationally excited molecules. Photoionization measurements on these molecules, employing energy resolution of about 0.01 eV and a cooled or heated ion source operated over a range of temperatures, have shown the importance of hot bands and the necessity of revising data on the ionization energies of these molecules. In a related study of chlorine monofluoride, the threshold for dissociative ionization has been measured, the results supporting the low value proposed by this laboratory for the dissociation energy of the F_2 molecule. The work was supported in part by the Atomic Energy Commission.

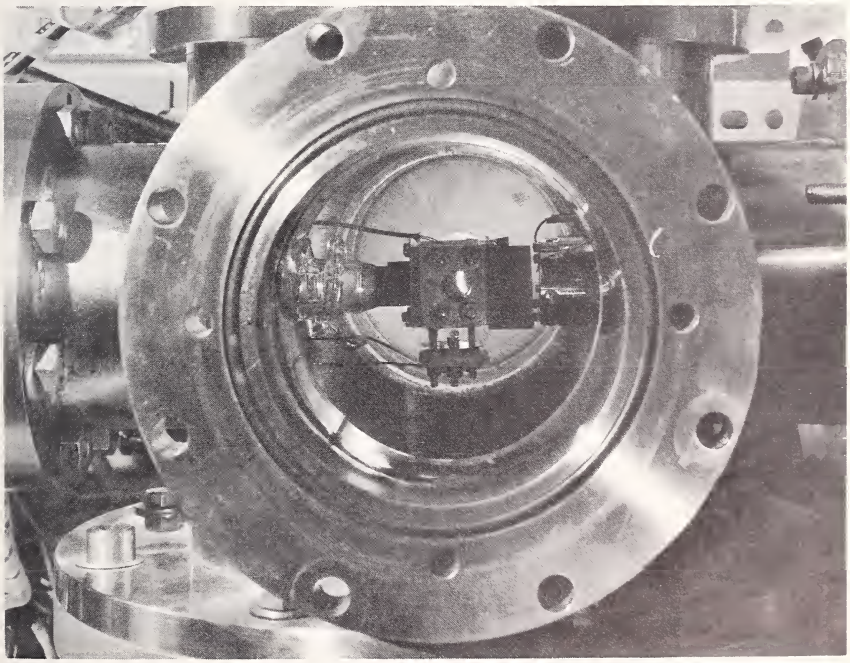
Structure and Reactivity of Hydrocarbon Ions—In the past, the structures of carbonium ions and the effects of structure on reactivity have been studied primarily in liquid phase organic systems in which the ions are generated through ordinary chemical reactions. Under such conditions, the ions generally have very short lifetimes, and slow processes are not easily observed. Recently, NMR and mass spectrometric techniques have been applied to the investigation of such problems, but both these techniques have certain limitations—under the conditions employed in the NMR studies, the ions are chemically unreactive, while in the mass spectrometer, the structure of the ion cannot be directly determined. Investigations have been made of the structures and reactivities of hydrocarbon ions in which the ions were generated in the gas phase by the action of high energy radiation. In these experiments the lifetime of the ions was varied by changing the pressure, and other simple techniques (rare gas sensitization) were used to vary the internal energy of the ions. Ionic structures are derived through an analysis of the products formed in the reactions of the ions; sophisticated analytical techniques and the use of deuterium labeling give detailed information about ionic structures. Because of this versatility, the results obtained

in these studies have resolved contradictions between conclusions drawn in studies using the different techniques described above.

Energy Partitioning in Photodissociation—The partitioning of the excess energy among photodissociated fragments has been studied. The vibrational and rotational energies of CN $B^2\Sigma$ produced from various cyanogen compounds have been determined from the CN emission spectrum, leading to the conclusion that when small molecules are photolyzed in the vacuum ultraviolet, the excess energy goes mainly into the kinetic energy of fragments.

Production of Electronically Excited Species in the Vacuum Ultraviolet—O^1S, an important species in the upper atmosphere, was produced in the laboratory from the photolysis of N_2O in the vacuum ultraviolet. The production was detected by its emission $O^1S \rightarrow {}^1D$ at 5577 Å. Since the emission is forbidden, the intensity is extremely weak. It was found that certain gases, especially Xe, stimulate the emission by forming a loose molecular complex. Using collisional stimulation, it was found that O^1S was also formed from CO_2 photolysis at 1165 Å with a yield less than 7 percent.

Electronically excited Cl_2 was produced from the photolysis of $COCl_2$. From the threshold energy of photons used to produce the Cl_2 emission, the electronic energy of Cl_2 responsible for the emission continuum at 2570 Å was obtained.



Ionization and reaction chamber (center) of the photoionization mass spectrometer as seen through a side port. The sample being studied enters the chamber through the system at center left, and reaction byproducts are analyzed with the quadrupole mass analyzer at center right. Ionization of the sample is caused by absorption of high energy photons emitted by the lamp at the rear.

High Pressure Photoionization Mass Spectrometer—The high pressure photoionization mass spectrometer is particularly well suited to the study of ionic processes that occur in systems under high energy irradiation, because reactions of thermal ions can be observed at ambient temperatures. In this instrument, ionization is caused by absorption of a beam of photons with a well-defined energy. Numerous previously unknown ion-molecule reactions have been observed. For example, an important discovery was that the ethane molecule ion, $C_2H_6^+$, reacts with the ethane molecule to form a dimer ion, $(C_2H_6)_2^+$. Similar dimerization reactions were observed for propane and isobutane. Of particular interest to upper atmosphere and petroleum chemists were the determinations of absolute rate constants for (1) the reactions of NO^+ ions with hydrocarbons, (2) the reactions of hydrocarbon molecular ions with water vapor, and (3) the reactions of carbonium ions with hydrocarbons. (See figure on p. 87.)

Electric Lighting and the Tungsten-Oxygen-Halogen Reactions—Research on the surface chemistry of tungsten in oxygen-halogen mixtures has been stimulated by the important effects of volatile tungsten compounds in electric lighting technology. At NBS, mass spectrometric studies have been made of the volatile products resulting from direct exposure of clean incandescent tungsten to oxygen halogen mixtures. A large number of tungsten halides and oxyhalides are thermodynamically stable and this work identifies which of these are important reaction products. Information on the surface reaction kinetics also resulted from these experiments. In terms of tungsten erosion, the combined gases are very efficient compared to either oxygen or halogen separately. In the oxygen-chlorine system, the surface reactions lead predominantly to the dioxydichloride, WO_2Cl_2, with lesser amounts of simple oxides. Significantly, none of the four simple chlorides are found. With fluorine-oxygen, the principal products are WOF_4 and WF_6, both of which are very volatile. Extensive measurements of the dependence of the surface rate processes on temperature and partial pressure variations have shown that oxygen is always adsorbed in preference to any of the halogens, and that the principal reactions on the metal surface are between WO (or WO_2) and adsorbed molecular halogen.

Isotope Effect in the Electron Stimulated Desorption of Oxygen Adsorbed on Tungsten—A large isotope effect has been found in the desorption of oxygen chemisorbed on tungsten caused by electron bombardment of the surface. The probability of $^{16}O^+$ desorption was shown to be 1.5 times greater than that of $^{18}O^+$ with 100 eV electrons. This experimental finding supports the electron stimulated desorption mechanism proposed for O^+ but not for total desorption. In fact $\frac{Q_{16}}{Q_{18}} = 1.06$, where Q_{16} and Q_{18} refer to cross sections for

total desorption of the 16 and 18 isotopes. The proposed models, although indicating a somewhat lower ratio of 16 to 18 species in total desorption than ionic desorption, cannot account for the quite small isotope difference in total desorption experimentally measured.

Infrared and Ultraviolet Spectroscopic Studies of Free Radicals and Molecular Ions Isolated in Inert Solid Matrices—In studies of the vacuum-ultraviolet photolysis of silane isolated in an argon matrix at a temperature of 4 or 14 K, all of the vibrational fundamentals of the species SiH, SiH_2, and SiH_3 have been identified, and positive confirmation that SiH_2 is a singlet in its ground state has been obtained. The Si-H stretching force constants of all three radical products are exceptionally small. In addition, two band systems previously assigned to Si_2 have been observed in ultraviolet absorption studies of this system, and a third band system, previously unreported, has also been assigned to Si_2.

Studies of the vacuum-ultraviolet photolysis of D_2O in a CO_2 matrix have definitively excluded the possible presence of a hydrogen atom in the species previously identified as CO_3. A normal coordinate analysis of the infrared absorption data for various isotopically substituted species of CO_3 has indicated that the most satisfactory structure is planar, with a three-membered OCO ring and an exceptionally strong carbonyl bond.

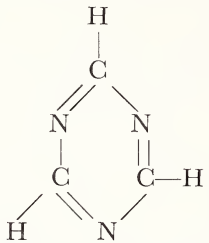
Much information has been obtained on free radicals stabilized on vacuum-ultraviolet photolysis of various halogen-substituted methanes isolated in inert solid matrices. In studies of the photolysis of methyl chloride, the vibrational fundamental and two electronic transitions of CCl have been observed, and several infrared absorptions have been assigned to H_2CCl. Studies of the vacuum-ultraviolet photolysis of matrix-isolated CH_2ClF, $HCCl_3$, $HCCl_2F$, and $HCClF_2$ have led to the infrared identification of the species ClCF, CCl_3, CCl_2F, and $CClF_2$, respectively. An electronic transition of ClCF near 3900 Å has been observed in both absorption and fluorescence. The corresponding transition of CF_2 has also been observed in fluorescence. In the studies of the vacuum-ultraviolet photolysis of the trihalomethanes, considerable evidence has been obtained for the occurrence of photoionization and electron attachment processes. Two of the vibrational fundamentals of the positive ion species CCl_3^+ and $HCCl_2^+$ have been assigned.

It was found that infrared absorptions previously assigned to the ClHCl radical are also produced by the interaction of photoelectrons with samples of HCl in an argon matrix. This strongly indicates that these bands should be reassigned to the bichloride anion, $ClHCl^-$, isolated in an inert, nonionic environment.

Energy and Structure of Triazines—The enthalpies of combustion and formation of six substituted triazines in the crystalline state were determined. These measurements provide necessary data for the cor-

relation of binding energy with structure. Substituent groups included methoxy, ethoxy, and fluoro- and nitro-ethoxy groups.

Triazine itself is a symmetrical heterocyclic unsaturated ring compound ($C_3N_3H_3$) which is stabilized by resonance.



The presence of substituents allows substantial variations in stability and in the energy of combustion of the molecules. This work was sponsored by Picatinny Arsenal.

Carbon Monoxide Adsorbed on Transition Metals—In a continuation of previous studies, the adsorption of carbon monoxide on rhenium and ruthenium was observed with the field emission microscope. These two metals crystallize in the hexagonal close packed system and are the first of this type to be studied in some detail in interaction with CO using field emission. These two metals, and especially ruthenium, find important uses in catalytic processes. Chemisorption of carbon monoxide on rhenium is similar to that on tungsten in that there are two binding states, one desorbing in the temperature region 250–350 K and the other 600–900 K. There are also two binding states of CO on ruthenium, but most of the desorption occurs below 350 K whereas most of the CO desorbs above 600 K for rhenium. The monolayer work function increment is 0.8 eV for CO on rhenium and 1.3 eV on ruthenium, a rather surprising result in view of the weaker binding on the latter.

Bibliography and Property Substance Index of Chemical Thermodynamic Literature Published in 1969—The Chemical Thermodynamics Data Center has prepared a Bibliography and Substance-Property Index for the literature published during 1969 on chemical thermodynamic data of inorganic substances, including calorimetry, chemical equilibria, phase change data, heat capacity, and heat content measurements. The Bibliography includes 2566 references to material covered by Chemical Abstracts. The content of these articles is indicated by a substance-Property Index, which tabulates the substances and properties or reactions measured. There are more than 9000 entries in the Index, covering about 3000 different chemical species. This material will be published in the 13th Annual Bulletin of Thermodynamics and Thermochemistry, which is prepared under the auspices of the International Union of Pure and Applied Chemistry.

Ketene–Heat of Formation—Ketene (CH_2CO) dissociates into methylene (CH_2) and carbon monoxide (CO) when subjected to

photodissociation and has been used as the source of the very transitory substance CH_2 in many studies. An inconsistency has been observed in the relationships between the enthalpy of formation of $CH_2(g)$, various photodissociation processes and photoionization processes involving it, and the enthalpy of formation accepted for ketene. As an example, the bond dissociation energy of ketene calculated from previously accepted enthalpies of formation of ketene, methylene, and carbon monoxide is about 80 kcal mol^{-1}, which corresponds to photons having a wavelength of 358 nm. However, photodissociation has been observed as a result of irradiation at wavelengths as long as 369 nm. Dissociation caused by photons of such low energy could be interpreted as due to errors in the interpretation of the photodissociation and ionization processes, or to an error in the enthalpy of formation of ketene.

In order to decide between these possible sources of error, an experimental redetermination of the enthalpy of formation of $CH_2CO(g)$ was carried out by reacting a carefully prepared and purified sample with aqueous sodium hydroxide solution. The new value ($\Delta H^\circ_{f298} = -11.4$ kcal mol^{-1} as opposed to the previous value of 14.8 kcal mol^{-1}) removes the previously observed inconsistency, and allows further research on the photochemistry of CH_2 to be carried out with much greater confidence. This work was supported in part by AEC.

Structure and Spectra of High Temperature Species—The infrared spectra of matrix isolated RbOH, RbOD, NaOH, and NaOD were observed and are consistent with the earlier results obtained for CsOH and CsOD indicating that these species have a linear structure. The infrared spectra of matrix isolated CCl_3 and CBr_3 were obtained using the reaction of lithium atoms and the appropriate carbon tetrahalide. Analysis of the spectra gives no reason for not assuming that these species have a planar structure.

Orientation and Momentum Correlation Times Compared—The spin-lattice relaxation times of ^{35}Cl and ^{19}F in ClO_3F have been measured by NMR pulse techniques over the entire liquid range (130–368 K). The data were used to calculate both the angular orientation correlation function and the angular momentum correlation function for the quasi-spherical molecule. The relation between the two relaxation times agreed well with recent theoretical predictions.

Dielectric Relaxation of Symmetric Top Gases—The dielectric relaxation times of several typical symmetric top gases (CH_3F, CHF_3, and CCl_3F) in dilute mixtures with a large variety of foreign gases have been measured. A new method for studying gas collision dynamics and molecular forces has been developed. The results of this work will provide general information about the effect of planetary atmospheres on microwaves.

Internal Friction in n-Eicosane ($C_{20}H_{42}$)—The normal alkanes as

well as many other related low-molecular weight, normal hydrocarbons have been widely studied as model compounds for high polymers. The development of theoretical models to account for the observed mechanical and dielectric relaxation behavior of linear crystalline high polymers, such as polyethylene, has often relied in part on data obtained on polycrystalline samples of these low-molecular weight analogs. In some models impurities as well as crystal defects have been proposed as the important parameters in determining the observed mechanical behavior. Therefore, as a critical test of these models, an internal friction study of pure single crystals of one model compound, *n*-eicosane, was undertaken.

Single crystals of sufficient size for the mechanical study were obtained only after several purification steps, which involved very slow crystallizations from the melt. The final crystals used had the shape of platelets several centimeters long and up to 0.3 centimeter thick. The unit cell was determined by x-rays to be triclinic and the crystals grew so that their growth direction (long dimension of the platelet) was [210].

Mechanical measurements, in the form of the logarithmic decrement, were made in the temperature interval from 100 to 300 K for several crystals driven in flexure. The two mechanical loss peaks characteristic of both polyethylene and polycrystalline *n*-alkanes of less purity were completely absent in all the single crystals measured. This result indicates the importance of impurities and crystal defects on previously reported effects.

X-Ray Diffraction from Piezoelectrically Vibrating Crystals—The acoustic modes that may be piezoelectrically excited in most finite α-quartz plates present a difficult mathematical problem. These modes are generally studied by dusting the surface of vibrating plates with powder and observing the nodes as powder concentrations or by other techniques. However, these techniques involve great technical difficulty.

A crystal which contains imperfections—such as dislocations, defects, and impurities—diffracts x rays to give fine structural detail in the diffracted beams that represent topographic images of the imperfections. Those images are produced by lattice strain due to imperfections. Because piezoelectric vibrations cause lattice strain in the crystal, an x-ray diffraction study of acoustic modes in crystals has recently become common. However, the standard diffraction theory for a perfect or slightly imperfect crystal cannot be used to explain the intensities and the details of observed topographs.

A newly developed dynamical diffraction theory for imperfect crystals has been applied to analyze those intensities and details. The transmission of the x rays is greater through vibrating regions of the crystal than through stationary regions. The intensity distribu-

tion of diffracted x-ray beams is given as a function of the vibrational amplitudes of the crystal.

Morphological Stability of Ice—From experiments on the morphological stability of ice cylinders in water, a value of 22 mJ/m^2 has been obtained for the ice-water surface tension of planes parallel to the c-axis. Single crystal ice cylinders, oriented with the c-axis of ice parallel to the cylinder axis, are grown radially into slightly supercooled water. The cylindrical shape is unstable and approximately sinusoidal perturbations develop parallel to the cylinder axis. If the bath undercooling is reduced to zero, the perturbations decrease in size and eventually disappear. From measurements of the perturbation growth and smoothing rates and wavelengths, the solid-liquid surface tension can be calculated from the appropriate morphological stability equations. The value of the surface tension obtained is in agreement with those obtained by other methods such as homogeneous nucleation experiments.

BIOMATERIALS

Tris/Tris • HCl Buffers for Biologic Fluids—*Tris* (hydroxymethyl) aminomethane in combination with its hydrochloride salt is widely used as a biological buffer in the pH range from 7 to 9. In order to match the pH of *tris* buffer solutions with the acidity range found in biologic fluids, while maintaining their buffer capacities, the conventional pa_H values of several buffer solutions were determined at various ratios of *tris* and *tris*•HCl. One result of this study has indicated that a solution containing 0.002m *tris*•HCl in a ratio of 3 to 1 of the protonated base to the free base has a pa_H value of 7.350 and should be suitable for blood pH standardization. Partial support for this research has been obtained from the U.S. Army Medical Research and Development Command.

New Pulsed NMR Method—IMR scientists and colleagues at the National Institute for Arthritis and Metabolic Diseases have jointly developed a new method for executing high-resolution ^{13}C Fourier-transform nuclear magnetic resonance spectroscopy. The method, which they call DEFT (*D*riven *E*quilibrium *F*ourier *T*ransform) NMR spectroscopy, results in a time saving factor of 1000 or more. This makes possible the study of many naturally occurring biological systems by ^{13}C NMR spectroscopy that are not amenable to study by ordinary NMR techniques. The DEFT technique is being used in numerous NMR laboratories throughout the world.

Finishing Composite Restorative Materials—In the past few years several new composite materials have been developed primarily as replacements and substitutes for silicate cements in restorations in anterior teeth. One of the shortcomings of the composite materials is that they are difficult to finish to a smooth surface using instruments commonly available to the dentist. Lack of a smooth surface

results in restorations that do not have optimum esthetic properties, are rough to the tongue, and may have increased tendency to collect debris and harbor microorganisms.

A procedure has been developed in the Dental Research Section for smoothing these surfaces with an instrument made by bonding very fine (1–5 μm) diamond particles to flexible paper disks. The disks are used with conventional low-speed dental handpieces. Electron photomicrographs clearly reveal the improved surface achieved with this technique as compared with that achieved by fine cuttlefish or sandpaper disks.

Amine Accelerators for Methacrylate Resin Systems—The use of composite restorative materials in dentistry is experiencing a dramatic upswing. Commercially available materials contain low molecular weight aromatic amines as polymerization accelerators. While effective as accelerators, these substances are difficult to purify of by-products that tend to induce discoloration in the restoration. Also the low molecular weight of these substances is undesirable from the view of tissue toxicity. To meet these shortcomings, several high molecular weight aromatic amines have been synthesized, one of which (N,N-*bis* (3-p-tolyloxy-2-hydroxypropyl)-sym-m-xylidine) appears satisfactory in its hardening accelerator characteristics and gives composites with good color and color stability. Being crystalline, it may be purified easily, and having a relatively large molecular weight, its toxicity should be minimal, thus giving an accelerator superior to those presently in use.

Grafting of Monomers to Collagen and Dentin—Grafting of monomers to collagenous tissue such as dentin, bone, or skin, followed by a polymerization reaction that incorporates bound monomer, offers an attractive means of securing modified biological surfaces. Such a technique has potential application to dentistry and surgery where omnipresent water inhibits many potentially attractive reactions. Exploratory work at NBS is being supported by the Dental Division of the U.S. Army Medical Research and Development Command. A grafting process has been investigated that is based on the use of ceric ammonium nitrate as the redox initiator by which a hydrogen is abstracted from a hydroxy containing amino acid residue of collagen to give a reactive-free radical. Conditions for grafting to the surface of collagen powder have been optimized. Both infrared analysis and weight change have shown that at least twenty monomer systems have been successfully grafted to such surfaces. Glycidyl methacrylate, methyl methacrylate, 1,3-butylene dimethacrylate, and vinyl acetate have been grafted to a purified collagen film. Butylene dimethacrylate was also grafted to bone. The relative grafting efficiency of the selected monomers to the solid substrate decreases in the order: powdered collagen > collagen film > powdered bone > powdered dentin.

Pretreatment of Enamel Surfaces to Improve Bonding—Simple surface treatments for enamel and dentin that lead to more efficient bonding of acrylic restorative materials are needed in dentistry. Current research at NBS supported by the Dental Research Division, U.S. Army Medical Research and Development Command, has shown that significant bond strength between a cold cure acrylic resin and bovine enamel is obtained by first applying chelating agents containing carboxyl groups to the enamel surface. Repeated pretreatment improves bond strength. Swabbing the enamel surface with 5 percent aqueous tetrahydrofuran-2,3,4,5-tetracarboxylic acid dianhydride for 10 seconds, rinsing with water, drying, and repeating this treatment resulted in significant enamel-acrylic bond strengths. Conditions for optimizing the bond strength were developed. Of importance is the fact that a one-month exposure to water did not destroy adhesion. Other effective pretreatments include quinic acid, 2-(hydroxyethyl)-ethylenediaminetetra-acetic acid and *cis,cis,cis,cis*-1,2,3,4-cyclopentane tetracarboxylic acid. Scanning electron micrographs of the treated enamel surfaces indicate that crevices are created into which uncured resin of the restoration flows and by which mechanical retention is achieved on hardening of the resin.

Dimensional Changes of Tooth Structure—With the advent of improved dental materials and their availability to larger segments of the population, a more precise characterization is needed of the natural components of the oral system with which interaction occurs in clinical practice. This is of particular importance in view of the strong efforts in these and other laboratories to develop truly adhesive restorative materials. Thermal expansion differences in tooth and restorative materials must be minimized to avoid degradation of interface bonding and creation of marginal failure. Determination of accurate thermal expansion data is made difficult by the small size of the specimens obtainable from natural teeth. In the present study, the expansion of enamel, dentin, and inorganic dentin was measured interferometrically in water over the range 25–60 °C and in air at 23 °C at relative humidities varying from 10 to 80 percent. Because measurement of the thermal expansion of the dentinal component of a tooth is complicated by a little understood structural change that appears to occur at temperatures as low as 45 °C, the effect of heating rate has been examined. With a fast heating rate (5 °C/min), expansion of dentin is approximately linear to 60 °C and a value of 8.7 ppm/ °C was measured as compared with 6.0 ppm for a slow rate of heating (0.5 °C/min). The expansion of inorganic dentin and of enamel was much less sensitive to rate of heating, being 8.4 and 11.8 ppm, respectively, for the slow rate of heating, and 9.9 and 13.1 ppm for the faster rate of heating. Dentin was observed to expand 0.65 percent over the relative humidity range 8.5–28 percent and 0.40 percent over the relative humidity range 28–80 percent.

Crystallographic Studies of Phosphates—Accurate determination of

the crystal structures of a related series of PO_4 containing compounds is in progress to provide a firmer understanding of important biological processes, such as mineralization and demineralization, fluoride incorporation into teeth and bones, etc. Recent acquisition of a computer-operated, single crystal x-ray diffractometer has increased both quality and quantity of these crystal structure analyses. Analysis has shown the relationship between the crystal structure of $Ca_5(PO_4)_2SiO_4$ and hydroxyapatite, $Ca_5(PO_4)_3OH$, the skeletal material of mammals. Some collapse in the former structure relative to the latter has occurred because of the missing ion in the OH site in hydroxyapatite. The structure of $Ca_7Mg_9(Ca,Mg)_2(PO_4)_{12}$ has been determined because of its relation to β–$Ca_3(PO_4)_2$, a constituent of dental calculus, and perhaps to the higher temperature phases α–$Ca_3(PO_4)_2$, and $\overline{\alpha}$–$Ca_3(PO_4)_2$. The present study helps explain how ranges in composition are accommodated in the arrangement of the solid state.

Crystalline Dimethacrylate Monomers for Dental Composite Restoratives—Composite restorative materials based on earlier exploratory research at NBS are proving increasingly popular in dentistry. However, these materials must be upgraded in certain respects if their continued and probably expanded use is to be achieved. To a large degree, the organic binder reinforcing the inert inorganic filler component of these composites is a dimethacrylate monomer, BIS-GMA, the reaction product of an epoxy resin and methacrylic acid. To overcome a variability in color stability and to eliminate the need for thinning with methyl methacrylate, a new monomer complex has been synthesized. It consists of a ternary eutectic, liquid at room temperature, composed of the crystalline *bis*(2–methacryloxyethyl) esters of phthalic, isophthalic, and terephthalic acids. Purification of these monomers by recrystallization procedures provides a means of attaining desired purity and of facilitating production control. Clinical examination of restorations preapred with composite materials using the newly synthesized binder component is in progress.

Radiopaque Denture Base Materials—The seriousness of ingestion or aspiration of dentures or denture fragments by the denture-using public would be significantly reduced if such materials could be readily located within the body by x ray. Techniques have been investigated for incorporation of radiopaque materials into dentures that would produce a denture of satisfactory esthetic quality as well as required physical and mechanical properties. A series of resin-glass combinations was investigated. An experimental denture base material made with the addition of a radiopaque, silane-treated glass powder to poly(methyl methacrylate) appears to offer the best combination of properties for immediate development.

Bonding and Alloy-Mold Reactions in Dental Investments—Chromium base alloy investment castings are used almost exclusively in partial denture prosthesis. In an effort to improve the quality and perhaps decrease the cost of these devices, a study is being conducted of the reactions that take place during the wax burnout, firing of the investment, and the casting operation. Petrographic microscopy has been employed to evaluate reactions occurring within the various micro-environments (at the casting-investment interface) between the investment and the investment protective coat, and within the investment itself. Many of these complex reactions are being delineated for the first time. Liquefaction, which depends upon the composition of the micro-environment, has been shown to be an important factor influencing dimensional stability, gas permeation during the casting operation, and surface smoothness. The gross composition of the investment, as well as the presence of relatively small amounts of impurities and of metals evolved from the casting, are important factors controlling liquefaction.

Bonding Denture Base Materials—Bonding between acrylic teeth and cold-curing denture base materials, especially of the "pour" type, is needed to replace current dependence on mechanical retention, which the dental laboratory technician laboriously produces by modifying stock teeth. Three approaches were explored: (1) the acrylic teeth were coated with silica, after which a treatment with a silane coupling agent was applied; (2) swelling and softening of the acrylic teeth with solvents prior to flasking was examined; and (3) the teeth were treated with poly(methylmethacrylate) dissolved in a mixture of methylene chloride and methylmethacrylate. The most successful technique, (3), can be incorporated into the current procedures used in prosthetic laboratories without involving additional equipment while saving time. No crazing or softening of the teeth as a result of the treatment was observed.

Mobile Water in Frozen Collagen—The nature of water in biological materials such as cells and tissues continues to be an important and controversial subject. Recent nuclear magnetic resonance spectroscopic studies of water adsorbed in tendon fibers (essentially pure collagen) below –10 °C have revealed that only water in excess of about one half of the weight of dry tendon can be frozen. The rest remains in a state of high mobility, even at temperatures as low as –50 °C. The quantity of water that does not freeze has also been determined from the heat evolved on melting "frozen" wet collagen, and the result is in good agreement with the estimate obtained from NMR.

METALLURGICAL MATERIALS

Studies of Metal Pitting—Using the new technique of ellipsometric spectroscopy in work sponsored by the Office of Saline Waters, re-

searchers have studied the events occurring in 40Å protective oxide films on iron prior to the breakdown (loss of protection) of the film that leads to pitting. This technique can detect by in situ measurements the entrances of chloride ions into the very thin film and their exit after chloride is removed from the environment. These studies have revealed that significant changes in the optical properties of the protective film occur prior to breakdown at only a few discrete wavelengths. Such studies are important in learning how to prevent the pitting that leads to failures in desalination plants.

Corrosion Study of Stainless Steels—A new, long-range study has been initiated on the corrosion of stainless steels in underground environments. This study, sponsored by the American Iron and Steel Institute, involves 5000 specimens that will be buried at selected corrosion-test sites from one to eight years. The investigation was prompted by the growing new and proposed applications of stainless steels in underground environments for use as culverts, ground rods, sewage and waste disposal systems, waste service, eelctrical distribution, and telephone cable shields. Such data is not now available for some of the newer alloys and for conditions where the stainless steel is under mechanical stress. This study will provide the data that will enable the designer to choose the most economical steel for a given underground application.

Dielectric Relaxation Spectrum of CaF_2 Crystals—Rare-earth doped CaF_2 is potentially useful as a material for tunable lasers and photochromic devices and as a system for applying theoretical notions to the understanding of its properties. Each Gd^{3+} ion, occupying a Ca^{2+} site, is accompanied by either an F^- interstitial or a Ca_2^+ vacancy to keep the crystal electrically neutral. An F^- interstitial ion can associate with a Gd^{3+} ion to form a close pair ("tetragonal center") or they can be separated, leaving an isolated Gd^{3+} ion ("cubic center"). In a study of the ratio of intensities of the electron spin resonance (ESR) spectra from tetragonal and cubic centers, it was shown that F^- interstitials alone cannot account for the temperature and concentration behavior of this ratio. By including cation vacancies in the model, the effects can be reproduced, but only in a qualitative way. To make it quantitative a way is needed to count the "centers" present; this is notoriously difficult to do with ESR. Use was made of the observation, in the ESR spectrum, that orientational diffusion of the F^- interstitial trapped at a Gd^{3+} ion (the tetragonal center) occurs at elevated temperatures. Using the temperature dependence of the relaxation time for this process, data were extrapolated from the ESR frequency into the dielectric part of the spectrum, revealing a relaxation phenomena of the expected kind in the dielectric spectrum. Detailed comparison of the ESR and dielectric data shows quite clearly that they arise from the same

phenomenon. Since the dielectric relaxation data can be interpreted readily in quantitative terms, it should be possible to combine ESR and dielectric data to determine in an absolute way the concentrations of both tetragonal and cubic centers. Quantitative data of this kind should make possible the development of a much more definite physical chemistry of the defect equilibria in CaF_2 and related compounds, and therefore give better control over the preparation of useful materials.

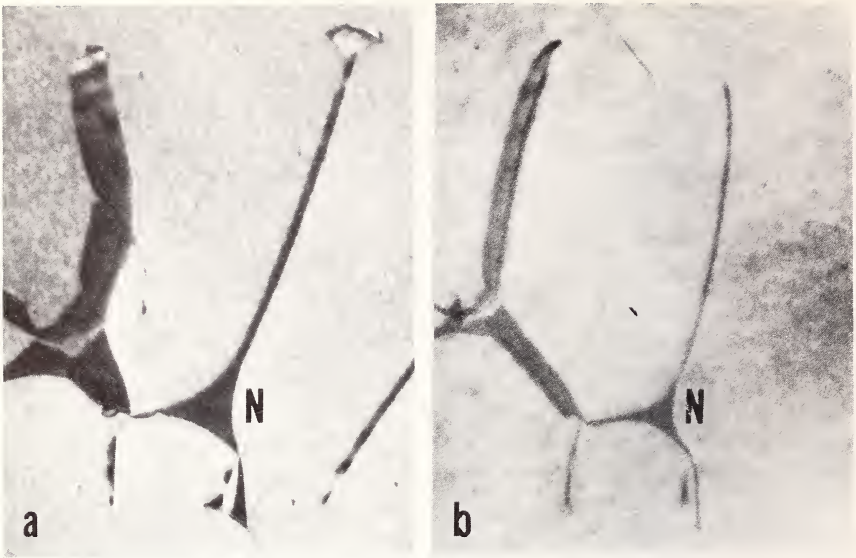
Contact Resistance of Tin Alloy Coatings—The electronics industry sometimes makes use of structural steel electroplated with coatings that serve a dual purpose: protecting the steel from corrosion and providing a surface with low electrical contact resistance. For use as such dual purpose coatings, a number of tin alloys were evaluated in an investigation jointly sponsored with the International Business Machines Corporation.

Tin and binary alloys of tin with zinc, lead, cadmium, antimony, and nickel were electrodeposited on steel and exposed to indoor and outdoor atmospheres. The exposure tests are being continued, but after 400 days of exposure the superiority of the tin-cadmium and tin-zinc coatings was clear. These electroplated coatings are giving good corrosion protection and maintaining a low contact resistance.

Effect of Pressure on Interdiffusion in V–Al—Measurements were made of the interdiffusion of vanadium and aluminum in vanadium-rich V–Al alloys. An appreciable pressure dependence was found. Conditions under which the compound V_3Al might form have been a matter of controversy in the metallurgical literature for some time. The smooth diffusion profiles found in the present experiments have helped to resolve this question by demonstrating that pressures up to 47 kbar at 1400 °C are insufficient to cause formation of this compound.

Anisotropic Elasticity—The dynamic Green's tensor for anisotropic elasticity has been studied. This tensor, which provides an essential tool for the dynamic study of crystalline materials and defect properties, has previously been determined only by approximate stationary phase methods, which allow the prediction of wave fronts but fail to yield an accurate description of wave properties between the fronts. As a result of the new study, a numerically useable line integral formula has been obtained for the dynamic Green's tensor giving the entire wave shape. The same methods have also been applied to calculate the elastic fields due to a rigidly vibrating dislocation in an anisotropic body.

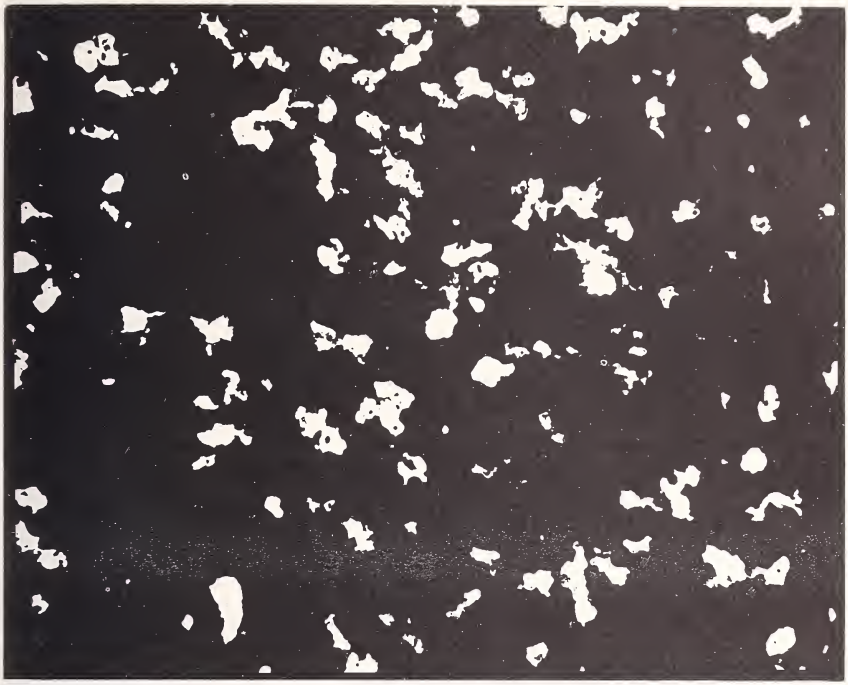
High Temperature Characterization of Alloys—Techniques for characterizing defects, e.g., dislocations and stacking faults, have recently been extended to elevated temperatures. Quantitative measurements are made to determine the stacking fault energy as it is known to



Transmission electron micrographs of an extended dislocation node (N) and other faulted features at (a) 20 °C and (b) 500 °C in a cubic alloy of silver—9.1 percent tin. The reduction in node size of 500 °C indicates an appreciably higher stacking fault energy. The faulted features are made visible by electron diffraction contrast. × 52000.

influence directly the behavior of dislocations contained in crystalline materials. As dislocations are primarily responsible for strength and the creep and fatigue behavior of materials, a knowledge of the stacking fault energy can lead to a better understanding and control of these important properties. The stacking fault energy is calculated from the measured dimensions of certain extended dislocation configurations observed directly in thin foils of various silver-tin alloys using transmission electron microscopy. By utilizing a micro-furnace stage installed in the electron microscope, measurements are obtained at temperatures up to 500 °C. It is found that in cubic silver-tin alloys the stacking fault energy increases with increasing temperatures while the opposite effect is observed in the hexagonal alloys, as predicted by theoretical phase stability considerations. This different temperature dependence can have important consequences in the mechanical behavior of two-phase alloys, particularly concerning ductility and strength at elevated temperatures.

Optical Scanner for Digitalizing Micrographs—An advanced scanner now in use is automatically scanning micrographs and producing data for metallographic analyses. Called SADIE–III, the scanner was devised under a program supported in part by the National Institutes of Health. This device examines a photographic image of 24 × 24 cm at almost a million discrete points and assigns to each a density value from a 64-level gray scale. Photographic prints, negatives, or transparencies can be scanned, as well as drawings. The scanner



An optical micrograph of nominal 10 percent austenite in ferrite matrix. × 25. Measurement on the NBS scanner determined the austenite (white) phase area to be 9.96 ± 0.03 percent.

presents analytical readouts and has a digital output of the image data, which can be recorded for later computer processing. It also contains specialized computer circuitry that at the end of the scan displays a partial analysis of the data on two six-digit counters. This feature makes unnecessary the time and cost of a large computer for exploratory work or when only simple results are required. SADIE's speed of about two minutes for a complete scan and its resolution of a quarter of a millimeter make it extremely useful for metallurgical and biological analyses.

Mossbauer Spectrometer Calibration—The utility of TiFe as a reference compound both for velocity calibration and as an isomer shift standard in ^{57}Fe Mössbauer experiments has been demonstrated. As an isomer shift standard TiFe has the advantage of giving a single line when no external magnetic field is applied. Velocity calibration has been made possible by the recent determination at NBS of the nuclear magnetic resonance Knight shift of ^{57}Fe in TiFe. By a precision comparison of the spectra obtained with TiFe in an applied magnetic field and those obtained for sodium nitroprusside with no applied field, the quadrupole splitting of sodium nitroprusside was precisely determined. This determination of the quadrupole splitting in the often used reference compound sodium nitroprusside has the advantage of being independent of any velocity measurement. This

determination makes possible the calibration of a Mössbauer spectrometer both in velocity units and magnetic field units. More precise measurements of magnetic fields using the Mössbauer effect are now possible.

Cluster Specific Heat at Low Temperatures—Specific heat measurements have been performed on copper-rich copper-nickel alloys at lower temperatures than previously investigated, giving interesting new results. These alloys are not ferromagnetic, yet there is a significant contribution to the specific-heat-giving anomalous term that is apparently related to magnetic clustering. This magnetic clustering occurs even in the absence of crystallographic clustering. At temperatures above 2 K the anomalous term can be approximated by a constant term, but when an alloy is examined over a range of temperatures down to 0.5 K this is not the case at all. The value of the anomalous term diminishes markedly below 1 K. A better approximation than the constant term might be an Einstein specific heat term, and indeed such a term fits the data considerably better at the lower temperatures.

Occupied Band Structure of Cu—As part of a continuing study of the energy distribution of electron states in metals and alloys, a new investigation of the $M_{2,3}$ soft x-ray emission spectrum of Cu has been carried out, using state-of-the-art advances in vacuum spectroscopic technique. The existence of fine structure in the spectrum was established, and a distinct correlation noted between this structure and that observed in Cu photoemission measurements. Both of these experiments agree quite well with the electronic state distributions calculated for Cu using the well-known Chodorow potential, which yields an accurate prediction of the Cu Fermi surface. Strong support is therefore provided for a one-electron picture of the occupied band structure of Cu.

Electronic Structure of $AuAl_2$—The intermetallic compound $AuAl_2$ has a remarkable bright purple color. One plausible explanation attributes this color to optical excitation of electrons from the *d*-bands to the Fermi surface. Recent band calculations, however, contradict this interpretation by placing the *d*-bands from six to seven eV below the Fermi level, well out of the range of visible light. Measurements were made at NBS of the $L_{2,3}$ emission spectrum of Al in $AuAl_2$, and the results compared to the distribution in energy of *s*-like charge at Al sites, the leading contribution to the Al L spectrum, as estimated from the band calculation. A striking confirmation of the theory resulted, which has been further confirmed by recent x-ray induced photoemission results.

Magnetic Moment Behavior of Iron in Copper Nickel Alloys—One of the fundamental problems in magnetism concerns the manner in which local moments form in transition metals and their alloys.

Using the ^{57}Fe Mössbauer effect, the local moment behavior of isolated Fe atoms in copper-rich copper-nickel alloys has been studied. Very dilute Fe concentrations were used. Three interesting aspects of the behavior of iron were discovered: (1) The low temperature moment compensation, or "Kondo effect," known to occur for Fe in Cu is still present for 10 percent Ni; (2) an Fe atom will induce a moment on any nearest neighbor Ni atom; and (3) the Fe atom will nucleate the formation of a giant moment "cloud" when the Ni concentration is greater than about 40 percent. These results should aid in the study of metallurgy of Cu-Ni-Fe alloys when the Fe concentration is increased to the level used in alloys under investigation for use in desalination plants.

Intergranular Corrosion of Copper-Palladium Alloys in Salt Water—In a study of the relation of alloy corrosion to electronic configuration, the surprising discovery was made that copper-rich copper-palladium alloys undergo intergranular embrittlement when exposed to a salt-water environment. This embrittlement was found to occur in single-phase solid solution copper alloys containing from about 1 to about 10 percent palladium. This embrittlement may be important since Pd is used commercially in brazing copper alloys.

Saline Water Corrosion of Titanium Alloys—Microstructural studies of corroded titanium alloys are being sponsored by the Office of Saline Water. The investigations concentrate on the corrosion of six

A scanning electron micrograph of intergranular fracture in a Cu 95/Pd 5 alloy. The alloy was exposed to a 3.5 percent sodium chloride solution at room temperature for several weeks.

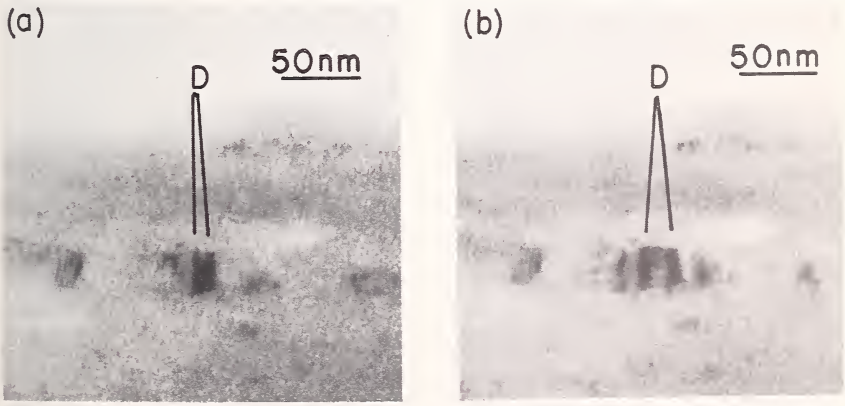
A transmission electron micrograph showing TiO_2 (anatase) crystals protruding from a titanium alloy after corrosion at 200 °C.

different titanium alloys in high temperature saline solutions with varying degrees in acidity or alkalinity. Specimens are corroded under conditions approximating those of desalination plants and subsequently analyzed by transmission and scanning electron microscopy and electron diffraction. Observations are made on the surface oxide films formed and the microstructural sites and corroding conditions leading to local pitting attack. Under certain conditions oxide crystallites can form on the surface and protrude into the corroding liquid, forming a rough surface that can collect additional films. This surface structure may lead to a deterioration of the heat transfer characteristics of the material in heat-exchanger applications for desalination. The role that such crystallite formation plays in the development of an adherent, protective surface film is under study.

Separation in Flowing System: Relation to Gel Permeation Chromatography—A predictive theory has been developed that relates the elution characteristics of networks of fine capillaries to the microscopic parameters of the system. The elution behavior of a stack of membranes, each membrane having a given distribution of pore sizes (capillaries), was determined. The system was found to separate particles on the basis of size (hydrodynamic volume). The resolution characteristics of such a system were evaluated by adaptating the method of J. J. Hermans (which allowed only for diffusion into pores) to include the effects of flow.

The theory serves as a model for gel permeation chromatography (GPC) in which each gel bead is viewed as consisting of many fine capillaries in which there is flow as well as diffusion. The resolution of such a system was found always to improve when beads with open pores (which allow flow) were used rather than ones with closed pores (which do not allow flow but are accessible via the mechanism of diffusion). For actual GPC columns the effect of the flow within the beads is appreciable in the high flow or large particle ranges.

Structure of Carbon Fibers—Carbon fibers prepared by the pyrolysis of fibers of polyacrylonitrile or other polymer fibers are finding increased use in high modulus, low weight, fiber reinforced polymer composite structures. The complicated structure of these carbon fibers is being analyzed. High magnification, dark-field and bright-field electron micrographs show carbon fibers composed of graphite crystallites ararnged in rows along the fiber axis. The presence of crystallites, with basal planes curved or twisted about the fiber axis direction, was found by observing the motion of diffraction contrast



(a) Bright field image of an area in a carbon fiber fragment.
(b) Same area after 1° rotation about horizontal fiber axis, leading to displacement of bands (D) relative to one another.

bands along some of these rows then the fiber was rotated about its axis.

"Rotator" Phase Transition in n-Alkanes—Chain and segmental motions are thought to dominate the mechanical and dielectric properties of many macromolecular solids of industrial and biological interest. Experiments to provide further insight into one class of such motions, those accompanying the "rotator" phase transition in the *n*-alkanes, have been undertaken with the cooperation of the NBS Center for Radiation Research. The spectroscopic technique used in these studies is inelastic scattering of neutrons. Preliminary results from experiments on *n*-nonadecane indicate that the transition to the rotator phase is accompanied by a greatly increased tendency for diffusive motions of a very large fraction on the protons in the hydrocarbon chain. Experimentation now underway may clarify some of the kinematic aspects of these diffusive motions.

High Pressure Polymerization—Research under the sponsorship of the U.S. Army Research Office (Durham, N. Car.) is producing many new types of high polymers. In particular, copolymerizations of tetrafluoroethylene with a variety of fluorine-containing monomers have been achieved with the use of high pressures. Samples with various compositions have been prepared and reactivity ratios determined with 3,3,3-trifluoropropene; 2,3,3,3-tetrafluoropropene; 2-trifluoromethyl; 3,3,3-trifluoropropene; and 3,3,4,4,5,5,5-heptafluoropentene-1 as comonomers. In most instances the reactivity ratios show that the incorporation of tetrafluoroethylene is not favored in the copolymerization. In line with this is the observation that high molecular weights were obtained only at high pressure. Copolymers that were soluble in the appropriate fluoro solvent and containing up to 90 percent tetrafluoroethylene were obtained.

Heat of Vaporization of Large Organic Compounds—Information on the molecular vaporization kinetics and heats of vaporization of large organic compounds is extremely meager. Measurements have been limited by numerous difficulties such as the availability of compounds for study, reliable and adequate instrumentation, and the decomposition of the sample during the equilibrium procedure. Using kinetic weight loss and vacuum procedures, measurements can be made in short times and at lower temperatures. Recent measments have been made on *n*-pristane, *n*-tetracosane, *n*-hexatricontane, and tetranonacontane where the heats of vaporization compared favorable with literature data. The results also show that large flexible molecules will vaporize approximately as compact spheres. Work in this area is of importance to the problem of pollution as well as to the elucidation of the liquid state.

Thermodynamic Properties of Polymers—The vibrational frequencies of a harmonic semirigid string-of-beads in a quasiharmonic

potential were determined using a normal mode calculation. The specific heat was calculated from the predicted frequency spectrum and the thermal expansion was obtained from the Gruneisen relation. The outstanding feature of the results was their sensitivity to the string length. The predicted volume-temperature values were found to be in good accord with *n*-alkane volume data and provided a likely explanation for the observed dependence of the unit cell volume of polyethylene on lamellar thickness. Results are expected to aid in a new approach to understanding orientational relaxations in organic solids as well as to provide basic information in supoprt of the fast growing polymers industry.

Polymerization in Monomer Crystals—Chemical reactions directed or constrained by physical structures of molecular scale are important in fields ranging from biology to metallurgy. The polymerization of trioxane to polyoxymethylene is an example of a crystal-directed reaction in which both the starting trioxane and the resulting polymer are crystalline. A new experimental method has been developed in which alpha particles emitted from a radioactive isotope of polonium are used to initiate the polymerization reaction. Polyoxymethylene crystals with new and unusual growth habits were found. The structural relationship between the polyoxymethylene crystals and the parent trioxane crystals was observed in greater detail than ever before.

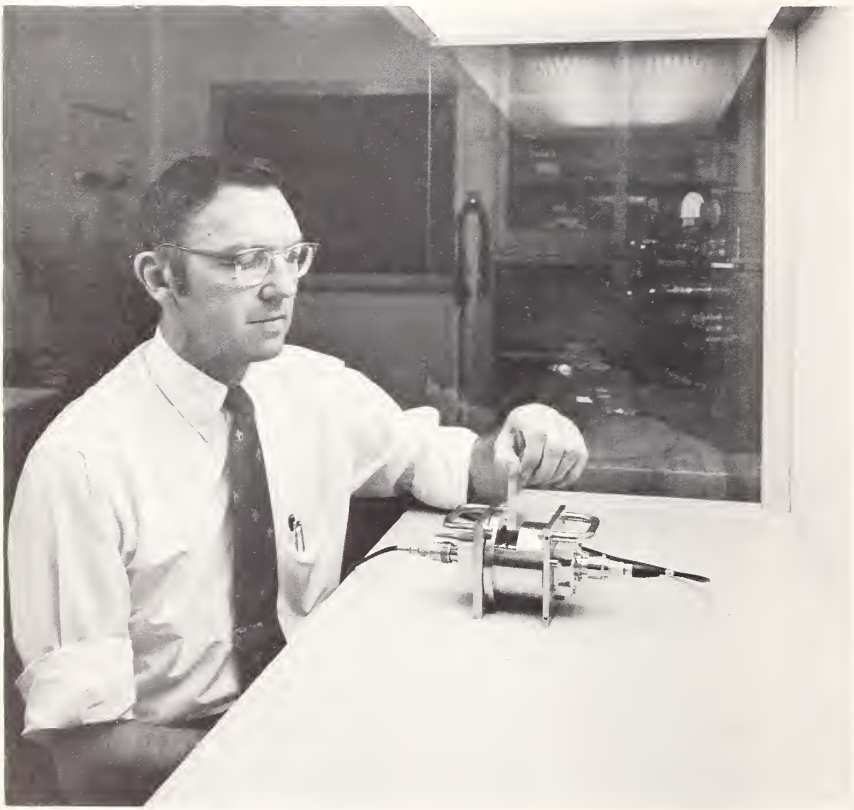
Thermal Expansion of Polyethylene Unit Cell—Unit cell dimensions have been measured at temperatures between 93 and 333 K for linear polyethylene samples with long periods of 385, 220, and 99 Å. At lower temperatures the dimensions are nearly independent of long period; at higher temperatures the basal area of the cell appears to vary linearly with the reciprocal of the long period. The proportionality constant increases with temperature and at 293 K is nearly the same for sets of data obtained with a number of different molecular weight distributions, crystallization and annealing conditions as well as for *n*-paraffins. It is concluded that the interaction of the molecules at the surface of the crystal is not as important as the length of the molecular stems between the folds in affecting the dimensions at higher temperatures. The stems probably alter the dimensions through their effect on the thermal energy.

Thermal Degradation Studies of Heat Transfer Fluids—The design and operation of some proposed power devices depend upon the use of thermally stable heat transfer fluids. On the basis of radiolytic and thermal stabilities, aromatic transfer fluids are preferred for use in organic Rankine cycle units (operational temperature range 650 to 750 °F). The fluids studied were biphenyl and phenyl ether, and their eutectic mixture. Precise and extensive kinetic data on the thermal decompositions of these aromatic materials were obtained

(650 to 750 °F for up to 1120 hours pyrolysis time) in order to examine their mechanisms of decomposition.

Dielectric Properties of Thin Polymer Films—Developments in the commercial manufacture of thin polymer films and their increasing use for electrical applications have resulted in a need for more precise dielectric measurements of films. A joint program between NBS and the American Viscose Division of the FMC Corporation has resulted in signficant advances in the acuracy, range, and convenience of these measurements. Details of the methods are being made available to the electrical industry to help meet their evaluation needs, and the new thin film measurement facility at NBS is being used to calibrate thin film reference standards.

Dilute Solution Theory of Polymer Crystal Growth—Linear chain molecules crystallize from solution in the form of thin lamellae, or plates, with usually well-defined crystallographic features. A theory for the growth and development of such crystals has been formulated for a polymer of uniform molecular weight (monodisperse).



Significant advances have been made in the accuracy, range, and convenience of dielectric measurements of thin polymer films, using a 2-fluid, 3-terminal cell.

The theory is able to estimate the thickness of the crystal and to predict the behavior of the crystal growth rate as a function of the crystallization temperature, the concentration of the polymer in solution, and the molecular weight of the polymer.

An important and interesting hypothesis is that nucleation on a crystal face is primarily determined by partially crystallized molecules already present in the crystal and not by molecules from the bulk solution. The theory allows the uncrystallized portion of a chain molecule to participate in nucleating a new growth strip on the crystal face. The anomalous dependence of polyethylene crystal growth rates on concentration can be readily understood in light of this new hypothesis.

Alpha Relaxation in Polyethylene—Data obtained by IMR scientists show that a previously reported correlation of the strength of the alpha relaxation in annealed solution-grown crystals of polyethylene with the inverse of lamella thickness is not unique. Nor is a previously reported dependence of relaxation temperature on lamella thickness unique. As the lamella thickness changes with annealing temperature, the unit cell dimensions, the macroscopic density, and the residual solvent content of the crystals also change. Thus, there are apparent correlations between these parameters and the relaxation strength and temperature. Since it is not obvious which, if any, of these correlations is the fundamental one with regard to the alpha relaxation, caution must be exerted in interpreting them. As an example, data have been analyzed that suggest at least one other presently unknown parameter of importance to the relaxation.

INORGANIC MATERIALS

Lattice Defects in Al_2O_3 by Transmission Electron Microscopy—Because plastic deformation by the generation and motion of dislocations ocurs in aluminum oxide (Al_2O_3) only at temperatures in excess of 900°, Al_2O_3 is generally regarded as a purely brittle material at olw temperatures. However, by using the argon ion-bombardment technique to thin specimens in a controlled manner for examination in the electron microscope, it was shown that plastic deformation occurs under hardness indentations at room temperature and that mechanical abrasion introduces high densities of dislocations within the near surface regions. Annealing at temperatures above 700 °C relieves the residual compressive surface stress of mechanically abraded specimens through the movement and rearrangement of the disolcations. These results are of technological and scientific importance because abrasion is used extensively in the surface finishing of aluminum oxide and the mechanical behavior of this material is strongly affected by its surface condition, particu-

A transmission electron micrograph showing dislocations under a single scratch on the (0001) basal plane surface of an aluminum oxide single crystal. The scratch and its associated damage illustrated here is typical of that produced by mechanically polishing aluminum oxide with a fine (¼ micrometer) diamond abrasive compound. Magnification = 37500 ×.

larly in corrosive environments. This research was suported partially by the U. S. Army Research Office, Durham, North Carolina.

Crystal Structure of Amine Coordination Complexes—An investigation of the structure of amine coordination complexes was carried out using crystals of hexakis (imidazole) cadmium (II) nitrate, $[Cd(C_3H_4N_2)_6]$ $(NO_3)_2$, grown from an aqueous solution of Cd $(NO_3)_2$ and imidazole. In addition to this complex, crystals of a second compound, hexakis (imidazole) cadmium(II)hydroxy nitrate-tetrahydrate, $[Cd(C_3H_4N_2)_6]$-(OH $(NO_3)\cdot 4H_2O$, were obtained from the same solution. The first is rhombohedral, space group $R\bar{3}$, and the second hexagonal, space group $P6_3/m$.

The structure determination permits a comparison of the cation $Cd(C_3H_4N_2)_6^{++}$ in two different environments, and gives information about the manner in which coordinated imidazole can conform to the requirements of hydrogen bonding. Although both structures consist of discrete cations $Cd(C_3H_4N_2)_6^{++}$ and nitrate anions, the packing of the two structures was found to be entirely different due to the presence of water and OH^- ions in the hydroxide complex. Furthermore, the conformation of the complex cation is considerably

different in the two structures because of the manner in which the coordinated imidazole ligands respond to the environment and orient themselves to accommodate hydrogen bonding. The hydrogen bonding network in the hydroxide complex is disordered and consists of three independent networks related to each other by the symmetry operation of the three-fold axis. All three networks may be assumed to be present in the structure so that the symmetry of the space group is preserved in the average.

Bismuth Oxide Compounds—On the list of materials that have considerable potential as modulators of laser light are some of the bismuth oxide compounds. A number of these crystals were grown by means of the Czochralski technique: $Bi_{12}GeO_{20}$, $Bi_{12}SiO_{20}$, $Bi_{12}TiO_{20}$, $7Bi_2O_3$:ZnO, and $17Bi_2O_3$:Ga_2O_3, all of cubic symmetry. Measurements of the optical activity and the Faraday rotation in the visible wavelength range indicate that both effects are large: optical rotation, 5 to 100 deg mm^{-1} and Verdet coefficient, 3 to 20 deg T^{-1} mm^{-1}.

Charged Defects in $SrTiO_3$—Charged and uncharged defects in oxide crystals profoundly affect the electrical, magnetic, and optical properties of these crystals. The techniques of electron paramagnetic resonance (EPR) and optical irradiation, in conjunction with optical absorption measurements, were applied to the study of several electron-deficient, i.e., hole, centers in $SrTiO_3$. Two principal centers have been explored: (1) the Al-O^- center, an electron deficiency surrounding a substitutional Al^{+3} ion at a Ti site, and (2) an X-O^- center, a hole shared in similar fashion, but more deeply trapped at a charged defect of unknown origin. The Al-O^- center arises after bandgap irradiation (near ultraviolet) and was studied at 77 K. The spectroscopic splitting factors and hyperfine coupling tensors were measured by EPR. Accompanying optical absorption bands have led to improved understanding of the role of various valency states of Fe in photochromic processes in $SrTiO_3$. Finally, a theoretical molecular orbital model has provided a firm basis for the interpretation of the various spectra in terms of shared holes.

Luminescence of Chromium in Oxide Semiconductors—Devices based on luminescene of solids require a fundamental understanding of the properties of ions substituted into a variety of host crystals. Cr^{3+} in rutile (TiO_2) has proved to be an altogether exceptional system in that in this system the lowest lying excited electronic state is the $^4T_2$ state rather than the usual $^2E_2$ state, a situation rarely encountered for this ion. More important, this system shows sharp line fluorescence because of the overlap of the zero vibrational state of the $^4T_2$ state with that of the $^4A_2$ ground state, a situation first demonstrated in this system. Lattice vibration cooperation was shown to be via local vibrational modes, which are different

for the ground and excited states. In most systems the excitation of the Cr^{3+} fluorescence takes place through processes internal to the chromium ion. In this system, as in a previous study of Cr^{3+} in $SrTiO_3$, the excitation of the fluorescence is via the host lattice and other defects present.

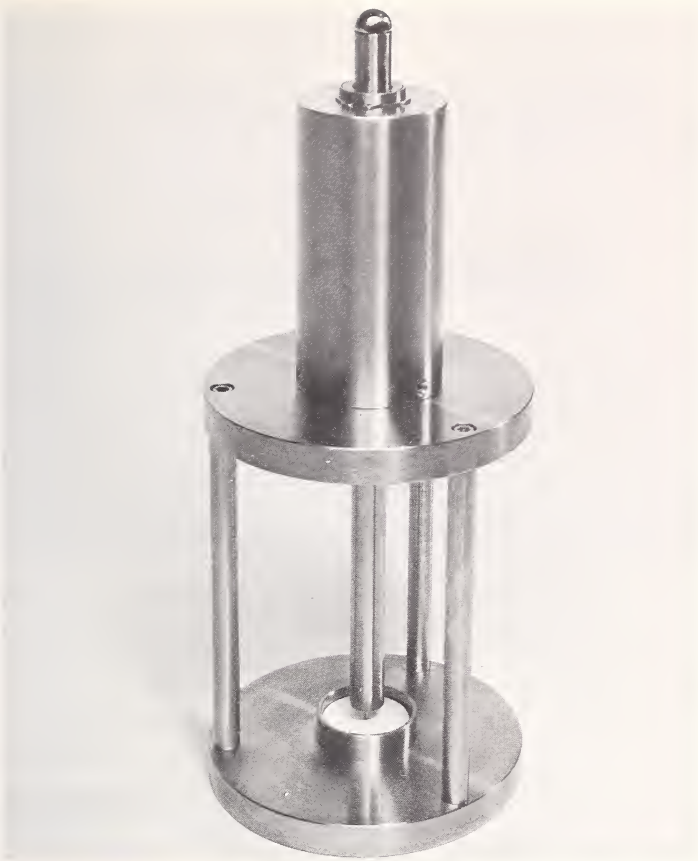
Transverse Electroreflectance Studies—Modulation techniques recently applied to measurements of the optical properties of materials are, for the most part, concerned with qualitative rather than quantitative behavior. Now quantitative measurements have been made of the electric field modulated reflectivity spectrum of silicon and gallium arsenide, solid state materials of great practical importance.

The technique developed—transverse electroreflectance—also enables polarization measurements that assist in identifying those band structure transitions responsible for the observed sharp structure in the reflectivity spectrum. A detailed investigation of the effects of collision broadening on the electroreflectance spectrum, in the one-electron approximation, is also underway. A method of measuring the collision broadening lifetime appropriate to the optical transition is applied to the fundamental band gap of gallium arsenide. This work was performed at the Physics Department of Brown University in collaboration with IMR.

Compressibility of Explosive Materials—Compressibilities of several explosive materials have been measured using the diamond anvil cell developed at NBS and a specially designed x-ray camera. Barium, potassium, sodium and thallium azide, and two polymorphic forms of lead azide were included in the study, which was sponsored by the Explosives Laboratory of Picatinny Arsenal. All of these have structures that exhibit anisotropic compressibility. Measurements were carried out to pressures of approximately 20 000 atmospheres.

A phase transition in thallium azide was found in the course of this study. Optical examination of lead azide at temperatures up to 300 °C and pressures up to 30 000 atmospheres showed it to be stable under these conditions.

New Strength Test for Ceramic Substrates—A new multiaxial bending test has been developed for determining the tensile strength of thin ceramic wafers used as substrates for printed circuits. At present there is no standard or widely used strength test for these substrate materials in the as-fired condition. Most tests require the use of flat specimens and linear knife edges, but this new test permits even slightly warped specimens to be properly supported. By supporting a specimen near its periphery on three symmetrically spaced steel balls and applying the bending load centrally by a small cylindrical ram, the fracture is forced to originate in the highly stressed central area. The fracture process therefore is independent of the condition



Ceramic wafer in fixture prior to loading to determine maximum breaking stress. Specimen (approx. 32 mm diameter) rests on 3 steel balls located near its periphery.

of the edge of the specimen. The modulus of rupture value derived from the breaking load reflects the condition of the body of the material and its plane or major surfaces.

NBS is conducting a "round-robin strength test to determine the reproducibility of results among laboratories. This test appears promising for routine quality control and for studying the effect of surface on the strength of ceramic materials.

Refractive Index of Fused Silica—The use of optical glass components in navigation devices for spacecraft requires a knowledge of the optical properties of glass over a range of wavelengths and temperatures. A study sponsored by NASA has recently been completed; the refractive index of fused silica was determined from +20 to −200 °C at ten wavelengths over the visible and near ultraviolet regions of the spectrum. An interferometric method was used in which the specimen itself, in the form of a plate with flat polished faces, is the interferometer. Interference fringes were observed between the faces of the plate, and the shift of these fringes with

change of temperature permitted the calculation of change in refractive index.

This work was part of a program for determining precise optical properties of single crystals and glasses as a function of temperature, stress, and wavelength.

Metastable Immiscibility Surface of the Na_2O–B_2O_3–SiO_2 System—The Na_2O–B_2O_3–SiO_2 system plays an important role in the formulation of many technical glasses. Chemical resistant, low thermal expansion glasses used for chemical glassware as well as alkali metal resistant glasses for gas discharge lamps are derived from this system. Furthermore, the system is the most widely studied prototype of of phase-separable leachable glass. To provide important technical data and also to help solve important theoretical questions with regard to the coexistence of phases, the precise location of the immiscibility surface was determined. Opalescence-clearing techniques were used for the measurement of the critical immiscibility temperatures.

Supercritical Phenomena in Glasses—A series of sodium-borosilicate glasses with widely different transition temperatures but similar high-temperature structures have been investigated for supercritical point phenomena by viscosity and ultrasonic relaxation experiments. The viscosity was seen to exhibit large unexpected increases of 200 percent near but above the liquid-liquid phase separation temperature as a result of critically induced fluctuations in local composition. This increase is six times larger than the anomalies seen in the more commonly studied binary mixtures. Further, the anomaly was seen at temperatures as much as 200 °C above the phase transition. Ultrasonic relaxation measurements proved to be even more sensitive. The anomaly observed reached 400 percent of the value expected from normal behavior, and was detected 360 °C above the transition temperature.

The large magnitude of these effects allowed a clear distinction between the supercritical effects and the normal material behavior. Further, the large span of temperatures for which these effects were observed allowed a detailed analysis of the critical point phenomena and their interaction with viscous flow processes. Therefore, such materials prove to be highly suitable for further studies of these phenomena.

Growth of Ultrapure Aluminum Oxide Crystals—Under the sponsorship of the Advanced Research Projects Agency, single crystals of aluminum oxide of the highest known purity have been grown. A vapor phase reaction technique was used according to the reaction: $2AlCl_3(g) + 3CO_2(g) + 3H_2(g) \rightarrow Al_2O_3(s) + 6HCl(g) + 3CO(g)$. Less than 0.1 ppm total impurities was found with neutron activation analysis. Further evidence of the extreme purity is the fact that magnetic susceptibility maesurements were unable to detect any

Single crystals of ultra-pure aluminum oxide. The crystals shown at the bottom illustrate the stages of growth beginning with a "whisker" seed weighing 0.002 gram at the left and ending with a crystal weighing 4.411 grams after approximately 40 hours of growth. At the top a group of crystals is shown attached to the aluminum oxide support used during the growth cycle.

paramagnetic impurities, and optical absorption measurements from the vacuum ultraviolet to the near infrared showed no evidence of absorption bands.

These crystals should be of value in studies of diffusion and other intrinsic behavior in aluminum oxide that formerly have been limited because of relatively impure crystals.

X-ray Powder Diffraction Data—IMR has been collaborating with members of the Associateship of the Joint Committee on Powder Diffraction Standards in obtaining powder diffraction data on groups of isostructural compounds and compounds with analogous chemical compositions. This work is part of a program for extending and improving the Powder Data File, which is used throughout the world for the identification of crystalline phases.

Working with a group of related compounds facilitates indexing and interpreting the x-ray diffraction patterns. Acurate cell constants have been obtained and are used to determine the range of elemental substitution as well as bond lengths and ionic radii.

The first group studied consisted of twenty-three $ABCl_3$ compounds, where A is an alkali or NH_4^+ ion and B is a divalent ion such as Ca, Cu, or Ni. In the case of ten of these, no crystallographic data had been reported previously.

More recent work has been concentrated on two groups of double sulfates: the langbeinites such as $K_2Mg_2(SO_4)_3$ and the Tutton salts such as $K_2Mg(SO_4)_2\ 6H_2O$. An interesting finding in the langbeinite

series was that $K_2Ca_2(SO_4)_3$ and $K_2Cd_2(SO_4)_3$ are not truly cubic as formerly reported, but have an orthorhombic distortion.

Ammonium Halides—Although ammonium halides crystallize readily from aqueous solution, entrapped water is an ever-present problem and one which detracts from their usefulness for many experiments. NH_4Cl, NH_4Br, and NH_4I have been successfully crystallized from the melt using a modified Bridgman technique. The melt process makes makes it possible to dope the ammonium halides with various concentrations of Tl, which for growth from aqueous solutions would be difficult to achieve due to the large difference in solubility of the thallous halides and the ammonium halides. The Tl-doped ammonium halides are being studied and comparisons made with more conventionally prepared materials such as NaI:Tl.

Oxygen Ion Diffusion in Oxide Single Crystals—Strength, electrical properties, and chemical reactivity of crystalline solids depend upon defects in the crystals. Among these defects are vacancies at crystal lattice sites normally ocupied by ions and ions in the voids (interstitial sites) between the lattice sites. The presence of either of these "point defects" makes it possible for ions to diffuse (migrate) through a crystal. By studying the oxygen ion diffusion in oxide single crystals, such as rutile (TiO_2), both as a function of temperature and oxygen partial pressure, the point defects in the oxygen sublattice of the crystal can be described. To observe the rate of diffusion of oxygen ions in a crystal with a normal isotopic oxygen composition, the crystal was heated in a special furnace containing oxygen-18 enriched oxygen gas. Since the oxygen-18 in the gas exchanges with the oxygen-16 on the surface of the crystal and then migrates into the interior of the crystal, the oxygen-18 content of the gas is reduced and that of the crystal is increased. The isotopic composition of the gas is measured continually with a mass spectrometer and the diffusion coefficient calculated from the diffusion rate. At a temperature of 1275 °C and a pressure of $4.29 \times 10^4 N/m^2$, a diffusion coefficient of 8.6×10^{-12} cm^2/s was found for rutile. This research is supported by the Advanced Research Projects Agency.

Color Centers in the Alkali Halides—Calculations of the energy states (e.g., from isolated impurities and various electron and hole traps) in the bandgaps of ionic crystals are essential to research on laser materials. These states play a role in the mechanisms by which laser light is used to "read," "write," and "erase" photochromic materials. The one-electron color center (F center) and the two-electron center (F′ center) occur in some photochromic materials. The photochromic process in the alkali halides results in part from the photoexcitation of these centers. The low-lying states of the F and F′ centers in KCl and the ionic polarization of the nearest neighbors have been calculated. To achieve maximum performance of photochromic

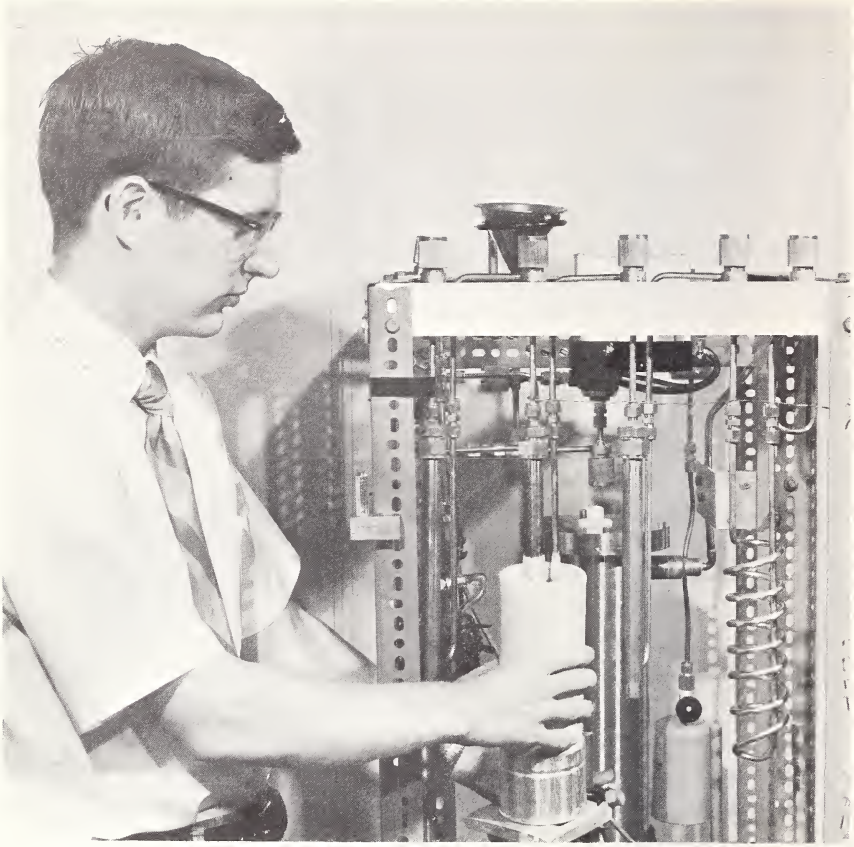
materials the lifetimes of the induced absorption bonds are being studied. The lifetime of the relaxed excited state of the F center determines in part the sensitivity of the "read" phenomenon. The theoretical value for this lifetime in KCl has been calculated and compares reasonably well with the experimental value.

Stress Corrosion Cracking of Glass—The strength of a glass structure is greatly infiuenced by the environment to which it is subjected, varying from those of spacecraft windows to those of submergence vessels in the ocean depths. Fracture mechanics techniques were used to investigate the stress corrosion cracking of glass by liquid water. Crack velocity data measured for several glasses suggest that crack propagation depends on the compound probabilities of the thermal activation of the Si–O bond breakage and the presence of hydroxyl ions at the crack tip. This research was supported by the Army Research Office, Durham.

Failure of Glass Under Biaxial Loading—Vessels made from glass may have the potential to fulfill in part the needs of the Navy for deep submergence vehicles. Designing such glass vessels requires engineering data on the mechanical failure of glass under the expected loading conditions and an understanding of the fracture behavior of glass under biaxial loading. The fracture behavior of fused silica, soda-lime, and borosilicate glass was found to be essentially independent of pressure, indicating that the mechanism of fracture may not change with pressure. The fracture is expected to occur in a brittle manner due to the stress concentrations, despite the imposition of high biaxial compressive stresses. Thus, when the fluid enters the crack, fracture was observed under applied loads of approximately 7×10^5 N/m^2, whereas when the fluid is prevented from entering the crack, applied stresses of approximately 2×10^9 (N/m^2) were required to produce fracture. This research was supported in part by the Office of Naval Research.

Synthetic Chemistry of Tungsten—Two major problems were solved as the result of work on the general preparative chemistry of tungsten in its highest oxidation state: stabilization of normally reducing organic ligands or functional groups in the presence of such a strongly oxidizing metal, and development of general and simple procedures that would make available a wide range of related compounds for extended properties measurements.

Work still in progress involves the use of readily available organosilanes with a number of tungsten halides. Reactions of alkoxy or aryloxy trimethyl silicon compounds with tungsten hexahalides have been found to yield substituted tungsten (VI) compounds, with good stoichiometric control over the degree of substitution. Complications from oxidation reduction reactions or complex formation can be avoided by a novel route involving silane derivatives.



Separating tungsten hexafluoride from a less volatile reaction product. The stainless steel vacuum line has been used extensively for synthesis involving both tungsten and molybdenum hexafluorides.

Reactivity of the remaining tungsten-halogen bond decreases with increasing organoxy-substitution, with particular stability achieved at the tetra-substituted dihalide. This gradation in reactivity will be particularly important in future efforts to introduce other ligands via more reactive intermediates.

Stereochemical assignments were made on the basis of ^{19}F and ^{1}H nuclear magnetic resonance spectra. The large number of potential ligand combinations should help elucidate the electronic or steric factors controlling isomer distributions.

Phase Separation in Technical Glasses—Research has established only in recent years that metastable liquid-liquid phase separation is not a scientific curiosity displayed by a few glasses but a dominant feature of many technically important glassforming systems.

The phase separation behavior in the classic immiscible systems was observable by opalescence techniques, i.e., the domains developed were large enough to give visible scattering of light. Systems with very low immiscibility temperatures were obviously too rigid to give

large enough domains and a viscosity drift method was developed to extend the measurements to such systems. The method consists of an analysis of the fiber elongation kinetics above and below the critical temperatures.

The surprising result of this study was the precise determination of the immiscibility temperature of a number of technical glass compositions that were previously considered to be stable. This new technique furnishes exact knowledge of the crtical temperature and thus permits the design of heat-treatment, forming, and annealing schedules. These schedules avoid product defects for which no explanation or known remedy previously existed.

Inclusions in Laser Materials—One of the severe problems encountered in high-power solid-state laser systems is the thermal damage to laser rods and optical elements. Inclusions with physical and optical properties substantially different from those of the host material produce major thermal stresses within the 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. In this work, the optical path length change for a probing light ray passing near the inclusion, the radial and tangential stress components, the changes of the refractive index for radially polarized and tangentially polarized light due to the thermal stress field were 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 was examined. The feasibility of using optical techniques to detect metallic and dielectric inclusions in laser materials before they cause damage also was studied. These computations suggest that the use of laser pulse widths of the order of microseconds may be more promising than nanosecond pulse widths for the detection of small incipient absorbing centers. Also, submicron sized inclusions between 5×10^{-5} and $5\times^{-4}$cm have the greatest probability to produce damage. The results indicate that focusing due to thermal changes in the refractive index is not probably a mechanism leading to damage.

Molecular Reorientation and Angular Momentum Correlation Times—IMR scientists have recently completed the first experimental measurement of angular momentum correlation times in a liquid. A combination of microwave and nuclear magnetic resonance (NMR) studies of gaseous ClO_3F were used to determine the "effective" spin rotation tensor for ClO_3F. This value, when combined with ^{19}F NMR spin-lattice relaxation studies in liquid ClO_3F, can be used to measure the angular momentum correlation times of the liquid. These results, which are in excellent agreement with predicted theoretical results, serve as the first experimental tests of the most recent theories of rotational diffusion in liquids.

Analysis of High-Purity Reagents—Potentially dangerous trace concentrations of heavy metals are being found in a variety of food products as a result of man's activities. Lead- and mercury-containing pesticides and fungicides leave residues on agricultural products. Heavy metals from industrial effluents are concentrated severalfold from plants to food fish and to the herbivores that are consumed. Because parts-per-million concentrations of these elements are critical, the analytical reagents used to dissolve the sample and to convert the elements being determined into a form suitable for instrumental evaluation must be especially pure.

A method was developed for simultaneously determining fifteen trace elements at part-per billion concentrations in high-purity reagents using isotope dilution and spark source mass spectrometry. Few methods can be used for such purity evaluations. Those that have been used rely on evaporating a large quantity of the reagent to obtain a favorable instrumental signal. But under these conditions, element losses can invalidate the results. Because isotope ratios of the isotopically spiked and equilibrated elements are measured, such losses are not a source of error in this method. The overall high sensitivity and reliability of the general method should make it attractive as a reference method for determining a number of physiologically hazardous elements in natural waters and in food products.

Analysis of Atmospheric Oxygen—Cooperative studies with NOAA completed in 1970 show no discernible change in the atmospheric oxygen content in the last 60 years. Using an absolute gravimetric method developed several years ago, samples of air collected in a nearby rural Maryland site showed an oxygen content of 20.946 percent by volume on a dry air basis. An evaluation of all absolute measurements made since 1910 shows that they fall within 20.945 to 20.952 percent, in agreement with the present NBS value. The NBS measurements were coordinated with the determination of oxygen in 78 atmospheric samples collected during the worldwide cruises of two oceanographic research ships. Here again, a value of 20.946 percent was obtained with no differences observed because of location of sample.

Calculations show that only minute changes, if any, can be anticipated with respect to the foreseeable combustion of fossil fuels. They further show that any effect of herbicides and pesticides on photosynthetic plants has been negligible. However, periodic reappraisals are advisable.

High-Speed Spectrometric Determination of Beryllium—A high-speed optical spectrometric method has been developed to determine the presence of beryllium in the air or as surface dust where beryllium or its compounds are handled. Beryllium is one of the most dangerous

pollutants among the chemical elements, with a prescribed limiting threshold value of 0.002 $\mu g/m^3$ of air. Surveillance studies for beryllium may involve many hundreds of samples for which speed and sensitivity of analysis are highly important. The method involves sampling by air filters and by paper swipes that are transferred immediately to prepared graphite electrodes. A buffer is added to the electrodes, after which they are arced and the intensity of the beryllium spectral line measured on a photoelectric spectrometer. The method can detect as little as 0.1ng (1×10^{-10} g) beryllium and, in routine application, is capable of analysis of 100 samples a day by a single operator.

Sulfur Dioxide Analytical Standards—Studies during the past year have established the reliability of permeation tubes as analytical standards for air pollution analysis and point the way for their issuance as standard reference materials in the near future. Plastic tubes containing a liquified gas such as sulfur dioxide were developed by National Air Pollution Control Administration chemists and recommended as analytical standards. As long as liquid remains, gas permeates the walls at a rate dependent upon temperature. Passage of air at a controlled rate past the tube results in an atmosphere of known sulfur dioxide content, which may be used to calibrate and standardize air pollution measurements. NBS studies have verified the constancy of the permeation rate and have established the conditions under which the tubes must be used to provide reliable standards.

Singlet Molecular Oxygen in Air Pollution—The reactions of singlet molecular oxygen with a wide variety of atmospheric pollutants have been studied. Contrary to speculation in the literature, it is concluded on the basis of the measured rate constants for these reactions that they play only a minor role in air pollution chemistry.

Reactions of Oxygen Atoms with Olefins—The reaction of atomic oxygen with olefins is of considerable interest in air pollution studies. Recent techniques for observing these reactions in the cryogenic region have been fruitful because relatively high activation energy secondary reactions as well as the atomic cracking reactions are eliminated. In a continuing program of research, stereospecific reactions with the 2-butenes were found, and a new transition state for the $O(^3P)$ addition to olefins was proposed. Several characteristics of this state were determined, and passage from the transition state to final products in the case of migrating groups was found to be of the concerted type. This was shown neatly by comparative studies with the isometric compounds 2-methyl-3-ethyl-2-pentene and 3,4-dimethyl-3-hexene. The two ketone products from each of the two compounds occurred in the same ratio.

TECHNICAL ASSISTANCE TO OTHER AGENCIES

Representative examples of advisory and consulting services provided to other Government agencies are given below:

Embossing of 55 Gallon Drums—More than 10 million of these drums are manufactured annually for use in commerce. A considerable proportion of this number is used in the shipment of hazardous materials. Representative drums were examined metallurgically and recommendations were provided to the Office of Hazardous Materials, Department of Transportation, governing the location, depth, and sharpness characteristics of the impressions made in the embossing. These recommendations are intended to eliminate premature failure of drums that could result from improper embossing.

Failed Boiler Tubes—The blistering and progressive thinning and bulging of boiler tubes in the General Services Administration's Central Heating Plant were examined and found to be due to the accumulation of scale within the tubes. The composition of the scale was determined and metallurgical examination of the tubes revealed that as the scale accumulates and the heat transfer becomes poorer, spheroidization of pearlite occurs, then grain growth and finally a critical stress distribution develops that produces the observed thinning and bulging of the tubes. Improvement in boiler feed-water control and boiler tube cleaning methods were recommended to reduce the scale accumulation and provide improved service life.

Gravure Printing Plates—The Bureau of Engraving and Printing has been assigned the task of providing the huge quantity of stamps that may be required in the Government Food Stamp Program. The gravure printing process has been selected for this purpose. At the request of the Bureau of Engraving and Printing Bureau metallurgists have initiated a program intended to provide acceptance criteria that will be used in the procurement of the electroformed copper plates for this gravure printing process.

Specification for Meat Hooks—Two types of meat hooks, submitted by the Department of Agriculture, were examined metallurgically for the composition, microstructure, and dimension of component parts. The thickness and hardness of the chromium plating on the meat hook that had a carbon steel shank were also determined. Detailed specifications of this meat hook were prepared at the request of personnel of the Department of Agriculture for their use in the preparation of bid requests and purchases.

SYMPOSIA

Symposium on Dental Materials Research—A symposium on dental materials was held to mark the 50th anniversary of the initiation

of the dental research program at NBS. The symposium brought to NBS the outstanding researchers in the dental materials field for a comprehensive examination of the present state of research in this field and a look at future needs and expectations. Of the 250 registrants representing government research organizations, educational institutions, industry, private research laboratories, and dental practice, 56 were from 16 foreign countries.

The program of invited papers covered future research needs, the oral environment, metals research, new developments in the nonmetallic restorative materials, modern methods for determining mechanical properties, relationship of physical properties to clinical behavior, evaluation of dental materials, and the development of specifications.

In regard to the future, speakers emphasized the need for more research on the interrelations of dental restorative materials, natural dental structure, and the oral environment. Also stressed was the need for research directed toward making dental service more widely available and directed more toward prevention of tooth destruction rather than repair. The need for basic research to provide a better understanding of the oral system to serve as a basis for improved materials was pointed out by many speakers. Research to determine valid relationships between physical and chemical properties and clinical service was indicated as one of the greatest needs in the development of specifications for dental materials.

Seminar on Biomaterials at NBS—On April 9 and 10, 1970, a seminar on biomaterials was held at NBS. This meeting was organized by the Solid State Sciences Panel of the National Academy of Science —National Research Council for the purpose of educating the Panel members about the possibilities of applying solid state methods to problems involving living systems. IMR planned and hosted the meeting (with the aid of the Director of the Heart Institute (NIH)). A program of twelve half-hour talks covered a broad range of biomedical research including such topics as Structure of Polypeptides, Information Processing by the Eye, and Magnetic Fields in the Human Body. Some 40 Panel members and about an equal number of guests (including 15 to 20 NBS employees) attended the meeting.

Electronic Density of States Symposium—The 3rd Materials Research Symposium sponsored by IMR was held Nov. 3-6, 1969, on the subject, Electronic Density of States. More than 350 scientists were in attendance from 14 countries. There were 16 invited papers on the subjects of optical properties, photoelectron emission, soft x-ray spectroscopy, electronic specific heat, Knight shifts, transport properties, magnetic susceptibility, ion neutralization, and many body effects in both ordered and disordered systems, which were supplemented by 80 contributed papers in these various fields.

INSTITUTE FOR APPLIED TECHNOLOGY

The Institute for Applied Technology (IAT) attempts to meet the Nation's need for measurements and standards related to the artifacts of our society. Thus, the IAT programs are concerned with technological or "engineering" measurements and standards which deal with products, commodities, devices, processes or systems. These measurements and standards are the language of the market place for coupling user requirements with the performance capabilities of products, processes or devices, and thus bring order and quantification to man's use of his technical skills.

The Institute provides a technical base for the development of engineering and product standards, and measurement methodology. Its programs are oriented to industry, to the States and regions of the country, and to all levels of Government. They bridge the interface between science and its applications, and by coupling science and technology with the daily activities of commerce, industry, and Government, they stimulate economic progress.

The Institute is responsible for several mandatory legislative assigments. Among them are the Flammable Fabrics Act as amended in 1967, the Fire Research and Safety Act of 1968, and the Fair Packaging and Labeling Act.

IAT activities fall into two major categories: Technological Measurements and Standards, and Technical Innovation. A substantial part of the work done in the IAT program is technical assistance to other parts of the Bureau, other Government agencies, and to industry. Work done in motor vehicle safety research and technical analysis is virtually all done in support of the mission of other agencies of Government. In other fields, a lesser but still substantial volume of IAT work is done at the request of others.

TECHNOLOGICAL MEASUREMENTS AND STANDARDS

This category covers the Institute effort for the broader extension of the national measurement system into engineering and technological fields. It is a program to apply principles of good measurement, rather well defined in the science area, to the determination of performance or other significant characteristics of products systems and devices important either in Commerce or to Government needs. In essence, the objective is to find ways by which standards or a national and sometimes international consensus of measurement methodology

can be developed for items, systems, and devices which are not readily evaluated in terms of existing measurement methods.

The performance concept introduces man into the measurements and standards process, and the whole idea centers on the belief that products, processes, services, and systems can be described and their performance can be measured in terms of user's requirements without regard to their physical characteristics, design, or method of their creation. Key to this method is the identification of measureable performance criteria for meeting the user's requirements, thereby coupling subjectively derived needs with objective technical measurement methods.

As the complexity and technical sophistication of articles of commerce increase, it becomes increasingly difficult to define those characteristics of a product which best measure its performance. The virtue of the performance concept in measurement and standard development is that it stresses the end to be attained, and leaves the means to obtain the desired end wide open.

Today many complex products are actually complete "systems," and the only feasible way to evaluate them is in terms of their performance against criteria established to meet the user's requirements. The concept encourages innovation when producers can meet the performance required by whatever design of product will do the job.

The idea of performance criteria also has ramifications beyond those concerned with articles of commerce. Our national welfare depends critically on making informed decisions related to complex social and economic policies and programs. To do this, one needs to define criteria of performance for these policies and programs and be able to measure or predict possible benefits and costs of alternative actions. Through the techniques of system analysis and operations research, technology has provided a means for helping such decision-making.

Institute activities in technological measurements and standards range from the development of performance criteria and test methods for individual items to the study and analysis of complex systems such as multi-State transportation network.

Program elements include:

Technological Measurements and Standards
- Building Technology
- Electronic Technology
- Systems Analysis
- Motor Vehicle Safety
- Engineering Materials and Product Evaluation
- Industrial and Consumer Products

Technological Innovation and Diffusion
- Invention and Innovation

Flammable Fabrics

This program has received unusually high priority in the allocation of resources available to the Bureau. This priority points up the gravity of the fire death and loss problem facing the Nation. An estimated 150,000 injuries are sustained annually from clothing fires, with as many as 6,000 involving children burned when their nightclothes catch fire. Survivors of all ages often spend years undergoing difficult and expensive medical treatment. Statistics show that older people and children are more likely to be victims of such disasters.

The program started with four people and $65,000 in FY 1968. During 1970, the program represented 23 man-years of effort and obligations of about $550,000. The major effort of the program has been in the development of test methods necessary for standards of flammability. Development of these tests is a direct responsibility assigned the Bureau under the Flammable Fabrics Act.

The staff has conducted research on fires; made feasibility studies on reducing the flammability of fabrics; and analyzed burn case data received from the Department of Health, Education, and Welfare (HEW) and other sources. During FY 1970, significant achievements were made in five areas—carpets, small rugs, children's clothing, mattresses, and blankets.

A mandatory standard for flammability of carpets and rugs was published in the Federal Register April 16, 1970. This first-generation standard for carpets and rugs is designed to protect the public from high-risk carpets that propagate flame from small ignition sources such as matches. The test does not deal with the more complex hazards of smoke and toxic gas production in a fully developed fire. The Bureau is continuing its studies of carpets in larger fires affected by drafts and heat radiation. This includes full-scale studies of fires involving carpets and rugs in corridors and rooms. Results of these studies will provide the technical basis for second-generation carpet standards.

A proposed standard for small carpets and rugs was also published during the year. This proposed standard is currently subject to public comment and technical review, after which a final standard is expected.

From data and information received by the Bureau, top priority for future standards was given to children's apparel. In January 1970, a Finding of possible need for standards in this area was published, and work has proceeded in development of a proposed standard.

Second priority in standards development has been assigned to bedding. This priority is a result of accident case data and research which have indicated a need for more protection from bedding fires. A re-

view of Findings of possible need for blanket and mattress standards is underway.

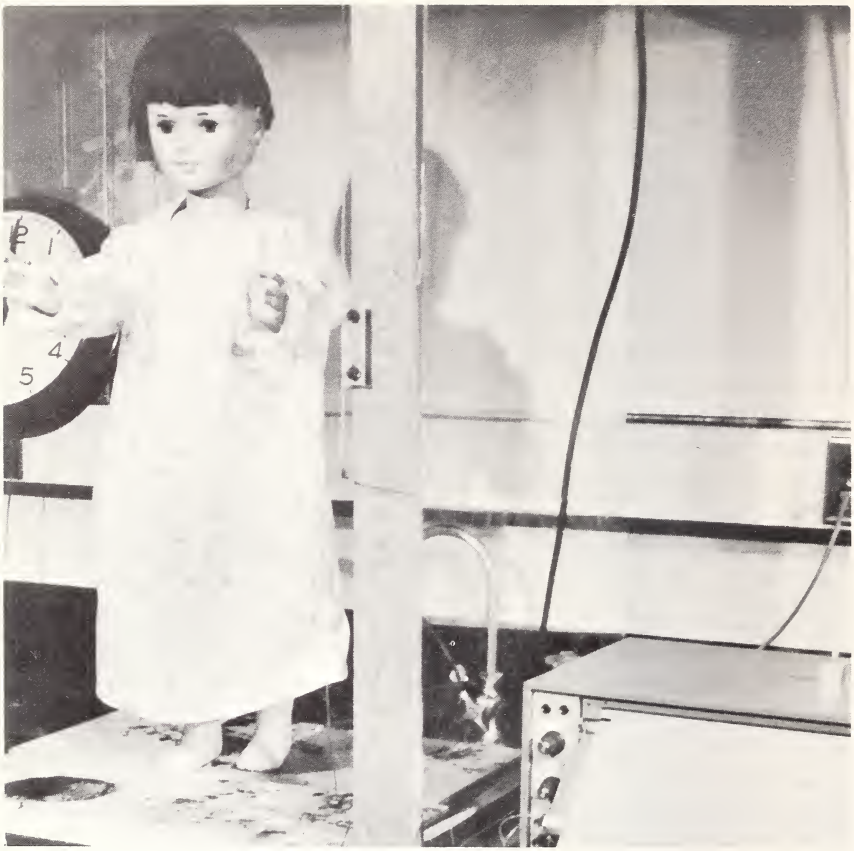
Many organizations, in and out of Government, have assisted the program. Under the Act, HEW, the Federal Trade Commission, and the Treasury Department have obligations in a joint effort with the Department of Commerce. The National Advisory Committee for the Flammable Fabrics Act, described in the Act, and appointed by the Secretary of Commerce in 1969, has given advice and comments in a series of meetings held with the Department and the Bureau staff. The National Commission on Product Safety, the Special Assistant to the President for Consumer Affairs, and the National Safety Council have have provided useful input to the program. Voluntary standards groups and industry associations have also cooperated in test development and standards evaluation.

In June of 1969, the Bureau sponsored a Symposium on Measurement of Flammability. More than 600 experts and interested persons attended the two day sessions. Methods of applying flammability measurements to flammable items were discussed for such categories as wearing apparel, blankets, mattresses, upholstered furniture, drapes, rugs, carpets, and linens. This symposium is another example of the effort to give careful consideration to all aspects of the fabric flammability problem, and to the views of many interested groups and individuals in developing standards and regulations.

Lack of adequate information is a difficulty in the advancement of the program. There is the problem of correlating injury with specific characteristics of fabric flammability. For example, it might be expected that one or two types of material of which children's sleepwear are made could be the source of a large fraction of injuries suffered by children in fires.

If this were so, accident statistics would be expected to show these fabrics involved in fires more frequently, based on their share of the market. But with the small amount of data available, and the uncertainty in the numbers because of the smallness of sample, there is no evidence that this is true. Moreover, although fabrics differ in their flammability characteristics, this is only one factor in determining injury that a child may suffer. The nature of exposure to fire, and the circumstances of the fire are also important factors.

In fabric flammability things are not always what they seem to be at first glance. The Bureau's research staff has encountered unexpected phenomena. An example of this was found in vertical flame tests of a fire-retardant-treated cotton flannel fabric of a type used in a child's nightgown. When a burner was applied for the generally accepted test of 12 seconds, and then removed, the fabric flame went out—an apparently successful test. Yet, exposure of the same fabric to the same flame for 2 or 3 seconds resulted in its destruction, despite



An instrumented mannequin. The burning of garments on such mannequins, and the measurement of temperatures and amount of heat transferred to the body, will make possible the development of more meaningful tests for apparel fabrics.

the fact that self-sustained flames did not occur on the longer exposure. It was determined that the source flame, when applied for longer times, consumed the oxygen needed for the fabric to burn. This critical dependence on oxygen supply has been noted only in fabrics treated with marginal amounts of flame retardant chemicals. Properly treated cotton materials do not react in this way.

With an understanding of this kind of problem, children can be protected from fabrics which classical test methods show to be safe, but which in reality are not. This type of knowledge is the basis for the development of tests which will protect both the manufacturer and consumer from being misled.

Other priority areas under study include apparel for elderly citizens and the general public, and interior furnishings, especially upholstered furniture and draperies. Finishing construction steps were underway on a special facility for carrying out full-scale burn studies of room and corridor fires. Studies planned for these facilities

include smoke, flame sources, fuel contribution, and heat development under use conditions for carpets, upholstered furniture, and draperies. The results will be correlated with small-scale laboratory tests as part of the program objective to develop reasonable and appropriate standards that reflect as nearly as possible the measurement of risks under use conditions.

Fire Research and Safety

Plans were completed for the Bureau program to be carried out under terms of the Fire Research and Safety Act of 1968. The plan was published as "A Program for the Fire Research and Safety Act" by the NBS Subcommittee of the Committee on Science and Astronautics of the House of Representatives. Three pilot programs are already in progress: (1) Implementation of a uniform fire reporting system in the greater Washington area, (2) study of fire department operations, expanding on previous Bureau work and work of RAND in New York City, and (3) development of specifications for improved protective clothing for firefighters. In addition, detailed plans are being prepared for specialized fire officer training programs so that training may start soon after funds are available.

Building Technology

The spiraling of construction costs combined with the tremendous backlog of housing units required to be produced in the next 30 years have accelerated the move to the industrialization of the building process. This change, from an industry heavily dependent on hand craftsmen techniques, to one of mass-production is generating pressures for up-dated standards, improved techniques for determining user requirements, and advanced capability for evaluating the performance of complex components. In order to meet this demand, the NBS programs for building technology have been broadened to cover more than the traditional materials research, which alone is no longer adequate to provide answers for the new questions raised by industrialization of the building process. All of these questions involve a consideration of cost to some extent. Therefore, this broadened scope must include studies of building economics. The program of economic studies has been initiated as a multiagency project, designed to develop a computerized construction cost control system that relates unit building prices, operation, and maintenance costs. This information can be used to project estimates of both building and operating costs from preliminary planning, through construction, to ultimate building use.

A new program in urban technology has been initiated to develop an information framework of user needs for housing, especially for low-income housing. The questions to be examined include what information is germane, how it may be manipulated, where it falls in

relation to other information, when it is applicable, and to whom it pertains. Criteria for user needs are derived from all sources in dividing the fields of sociology, physiology, and psychology. Where criteria cannot be developed from these sources, the program will develop substitute evaluative techniques and a basis for judgment decisions.

The building technology program continued the traditional laboratory and field support provided to Federal agencies, State, and local government groups concerned with building construction and technology. Technical consultation and advice was made available to industry, and the staff continued to work closely with the many private standards-making groups throughout the country.

Outdoor Exposure of Building Materials—The Building Research Division maintains six outdoor sites for testing of building materials. These sites were selected to provide diverse weather conditions and are located at the following facilities:

NBS, Gaithersburg, Maryland
Fort Holabird, Baltimore, Maryland
U.S. Naval Station, Roosevelt Roads, Puerto Rico
Nellis Air Force Base, Las Vegas, Nevada
Fort Lewis, Tacoma, Washington
Fort Greely, Fairbanks, Alaska

Permanents racks of specimens and materials are being exposed at all sites.

Many studies are underway to evaluate the effects of these various climates on materials. Some of the current studies are concerned with (1) weathering characteristics of aluminized steel and roofing, (2) the spalling resistance of porcelain enamels, (3) the color stability of plastics, and (4) the durability of paints.

The Performance of Masonry Structures—NBS has conducted extensive research on various types of masonry wall construction. A new analytical technique was developed by which the effects of vertical loads, wall thickness, and other variables can be evaluated. The application of this approach is expected to lead to national procedures for masonry walls similar to those recently introduced for other materials, such as reinforced concrete and steel.

Plumbing Research Facilities—Construction of new plumbing research facilities are near completion. A medium-rise tower structure will accommodate prototype tests up to seven stories in height; a lower-rise section will provide for simultaneous tests on 2- to 3-story systems. A modern electronic data acquisition system will be included for retrieval and processing of experimental data from 256 transducers. These facilities will be used initially for research in reduced-size venting, single-stack and vacuum drainage systems for housing,

and the development of performance criteria for evaluation of plumbing systems.

National Conference of States on Building Codes and Standards—NBS continued secretariat support for the National Conference of States on Building Codes and Standards. Staff members directed the administration of the Conference and provided support to state legislative hearings, study commission meetings, interstate conferences, and transmitted research results from the Bureau to these groups. The Bureau also provided a central repository for information on state activities providing for more uniform codes and standards. The 3d Annual Conference of the NCSBCS was held in Wichita, Kansas, in April 1970, with 34 states and territories officially represented. The Conference was also attended by other State and local officials and representatives of industry and business associations. Committee recommended programs for achieving a common code framework, improved standards, laboratory accreditation, innovation evaluation, educational standardization, and computer utilization were approved by the Conference.

Pyrolysis of Poly-vinyl Chloride—Studies of the pyrolysis of PVC revealed that in the early stages of a fire, before any visible smoke is produced, fire fighting personnel are endangered. Additional experiments are underway to identify the important chemical reactions occurring during pyrolysis. A very low temperature isolation cell is being used in conjunction with infrared spectroscopy to study the reactive products.

Fire Safety Test Methods—Two tests were developed for standards of materials involved with fire safety in buildings. Submitted to ASTM for adoption in the standards were: a smoke density chamber test for measuring the smoke-generating properties of materials; and a potential heat test, for measuring the contribution of materials to the intensity of a fire in a building. Work was also initiated on a test method for evaluating the rate at which materials contribute to fire intensity. In the area of materials ignition, a state-of-the-art study was started and a new test procedure is under design to evaluate "ease of ignition" of building materials.

Connections in Prefabricated Structures—Tests developed for different types of beam-to-column connections have produced data that are expected to result in more rational and economical building design practices. Continuous beam-to-column connections fabricated for precast reinforced concrete and precast post-tension concrete, which are used in prefabricated structures, have been tested.

The tests covered five types of reinforced and four types of post-tension connections (including monolithic construction for both groups). Each connection type was studied under two different loading situations: (1) beams subjected to vertical load only; and (2)

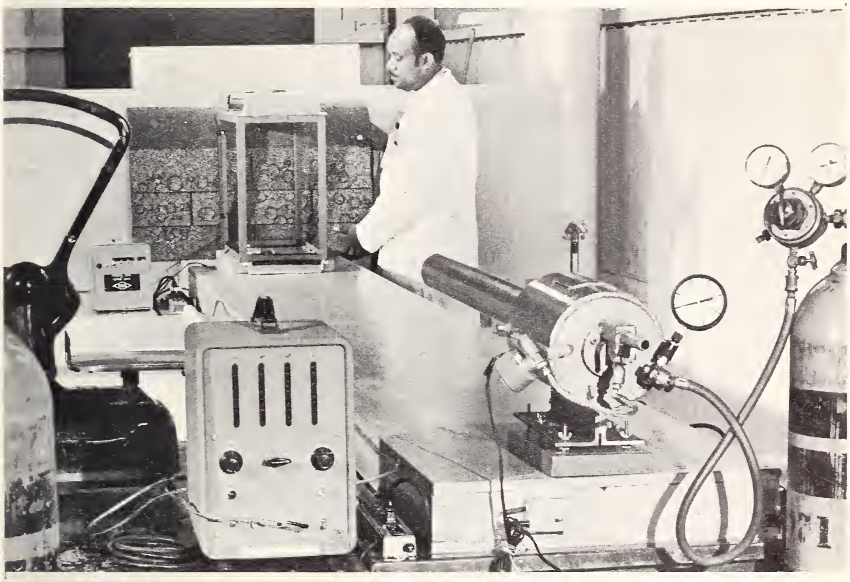
beams subjected to vertical load plus an axial tension load. Six reinforced and eight post-tension samples were tested. These tests completed the laboratory phase of the project and the information developed will be used as design criteria by architects and the construction industry.

Study of Occupancy Loads in Buildings—Structural engineering can be defined as the design and analysis of structural systems to resist loads. In many cases, there is insufficient knowledge of the actual loads that structures experience, and true measures of safety and economy are indeterminable. Past efforts to study actual loads have produced only limited information. The Bureau is now acquiring a large sample of data representative of existing loadings to measure statistically and describe characteristic load magnitudes and distributions. Survey techniques and evaluative procedures have been developed for a broad study of occupancy loads in office buildings and a pilot study has been completed. In addition, the occupancy loads in a sample of mail handling facilities have been surveyed at the request of the Post Office Department and the project is in the data evaluation stage. The principle objective of the load studies is to arrive at suitable design loads related to expected actual loading for safety and economy.

Disaster Building Damage—Following two natural disasters (Hurricane Camille, August 1969, and the Lubbock, Texas, tornado, May

Carport roof of a large motel in Lubbock, Texas, was lifted completely from its supports, moved approximately 40 feet, and set down intact by a tornado. The remainder of this motel was demolished.

1970), NBS sent teams of building experts to the scene for a survey of the kinds of construction damage suffered. The teams concluded, in general, that currently accepted good practice for the design and construction of buildings and mobile homes against wind loads would have greatly reduced damage. They also concluded that further research is needed to develop performance criteria for certain building elements. This is particularly true for roofs, cladding, masonry veneer, and glazing, where substantial damage was directly inflicted and severe internal building water damage from heavy hurricane rains resulted from destruction of these components. These findings have been widely circulated among Federal agencies concerned with building construction.



A special "hail gun," which propels spheres of ice at velocities simulating the impact of hail stones, is used to study the hail resistance of building materials.

Hail Resistance of Building Materials—Hail damage to buildings, particularly roofing, has increased over the years. This increase is not attributed to more frequent hail storms but to an increase in the number of buildings in areas susceptible to hail. Because there are no standards or criteria currently available, NBS, cooperating with industry, is carrying out hail tests on various types of products and assisting in the evaluation of these materials. Test methods developed in this study will be incorporated into standards for hail resistance, and the information will serve as criteria for the design of hail resistant buildings.

Paper Honeycomb Sandwich Panels—One of the more efficient structural systems is the sandwich panel, in which "skins" of a thin, strong sheet material are bonded to a "core" of a light, relatively weak ma-

terial. Although the skins take most of the direct, structural stresses, the core must stabilize the skins and transfer shear stresses. The Department of the Army and other agencies with need for demountable buildings are interested in the performance characteristics of the various materials and their combinations used in sandwich panels.

Wind Effects on Buildings—NBS, in a joint project with the Environmental Data Service of the Environmental Science Services Administration, extended the investigation of the effects of wind on buildings. This problem was highlighted by the hurricane and tornado damage during the year when losses may have exceeded the estimated $600 million yearly average for the continental United States. Techniques were developed for measuring steady and fluctuating wind pressures on building exterior walls. Also developed were measurement techniques for evaluating the structure of oncoming winds. A high-speed data acquisition system, capable of continuous, unattended operation was also designed and is currently being tested. Preliminary results indicate that wind gusts are effective over larger areas of buildings than was indicated from earlier tests in wind tunnels. It is anticipated that the study findings will provide guidelines for improving design techniques for structures exposed to wind.

One material commonly used as a core is paper honeycomb available in many grades and types, some of which are suitable for use as cores in structural sandwich panels. The NBS investigation evaluated the performance of many of the available honeycombs as cores in sandwich panels. The effects on the honeycomb of variables such as type of skin, type of adhesive, thickness of panel, and environmental conditions were studied.

New Heating and Cooling Load Calculation Procedure—NBS is cooperating with the American Society of Heating, Refrigerating, and Air Conditioning Engineers in a national effort to devise a means to machine-calculate the energy requirements for any building.

Computer calculation subroutines were prepared for use in an overall logic system designed to calculate the heating, cooling, and energy loads for buildings that operate under randomly fluctuating conditions (nonperiodic) of weather and indoor activity. Using input data on space operations, physical arrangements, and environmental information as supplied by the user, subroutines were developed for use in a computer program to produce an hourly heating/cooling load profile for a calendar year. Among the many factors considered were weather, distribution of heat sources, heat gained from lights, outside and inside heat transfer coefficients, and solar intensity and modifiers.

Planning Aids for Rehabilitation Facilities—A planning kit was developed for use in establishing performance requirements for mental health facilities. The planning method provides medical, social,

and building design professionals with guidelines for the rank ordering and weighting of desirable characteristics of any mental health facility. The requirements thus established aid building designers in making the facilities more responsive to user and medical needs.

Cost Studies for Building Construction Control—A study of cost analysis/cost synthesis systems for construction control has been completed as the first phase of a series aimed at the rationalization of the building process. The completed work was multiagency funded; it dealt with research into cost data collecting and retrieval methods for common use by Federal building agencies.

International Exchanges—Two international exchanges were conducted during the year. The first of these covered the subject, Industrialization of the Building Process. An eight man team of American building construction representatives was led by the Bureau representative on a two and one-half week tour of Soviet plants which fabricate building components and construction sites. In return, NBS was the host for a similar eight man Soviet delegation, which toured the United States to inspect industrialization of the building process as practiced in this country.

The second exchange was a US/French cooperative exchange of building research experts in which a team of five NBS representatives visited France. The host on this occasion was the Centre Scientifique et Technique du Batiment (CSTB) of France, a counterpart of the Building Research Division. The second part of this exchange took place in January 1970, when representatives of the CSTB visited America. Items of interest to the French visitors included mobile homes, urban acoustics, climatology, fire research, plastics in buildings, light-weight construction, and performance specifications.

Electronic Technology

The electronics industry is one of the fastest growing and most heavily research oriented in this country. New devices are developed faster than the measurement methods needed to control fabrication processes and to characterize the finished devices. The NBS contribution lies in the development of improved basic measurement methods of significance to advances in the entire technology.

Since the government purchases more than half of the industry output, NBS conducts programs on measurement methods for semiconductor materials, process control, electronic devices, and transducers. The goal of this work is to provide a set of measurement methods which have been carefully evaluated for technical adequacy, which are acceptable to both users and suppliers, and which can provide a common basis for the purchase specifications of government agencies.

The four-point probe holder has greatly improved resistivity measurements and minimized damage to specimens.

Resistivity of Silicon Wafers—Resistivity is the principal parameter used in the selection of silicon slices intended for device fabrication. The range of applicability of the four-probe method developed at NBS in cooperation with ASTM Committee F-1 was extended to both higher and lower values of resistivity. This extension permits the method to be used for both low-resistivity material for epitaxial substrates, and for high-resistivity material for high-voltage devices. Studies are underway to attain further extension of the improved four-probe technique to still higher resistivity material (important for nuclear radiation detectors) and thinner specimens (such as diffused or epitaxial layers). In addition there is a requirement for standard reference samples of silicon for calibrating four-probe

resistivity test sets. In response to this need, the feasibility of a collaborative reference program is being studied.

Radial Resistivity Variations in Silicon Wafers—The present procedure for measuring radial resistivity involves six four-probe resistivity measurements at various locations on the wafer. A new method is under development for measuring variation in radial resistivity with less likelihood of damaging the wafer surface during the measurement. Research has shown the feasibility of measuring these variations for lapped or polished circular silicon wafers by a photovoltaic method, which does not require contact with the wafer. Correlations have been obtained between profiles obtained by this method and by the more precise, but destructive, two-probe method, with which the four-probe method is standardized. Further development is required before the new method can be employed in industry.

Wire Bond Evaluation—Semiconductor device failure in both radiation and nonradiation environments is often due to failure of the wire bonds used in connecting external leads to the semiconductor chip. Evaluation of these bonds continued and techniques were developed insuring uniform and reproducible bonding conditions for ultrasonic wire bonding machines. These techniques involve direct measurement of the vibration amplitude of the bonding tool tip with a capacitor microphone or a magnetic detector. Observations have demonstrated that the vibration amplitide may be quite different for two or more operating conditions that have the same values of the usually controlled parameters. The variation appears to be a significant source of bond variability.

The relative importance of various conditions used in the pull test for bonds, in which adhesion is tested by applying a standardized pull to the wire is being evaluated. Bonds that fail are studied by examining the bonding pad by means of a scanning electron microscope, revealing that bonding occurs only at separated points rather than uniformly under the deformed wire.

Thermal Properties of Transistors—Thermographic phosphor techniques have shown that hot spots develop in many all-diffused medium-power and high-power NPN silicon transistors. The hot spots were attributed to current crowding and sometimes occur at voltage levels within the allowable operating range. Surprisingly, not all of the hot spots were reduced gradually with reduction of voltage; some persisted, once formed, until the collector-emitter voltage was reduced significantly below its original value. A hot spot would reappear at the same site when the voltage was again raised.

Although transistors subjected to hot spots for short periods were apparently unharmed, liability to hot spot formation and the thermal hysteresis effect greatly reduced the safe operating range of some transistors. Operation of these within the maximum operating area

curves obtained from second breakdown data does not insure against hot spot formation.

Hot spot research is continuing. If this phenomenon is shown to occur in a wide variety of transistor types, as preliminary results suggest, hot spot formation may be useful in a screening test for defective specimens. If so, this would solve one of the industry's most troublesome problems.

Microwave Semiconductor Devices—A project was undertaken to provide improved measurement methods for microwave semiconductor devices, with initial emphasis on microwave diodes. These diodes are critical elements in some civilian and military communication links and their quality controls the sensitivity, range, and reliability of radar systems.

While the civilian application of these diodes is rapidly increasing, most of the current production is purchased for government use. Serious trouble has been encountered by the Defense Electronic Supply Center (DESC) because of the inadequate measurements methods used to demonstrate conformance to performance specifications. The Bureau has undertaken to correct this inadequacy, as recommended by DESC and by industry, through the Joint Electron Device Engineering Council's Committee JS-3 on UHF and Microwave Diodes, in work jointly sponsored by the Naval Electronic Systems Command. Work has begun on measurements of such properties as noise figure, conversion loss, and impedance of mixer diodes.

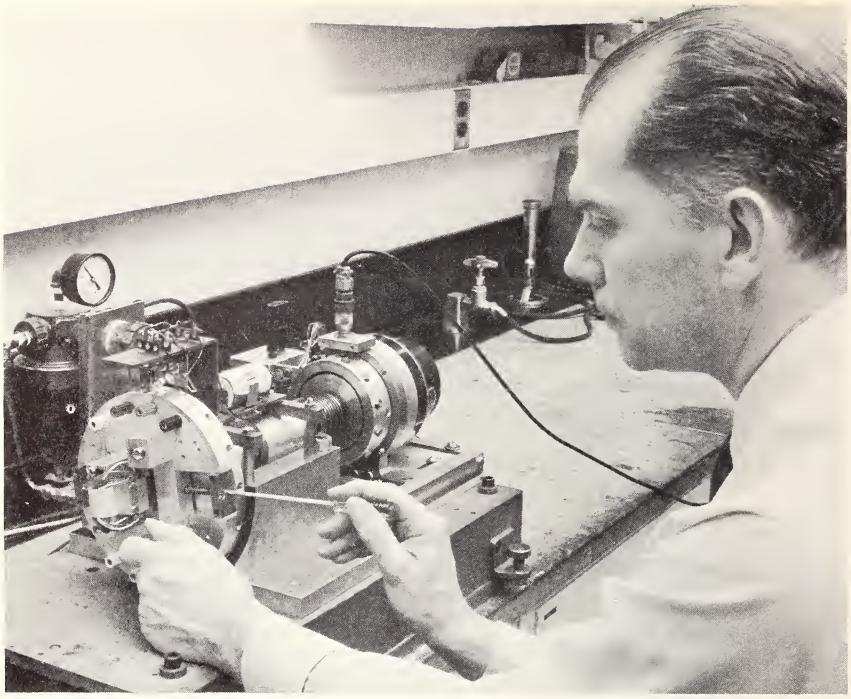
Characterization of Germanium for Nuclear Radiation Detectors—Methods of measuring the quality of germanium single crystals for gamma-ray detector fabrication, as well as for characterizing the detectors themselves, are being studied in cooperation with the Atomic Energy Commission. The resolution possible in a germanium radiation detector can be computed by means of the Fano factor for the semiconductor material, but values given for the Fano factor have changed over the years. A new determination of the Fano factor, made by means of a collimated gamma-ray beam falling on lithium-drifted germanium detectors, gave a value 20 percent lower than that found by previous determinations.

Determining the quality of material being processed, a problem throughout the semiconductor industry, is particularly severe in compensating germanium to produce radiation detectors. This compensation is done by "drifting" lithium partway into elemental germanium wafers, but the results of the process are only poorly predictable. A new model of the drifting process has been developed that takes into account losses among the lithium ions during drift. This led to the idea of using lithium driftability—its mobility and its loss time constant—as a basis for appraising material quality. The Bureau has now analyzed data for lithium precipitation in germanium during

A wafer of germanium is mounted in a cryostat for measurement of its performance as a radiation detector.

drifting by measuring oxygen concentration, using the dissociation constant of the lithium-oxygen complex. The value obtained was in good agreement with a previously published result.

Improved Piezoelectric Activity in Polymers—The wide range of mechanical properties of polymers makes it possible to construct transducers specifically for particular applications where conventional piezoelectric materials are inefficient. Techniques for producing a piezoelectric effect in polymers have been so improved that the activity of bulk polymers approaches that of quartz. Piezoelectric activity in rolled films of polyvinylchloride and polyvinylfluoride has been found to exceed that of conventional piezoelectric materials, such as ammonium dihydrogen phosphate and Rochelle salt. The use of a piezoelectric polymer transducer has been demonstrated in underwater reception of sound.



Accelerometers are dynamically calibrated in the earth's gravitation field by this device at frequencies from ¼ to 45 Hz.

Dynamic Accelerometer Calibrator—A dynamic calibrator for accelerometers was developed that uses as its reference standard the earth's gravitational field. It permits dynamic calibration at steady speeds of ½ to 45 revolutions per second that approach the accurate and highly reproducible values of static calibrations. This work was supported by the Office of the Director of Defense Research and Engineering through the Naval Air Systems Command.

Systems Analysis

In any program for promoting the application of technology to complex problems of industry or Government, the use of systems analysis or operations research is almost a mandatory requirement. The NBS Technical Analysis Division (TAD) seeks to develop, test, and disseminate systems analysis techniques which are applicable to public sector problems in terms of program planning, resource allocation, and program execution.

The IAT systems analysis group is the largest such organization within the civilian agencies of the Government. It serves other agencies in the solution of their specific systems analysis problems, and helps these agencies to develop their own capacity to tackle complex

systems problems. It also conducts research on the cost-benefit analyses for Government programs.

Mail Systems Studies—The Post Office Department was assisted in developing specifications for advanced mail-handling systems. A simulation model was developed for determining the cost and time required for delivery of mail at various volumes and flow rates. A human factors laboratory was established in which experiments were conducted in the use of two different kinds of keyboards in letter mail sorting, in encoding addresses by translation of voice into a form acceptable by computer, on reading time for ZIP codes and other portions of addresses, and to determine the most appropriate work/rest cycle for the highest productivity and lowest error rate in production. Data from these studies were given to Post Office engineers concerned with development of new equipment.

Safeguards for Nuclear Materials—How accountability techniques could be utilized to provide safeguards for strategic nuclear materials is being analyzed in collaboration with the Atomic Energy Commission and the Brookhaven National Laboratory. This program has resulted in the development of a set of criteria that make use of "material unaccounted for" as control criteria. The contribution made by sampling and measurement errors was considered in developing these criteria. Plans were made for conducting an integrated safeguards experiment at an industrial facility to test the practicality of this measurement methodology.

Air Pollution Sampler Distribution—Procedures were developed for proper placement of air pollution samplers in urban areas. This was done by using data on estimated emissions of pollutants and on meteorological factors in a computerized model of atmospheric diffusion to construct contour maps of concentrations of air pollutants. These maps are then used to pinpoint critical or preferred locations for the air pollution samplers. These techniques have been used in a joint exercise with National Air Pollution Control Administration personnel in planning the distribution of pollution sensors in a specific Air Quality Control Region. Such sampler systems will be used to monitor regional air quality and evaluate alternative air pollution control strategies to help improve our urban environment.

Airport Runway Systems—The increasing load of plane traffic at airports is a major concern of the Federal Aviation Administration. To assist the FAA a new concept to measure the capacity of an airport runway system, including the associated final approach air space is being formulated. Further investigation will extend the model to both arrival and departure streams of aircraft using the same runway. The problem of multiple runways at an airport will be considered as the model is developed. A parallel project is an analysis of the effectiveness of Visual Flight Rules control towers at airports.

The long term objective of these studies is to develop a simulation model for analyzing delays to traffic that would be encountered with alternative separation policies and/or traffic mixes.

Coastal Water Pollution—A primary responsibility of the United States Coast Guard is maintaining free navigation in the coastal and inland waters of the United States. This mandate includes the prevention, abatement, and cleanup of pollution that may occur as a result of accidental spills of oil or other hazardous materials. In response to a Coast Guard request, data on water pollution from the Coast Guard and the Army Corps of Engineers were examined and the extent of pollution in the maritime environment of New York harbor that resulted from accidental spills of oil and chemicals was identified. Deficiencies in the data were also indicated, as they are currently being collected, and existing data were analyzed in terms of sources and causes of pollution, types and quantities of pollutants, geographic location of spills, and other important characteristics. This project has increased the Coast Guard's capability to design a meaningful short term program for increasing its effectiveness in controlling, abating, and cleaning up pollution in the maritime environment.

Studies in Support of Law Enforcement—In a project sponsored by the National Institute of Law Enforcement and Criminal Justice (NILECJ), a study was made of the Washington, D.C. courts to provide data on whether pretrial detention should be considered in cases of individuals arrested and charged with certain types of crimes. A data base was assembled directly from court records, and the results of criminal action against 712 defendants selected from a four-week sample were analyzed. All additional criminal actions taken against these defendants while they were free on pretrial release (bail) were examined. These were analyzed for various categories of crimes and personal characteristics of defendants. The report on this study was used in Congressional deliberations on preventive detention legislation.

Another study, also sponsored by NILECJ, involved developing a plan for the establishment and management of a Law Enforcement Equipment Users Standards Laboratory. This laboratory would establish standards for equipment and facilities for use in prisons, courts, and other criminal justice areas, and for equipment and devices for use by law enforcement officers. Some of the types of equipment and devices considered for standards development included communications, vehicles, protective clothing and equipment, building and detention facilities, locks and security devices, weapons, and computers. The study emphasized the procedures for translating performance requirements to detailed specifications and for providing test methods to ensure that equipment meets these specifications.

Activities in the Continental Shelf Regions—In another project con-

ducted for the Coast Guard, an extensive annotated bibliography of articles and other published materials that describe activities now being carried out in the continental shelf regions of the United States was prepared. The trends of such activities were also analyzed.

The continental shelf is the location of a variety of activities extending from mining, fishing, and farming to research, exploration, and recreation. These activities are expected to increase rapidly in number, variety, and intensity during the 1970's. The information provided is currently being used by the Coast Guard for estimating the types of services and resources that will be required to support different levels of these activities, particularly with respect to such large pieces of equipment as helicopters and rescue vessels that will have to be purchased and the additional manpower that will have to be trained and utilized.

Motor Vehicle Safety

The research activities of the NBS Office of Vehicle Systems Research (OVSR) are part of the national program to reduce the deaths, injuries, and property damage occurring in motor vehicle accidents. This program, sponsored by the National Highway Safety Bureau in the Department of Transportation, continues to provide a technical basis for motor vehicle safety performance standards.

Occupant Restraint Systems—Research on the interation of seat belt restraint systems and occupants under impact was the basis for a standard recommended for a dynamic sled test evaluation of restraint performance. Reports were published on the variation of anthropometric dummy performance in impact testing and on human response under impact in production automobile seats.

A survey of anchorage locations was updated for current model cars to determine standard test locations. A space zone concept was developed, based on human measurements, to define the permissible locations of upper torso restraint systems. Tests of new and used belts are helping in the improvement of methods for evaluation safety standard requirements for retractors, corrosion resistance, webbing strength, and low temperature performance.

Braking Systems—The temperatures of brake linings, drums, disks, and fluids are being measured in vehicles run under normal-to-severe conditions. The effects of cold weather on brake fluid viscosity and performance, and especially its adverse effects on the performance of antilocking systems, were studied. The Bureau's tests indicate that the brake fluid hose is the penetration site of most of the water picked up by brake fluid.

Road and laboratory test methods are still being developed for braking system performance standards. A safety standard for replacement brake linings, now under development, uses an inertial dynamometer test method. A significant revision of the brake fluid

standard, including new requirements for containers and labeling, was proposed to the Department of Transportation.

Research continued on the development of the technical basis for a uniform quality grading system for tires that would enable consumers to make an informed choice in the selection of tires. Test methods and standards were developed for assessing the temperature sensitivity and strength properties of tires. Methods for rating tires for their tread wear, resistance to impact damage, and resistance to casing breakdown are now being developed.

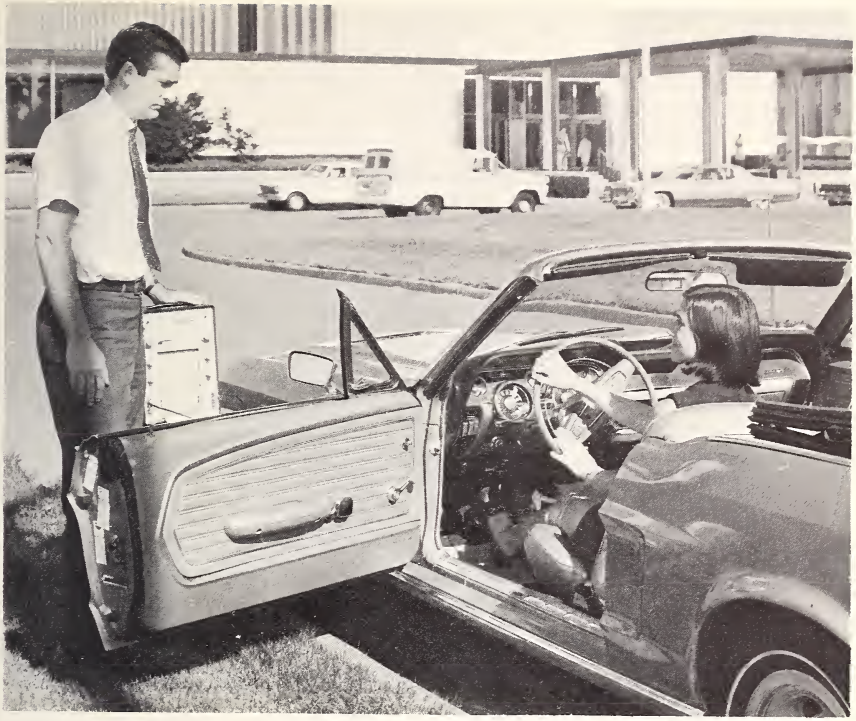
A vehicle has been instrumented to measure ground-to-tire forces in various maneuvers for correlation with data obtained with the use of instrumented trailers. This research will lead to a traction standard for passenger car tires.

Tire Noise Investigation—Research for gaining more fundamental knowledge about the sound-generating characteristics of tires was sponsored by the DOT Office of Noise Abatement. The OVSR personnel are being assisted in this by sound and acoustics specialists of the Building Research Division.

The specific research objective is to determine whether physical and subjective measurements of tire noise are closely correlated under a variety of experimental conditions. If the findings substantiate the positive hypothesis, it might be possible to establish a grading system for all automotive tires, using a series of standardized physical measurement procedures known to correlate highly with subjective responses to tire sounds.

The study consists of recording tire sounds and measuring them by a noise level meter. The recorded sounds are played back under standardized conditions before a randomly selected panel of listeners that is asked to rate each tire on the objectionableness of its sound. The ordering by the panel of the noise of five tires tested on the Bureau's endurance wheel at three speeds, two inflation pressures, and loading simulating passenger car service correlated almost perfectly with the physical measurements of sound pressure level in decibels. Another phase of this program involves tests of the same tires on a nearby interstate highway. Still another phase produced data from the same tires in a "coast-by" situation (car coasting with motor cut off and out of gear) ; these data are now being analyzed.

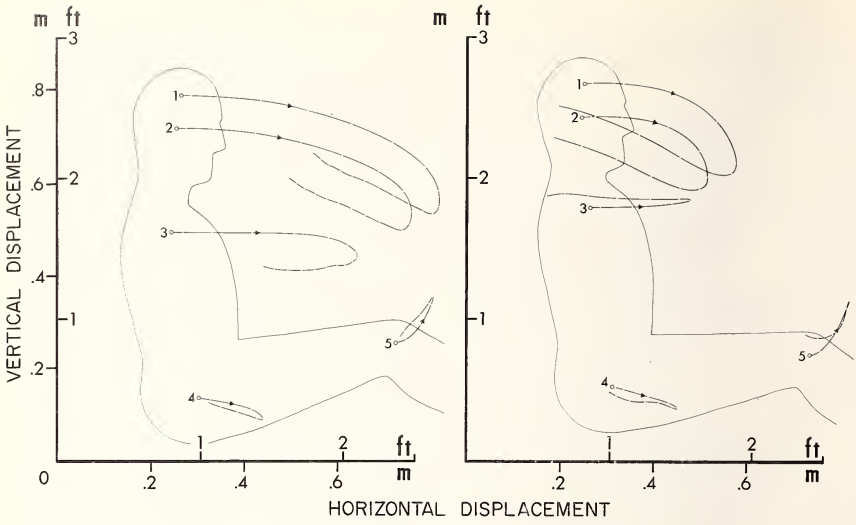
Air Tower Accuracy—The accuracy with which service station air towers deliver the indicated pressure was measured at 50 service stations in the Washington, D.C., area. There is a forty-five percent chance that tires inflated by such towers will differ by at least 3 psi from the pressure the tower is set for. As proper inflation plays an important role in tire wear, ride comfort, and safe handling, such errors are quite significant. Most of the errors could be reduced by periodic adjustment of the air tower.



Over 100 women volunteers were tested in specially instrumented cars to determine if current requirements for brake pedal force were reasonable.

Brake Pedal Force Study—Current automotive standards specify some levels of brake performance that require up to 200 pounds of force on the brake pedal. To determine if this 200 pound force was a reasonable requirement for the average woman, the force that 105 women volunteers could apply was measured in two specially instrumented autos. Tests were made with the vehicles at rest, and with the subjects wearing seatbelts. It was found that 20 percent of the women could not exceed an average pedal force of 135 pounds in one car, and 165 in the second, raising serious doubts about the practicality of the 200 pound allowance.

Occupant Restraint Effectiveness—That not all restraint systems are equally effective in preventing injury is demonstrated by data extracted from motion pictures of humans on sled "shots." Most of this film was obtained through use of airman volunteers on the Daisy Decelerator at Holloman Air Force Base. Data are obtained from the motion picture frames by use of OVSR's optical reader-digitizer. The accompanying drawings compare subject movement with use of only a lap-belt and with use of both lap and upper-torso restraints. The Bureau is continuing analysis of film from its repository, virtually the sole source of deceleration data for humans. (See figure on p. 146.)



Drawings of displacement of key points on human body on impact show the difference between subjects restrained only by a seatbelt (left 12.3 *g* on impact) and by both seatbelt and upper-torso restraints (14.8 *g*). An unrestrained subject would almost certainly have been injured and possibly killed.

Engineering Materials and Product Evaluation

IAT provides advisory, consultative, and laboratory investigation services relating to selected engineering materials. The laboratory work is mainly for the development of test procedures which can be used by other testing laboratories. The staff responsible for this program works with national and international groups to establish standards for these materials. Services also include establishing a technical base for other Government agencies to set purchase specifications.

Magnetic Tapes for Satellite Recorders—Early failure of flight recorders is one of the important causes of satellite failures, and satellites now being designed require several years of performance. In relation to recorder operation, NBS has continued its study of the changes of magnetic tapes after use, with special emphasis on the interactions of the tape and head surfaces. Material extracted from tapes has been identified by infrared spectroscopy and gel permeation chromatography as unreacted tape binder resin. It is believed that the transfer of this material to the recorded head surface is the cause of tapehead sticking.

NBS, in a project sponsored by NASA, has produced highly stable tape on commercial scale equipment at Battelle Memorial Institute. The tape resists a sterilization temperature of 145 °C for 24 hours without blocking or distortion. It is resistant to radiation and most chemicals, and its magnetic properties are comparable to commercial instrumentation tapes. Further work is planned, and samples of the

tape are being sent to several interested laboratories for evaluation.

Toy Safety—NBS is providing technical support to the Food and Drug Administration in the evaluation of toys for hazards and in the development of test methods and standards to be promulgated under provisions of the Child Protection and Toy Safety Act. The work is now primarily devoted to test methods for thermal hazards of heated toys and dangerous points and edges of toys.

Linerboard Collaborative Reference Programs—Interstate commerce regulations specify that paperboard shipping containers satisfy minimum bursting strength requirements. This requires that linerboard, one of the components of corrugated paperboard, be carefully tested for Mullen bursting strength. A linerboard collaborative reference program is now administered by the Bureau at the request of the Fourdrinier Kraft Board Institute. This new program provides a mechanism for participating laboratories to check periodically the level and uniformity of their testing in comparison with that of other laboratories. Samples are distributed monthly to the participants who test weekly and return test results to the Bureau for analysis. Monthly reports, in which laboratories are identified only by code number, include weekly and cumulative averages and standard deviations for individual laboratories and for the group as a whole. The first shipment of samples under the program was made in October 1969 to over 70 participating laboratories.

Vulcanized Rubber Collaborative Reference Program—The quality control of rubber products and of raw materials used in their production is dependent upon tensile tests of vulcanized rubber specimens. Standardization of laboratories making such tests is basic to the achievement of quality control of production by rubber manufacturers and their suppliers. To facilitate standardization, a collaborative reference program was initiated in January 1970 with 70 participating rubber laboratories. Pairs of samples are distributed bimonthly and are tested by participants for tensile strength, ultimate elongation, and stress at 300 percent elongation. In bimonthly reports laboratories are identified only by code number, except NBS, and averages and standard deviations are given for individual laboratories and for the group as a whole. Each laboratory is thus able to compare its performance with that of NBS and other participating laboratories and to take action, if necessary, to standardize its testing procedures.

Natural Rubber Stockpile—Some of the natural rubber in the national stockpile has been stored for over 20 years. Uncertainty in the condition of this rubber led to an evaluation of samples from five storage locations for the General Services Administration which is responsible for the stockpile. The condition of the rubber apparently depended on the place where the rubber was produced. Rubber from

some locations exhibited little or no deterioration in storage, while rubber from other locations had deteriorated extensively. The appearance of the rubber, except in extreme cases, was not indicative of the extent of deterioration. Recommendations were made for future purchasing of rubber to replace any in the stockpile.

Standard Brake Cup for Testing Brake Fluids—The increase in the use of disc brakes and high performance automotive vehicles has increased the temperature requirements of hydraulic brake fluids. In order to test the new high temperature brake fluids, a standard brake cup capable of operation above 150 °C (302 °F) was required. A formulation based on the recently developed ethylene-propylene-diene rubbers (EPDM) was developed for the Society of Automotive Engineers to be used for preparing standard brake cups to test brake fluids at this temperature. This rubber compound withstood exposures for three days at 175 °C with little deterioration. Brake cups made from this compound operated satisfactorily over the temperature range from −55 °C (−67 °F) to 165 °C (329 °F).

Viscosity of Rubber—The Mooney viscometer has been used since 1943 as the standard instrument for measuring the viscosity of synthetic rubbers. In this instrument, a disc rotates within the rubber enclosed in a heated chamber formed by two dies. The disc is rotated by a shaft which extends through an opening in one of the dies. The opening is normally sealed by a grommet which was found to cause systematic variations in the measured values. The variation was found to be greatly reduced or eliminated by the use of O-rings. Special O-rings, made from a rubber formulation developed for them, have been placed in the NBS Mooney viscometer used to measure the viscosity of the standard reference rubbers issued by the Bureau.

The Durability of Paper—A flexing device has been developed that uniformly destroys the physical structure of paper. The rate of destruction, as measured by changes in rheological properties due to flexing, may be taken as a measure of relative durability. Each property deteriorates at a rate independent of the others, with bending stiffness being the most fugitive property of paper and internal tear being least affected by flexing.

Supercalendering, a process used to increase density, smoothness, and gloss of paper, has been found to greatly improve the durability of paper towards flexing. Apparently the supercalendering enables the energy imparted to paper during flexing to be distributed uniformly throughout the sheet. As a result, interfiber bonding and fiber breakage occurs throughout the sheet in supercalendered paper but is more localized in the uncalendered paper causing a great number of "weak-links" to be formed during flexing.

Generally, the physical properties of paper deteriorate most in the direction of flexing with little or no change occurring in the opposite

direction. On occasion, especially with wood pulp papers, an appreciable decrease in physical properties occurs in the direction opposite to flexing. Scanning electron photomicrographs indicate that when the deterioration occurs primarily in the direction of flexure, cracking occurs parallel to the rollers with a minimum of interfiber debonding. In instances where deterioration occurs in both directions little or no cracking occurs and an appreciable amount of interfiber debonding is evident.

Engineering Standards

Revised Procedures for Voluntary Product Standards Development—Revised procedures for development of voluntary product standards were issued during the year. Participation by the Federal Government is recognized as a service to the public, and under the changed procedures, the Department of Commerce may initiate action to develop a voluntary product standard if it is deemed in the public interest to do so. This change is expected to result in a more active role for NBS in the consumer products standards and safety standards areas.

Product Standards—During the year, 14 voluntary product standards were published and another 18 were approved for publication. Publication of six amendments to existing standards was also approved. Forty-two standards are in process of evaluation for acceptability or committee approval. As part of the comprehensive review of existing standards, 91 are being reviewed and 201 standards have been recommended for withdrawal.

Standards Information—The standards information service of the Office of Engineering Standards Services (OESS) was further expanded during the year. A collection of State statutes, regulations, and administrative orders related to product safety was added to the information center. Also, 3,000 new standards were included in the standards library for public reference use.

The Key-Word-Index-In-Context (KWIC) index prepared in OESS covering 19,000 voluntary engineering standards was prepared for publication. OESS also participated in the development of a key-word index for the International Standards Organization (ISO). ISO used the index developed by NBS as the basis for its own key-word system.

Picnic-cooler Investigation—During a review of the efficacy of the mandatory standard covering refrigerator doors, it was learned that similar dangers existed with picnic-coolers and that 16 children had died from being trapped in such devices. NBS undertook a comprehensive study of coolers, and in a cooperative effort with manufacturers is developing a voluntary standard to eliminate this danger.

New State Standards—During FY 1970, ten more States received new standards for their weights and measures laboratories making a total of 40 State laboratories that have been updated. The plans of the final ten States, Puerto Rico, the District of Columbia, and the Virgin Islands, have been approved and the manufacture of sets of precise physical standards and instruments for them is proceeding.

OWM is assisting State "training officers" who will conduct future schools for industry inspectors or servicemen. This activity is a step in the direction of having the States assume greater responsibility for the training of weights and measures officials and industry people.

Standards Engineering—The engineering staff of the Office of Weights and Measures identifies and solves technical problems in commercial measurements. Recent studies of this type included belt-conveyor scales, electronic prepack scales, and an overhead gasoline delivery system. Fifty-eight prototype examinations were made to determine whether new types of commercial measuring and weighing devices complied with the basic weights and measures requirements listed in Handbook 44, used by the States as a guide.

Additions to Handbook 105 (Specifications and Tolerances for Field Standard Weights) were prepared for publication. These cover Specifications for Field Standard Flasks and Specifications for Metal Field Standard Provers.

Fair Packaging and Labeling—Implementation of the Fair Packaging and Labeling Act has continued, and thirty-six product categories subject to the Act have now been standardized by voluntary agreement in the industries involved. Five additional categories are in the process. Thirteen states adopted the Model State Packaging and Labeling Regulation proposed at the National Conference of Weights and Measures. Eight others are in the process of adopting the Regulation. Adoption of the Model Regulation assures consistency of the State regulation with Federal requirements under the Act.

Technical Training of Weights and Measures Officials—During the year, 27 State schools, and four regional interstate training seminars, were conducted by the Office of Weights and Measures. A total of 1175 officials and industry inspectors or servicemen attended the sessions. For State administrators, two seminars were conducted, one at the University of Colorado and the other at the University of Maryland. Training was provided at NBS for 51 metrologists, the courses ranging from basic to advanced.

National Conference of Weights and Measures—The 55th National Conference on Weights and Measures was held in Salt Lake City, Utah. At the Conference revisions were made in the Model State Packaging and Labeling Regulation to make them consistent with Federal requirements under the terms of the Fair Packaging and Labeling Act. The Conference also adopted a Model State Lumber

Regulation which covers the advertising, selling, and invoicing of lumber in terms of actual dimensions of width, thickness, and length, and complements the Voluntary Product Standard for lumber recently issued by the Department of Commerce. The conference updated Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Commercial Weighing and Measuring Devices.

TECHNICAL SUPPORT ACTIVITIES

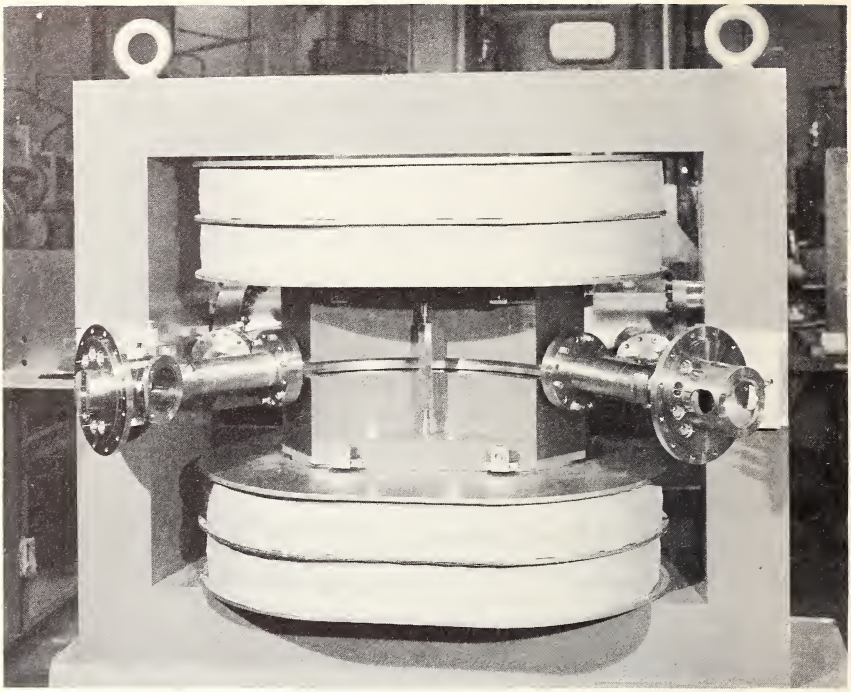
IAT provides engineering and development assistance in applying measurement technology to specific measurement problems. These services are used by other research programs in the Bureau, and by other Federal agencies. Work of this nature involves electronic techniques or combinations of electronics with mechanical, thermal, or optical methods. It also includes the production of instrument prototypes. Examples of the services follow.

Kinetic Properties of Letter Mail—Four instruments were developed for measuring the static and dynamic friction, cantilever beam strength, and column buckling resistance properties of mail envelopes. These properties must be known to set maximum limits on weights, accelerations, and bending stresses for machine handling of mail. The data derived from these measuring devices will be used in the design of automatic mail-processing machines.

Measuring Operator Performance on Mail-sorting Machines—Monitor equipment was developed for measuring operator error on mail-sorting machines. Judgment of the effects of human factors in sorting-machine design has been unreliable because operator error is hard to measure. The monitor system uses a test deck of envelopes containing the regular address (with ZIP code) and bar-code markings for monitor reading. The monitor records the operator's keying and its own response which should be identical. A count is kept of errors and the total number of envelopes. The monitor can be set for machine paced or operator paced speeds.

Double Crystal Spectrometer—A transmission double crystal spectrometer was built for use in an accurate redetermination of the electron-positron annihilation wavelength. In this instrument two spindles were located so precisely that two planes, each normal to an axis of rotation, present an average departure from parallelism of less than one second of arc. Careful fitting and loading of high precision bearings contributed to low friction spindles which permit angular rotations as small as 50 microarc seconds.

Lunar Sample Spectrometer—NBS participated with the National Aeronautics and Space Administration in the development of several mass spectrometers to be used for the analysis of lunar samples. Two models were designed in the Institute for Materials Research and built in the Instruments Shops. One, with a flight path of 12-inch



Part of the mass spectrometer designed for analysis of lunar samples.

radius through a 90° arc, has been delivered to NASA; a second with a 6-inch radius through a 60° arc is under test prior to delivery.

TECHNOLOGICAL INNOVATION AND DIFFUSION

Technological innovation may be defined as that process whereby means are devised and applied for stimulating new technologies, channeling them in promising useful directions, and exploiting their use for purposes other than those for which they were originally developed. Technological diffusion, in the context of IAT programs, is largely restricted to disseminating the results of Government sponsored R&D.

Invention and Innovation

The Office of Invention and Innovation is the IAT activity which helps to develop an environment conducive to technological change. Its basic program has three aspects: providing a national basis for formulation of climate-setting Federal policies, offering assistance to inventors, and education.

Invention Programs—Work is continuing with state development agencies and universities on inventor assistance programs. The pro-

grams involve invention expositions and seminars aimed at providing the inventor with useful information and assistance on problems relating to protecting, developing, licensing, and exploiting new inventive concepts. NBS provides assistance in planning and undertaking the expositions, seeks participation of other Government agencies on the programs, and provides speakers for the seminars.

Invention Policy—At the request of the Commissioner of Patents, NBS, in cooperation with the National Inventors Council, is directing its attention to the problems of the employed inventor. In this connection a report is being prepared identifying the problems and recommending the areas that should be the focus for a national conference on inventive talent and the public need. This conference will be planned in FY 71, following the above report, and will be held in FY 72.

A policy study is also in progress, in cooperation with the National Inventors Council, to determine the role of the Department of Commerce in encouraging and providing assistance to independent inventors and entrepreneurs. The study analyzes the problems faced by inventors and entrepreneurs who seek to bring their inventions to fruition, describes present programs and mechanisms for aiding them, identifies deficiencies in these methods of assistance, and explores alternative ways in which the Department of Commerce and other agencies might properly help to overcome these deficiencies. The study will be the basis of a report to the Secretary of Commerce by the National Inventors Council.

Education for Innovation—At the request of the Assistant Secretary for Science and Technology, and in conjunction with the National Inventors Council, the Office of Invention and Innovation is preparing a report to the Secretary of Commerce on specific ways in which the Department could aid in stimulating civilian technology; in particular, through establishing centers for technological innovation at universities, with the general goal of stimulating creativity, invention and innovation, and educating the technological entrepreneurs of the future.

Organization of American States—The Technological Unit of the Organization of American States was assisted in the design of a strategy for the technological development of Latin America. In addition, OAS Secretariat was advised with respect to its efforts to establish a proposed "Technology Bank" and a "Technological Diffusion Center" in Latin America. These efforts will form the basis for a conference to be held in 1971 on the application of science and technology to Latin America.

CENTER FOR RADIATION RESEARCH

The primary responsibility of the Center for Radiation Research (CRR) is carrying out the NBS mission in the area of ionizing radiation. This general area includes radiation produced by particle accelerators, reactors, and radionuclides, with energies in the range of approximately 5 keV to 300 MeV. Within this range, the Center develops improved techniques and instruments for detecting and measuring radiation, obtains basic data on the interactions of radiation with matter, and investigates the structure of the various forms of matter. Radiation sources and standards are developed and maintained for providing national services essential to industrial, medical, and research applications.

In concordance with federal policy on effective use of national scientific resources, the unique facilities and competences of the Center are available to other Government agencies, industry, and universities. This policy of facility sharing insures efficient utilization of large multipurpose facilities such as the reactor and linear accelerator by making them available to a broad segment of the scientific community. An increasing number of experimental programs are functioning successfully in which scientists from universities and other Government agencies collaborate with Center scientists on efforts of mutual interest.

The programs of the Center can be grouped in the following six general categories:

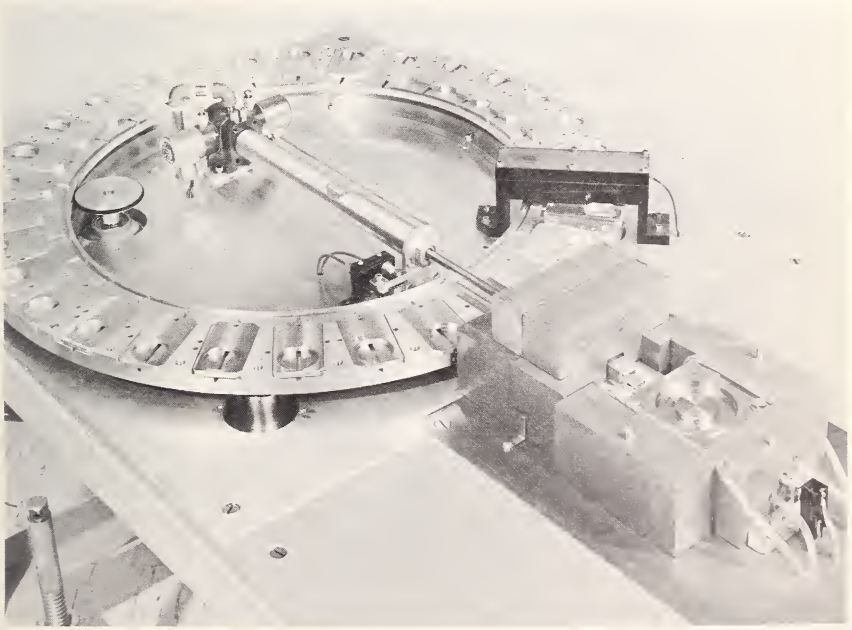
1. Radiation Measurement and Standards
2. Nuclear Physics Research
3. Structure of Materials
4. Radiation Theory
5. Facilities Operations
6. Technical Assistance to Others

RADIATION MEASUREMENT AND STANDARDS

Monitoring of High-Energy Electron Beams—The absolute accuracy of the high-energy, high-beam-power Faraday Cup has been measured for electron energies between 30 and 120 MeV using a ferrite toroid as a null instrument to compare the electron beam current with the Faraday Cup current. The Faraday Cup errors have been shown to consist of two components: a loss of electrons by back-

scatter from the front of the Cup (varying from 0.5 percent at 30 MeV to 0.1 percent at 120 MeV), and a gain of electrons by generation of secondaries in the entrance foil (0.7 percent at all energies between 30 and 120 MeV). The loss of secondary products from the back and sides of the Cup is negligible. The total Faraday Cup error is no larger than 0.6 percent in this energy range and can be determined with an accuracy of a few hundredths of 1 percent. With this information, the nonintercepting ferrite toroid can be calibrated to within about 0.1 percent for use as a continuous-duty monitor when the large neutron backgrounds generated by the Faraday Cup cannot be tolerated. Alternative means for providing an absolute calibration of the ferrite monitor are now being investigated.

Radioactivity Standards—An anticompton-anticoincidence shielded 8-in crystal arrangement, to be used in low level radioactivity calibrations and analysis, was constructed. This apparatus is composed of two 8-in × 4-in well crystals that can be used in coincidence, and a 30-in diameter by 20-in long cylindrical anticompton-anticoincidence scintillation plastic shield. This apparatus is capable of measuring large-volume sources with a high sensitivity of gamma rays per gram of source material. Mechanical construction was completed on a 4π beta-gamma coincidence counter with an automatic sample changer of new design.



NBS $4\pi\beta\gamma\gamma$ coincidence counting equipment with automatic sample changer. The γ-ray detector and its shielding have been removed in order to show the top of the $4\pi\beta$ gas flow proportional counter.

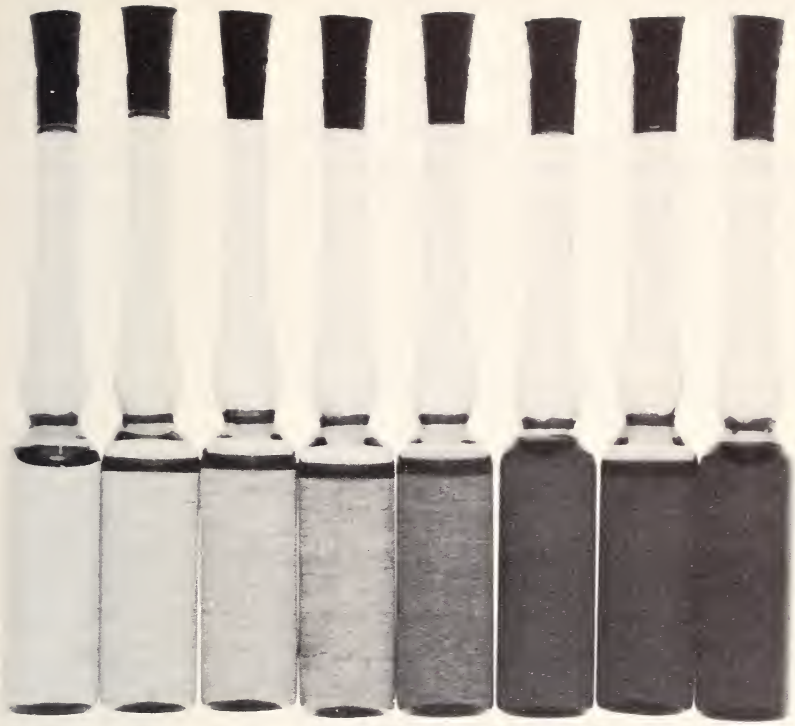
Fast Neutron ^{3}He Spectrometer—In collaboration with the University of Maryland, the resolution, efficiency, and use of ^{3}He semiconductor spectrometers as fast neutron spectrometers in the energy range 0.5 to 1.5 MeV have been investigated. Such a spectrometer has been used in conjunction with a specially designed collimator to measure the fast neutron distribution in the core region of the NBS reactor. At present, similar studies are being conducted in collaboration with the Harry Diamond Laboratories.

Spallation Products Due to Electrons in the GeV Energy Range—The 3 to 16 GeV electrons produced at the Stanford Linear Accelerator Center have been used to irradiate a number of high-purity materials. In collaboration with scientists at SLAC and Oak Ridge National Laboratory, measurements of the induced radioactivity were used to determine production cross sections for a large number of product nuclides. These results shed some light on the study of the various breakup mechanisms such as spallation, photofission, and fragmentation. The production cross sections have also been applied directly to the calculation of photon energy emitted after irradiation to assist in the health physics planning required to meet the hazards of residual radioactivity.

Multiple Scattering Corrections for the Associated-Particle Neutron Time-of-Flight Technique—The computer code, MAGGIE, for the calculation of multiple scattering and sample attentuation 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. The modified code and corrections to the original version have been published.

Chemical Dosimeters for Insect Control and Food Preservation by Radiation—Liquid radiochromic dye dosimeters have been developed to measure absorbed radiation dose between 1 and 100 kilorads. This is the dose range of interest for applications of gamma radiation to sterilization of adult male insect populations, for inhibition of sprouting of seeds and vegetables, and for extending the normal storage life of a number of foodstuffs. As a result, this new dosimeter is expected to have considerable economic value under circumstances where insect pests and storage of foodstuffs are serious problems.

Dose Produced by Electrons Striking Thick Targets—The 20 to 100 MeV electrons from the NBS linear accelerator have been used to investigate the thick-target dose produced in plastic phantoms arranged at a number of angles to the beam. Similar measurements have previously been available only for lower energy electrons. As higher energy accelerators are now being used for many medical and industrial applications these measurements will provide a basis for planning exposure rates and the types of shielding required when thick targets are used. The measurements, using LiF thermolumi-



The response of radiochromic dye solutions to absorbed radiation doses up to 100 kilorads.

nescent dosimeters, are being done in collaboration with scientists at the Stanford Linear Accelerator Center. Theoretical calculations of the expected dose for the cases studied show very good agreement with these experimental measurements.

Source for High Energy Photon Calibrations—A need exists in a number of institutions for a low-flux source of monoenergetic photons, in the energy region 10 to 180 MeV, for calibrating high energy photon detector arrays. These detectors will be flown in satellites, rockets, and balloons. With the support of the Goddard Space Flight Center a source of photons suitable for this purpose is being developed on the NBS 180 MeV synchrotron. Positrons produced in a target in the bremsstrahlung beam of the synchrotron will be momentum analyzed in a pair of magnets and focused in a region where detector arrays will be placed. Monoenergetic photons will be produced by positron annihilation in flight in a plastic scintillator. A second scintillator in anticoincidence will reject events where annihilation did not occur. This source will be completed and put into operation early in September 1970.

Inelastic Electron Scattering—The program to investigate the fundamental processes by which electrons interact with matter is continuing. Data on the inelastic scattering cross section have been recorded for carbon, copper, and gold targets at scattering angles from 20 to 140 degrees. These data have been recorded as a function of target thickness (in the range from 10 to 100 $\mu g/cm^2$) and incident electron energy (in the range from 0.1 to 3.0 MeV). These data have been analyzed and a report is being prepared comparing the observed electron spectra with the few available theoretical calculations.

Neutron Cross Sections—High accuracy, high precision, neutron total cross section measurements for carbon, nitrogen, silicon, and lead were determined in the neutron energy range 0.5 to 20 MeV. The neutron time-of-flight method was used in conjunction with the NBS electron linear accelerator. The neutron energy resolution was approximately 0.5 percent; both the precision and the accuracy of the cross section measurements were better than 2 percent.

Carbon is important as a neutron moderator and the cross section of the carbon–neutron interaction is used as a standard. Measurements showed that the previously accepted values for the carbon cross section were in error in the 3–to–4 MeV region. This measurement thus reconciled the discrepancy between a recent measurement and a calculation of neutron penetration in graphite.

An accurate knowledge of the nitrogen cross section is essential for solving the problem of neutron transport in the atmosphere; and lead and silicon are important constituents of shielding materials. NBS results are the only accurate, high-precision data for these elements covering the entire energy range of 0.5 to 20 MeV.

Thermoluminescence Dosimetry—A study was completed of the thermoluminescent response of CaF_2:Mn to 1 to 4 MeV electrons as a function of depth in an insulating (CaF_2) medium. The response-in-depth curves peak at shallower depths than would be expected from the theoretical depth-dose curves, and the response per unit energy absorbed is considerably lower than for cobalt-60 gamma rays. Nonreproducibility was shown to be due mainly to a dependence of the response-in-depth on irradiation rate. When the CaF_2:Mn samples were interleaved with a conductor (Al foil), the effects observed in the insulating medium tended to become less pronounced, or disappeared completely. This indicates that care must be used in interpreting depth-dose measurements in dielectric media.

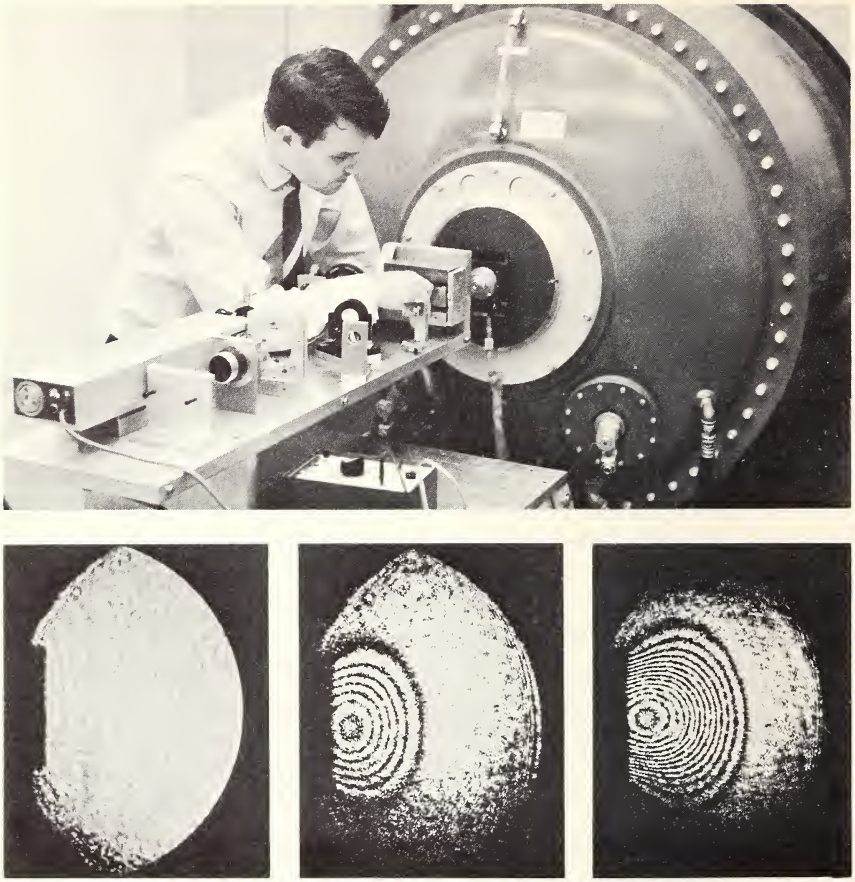
The thermoluminescent response of CaF_2:Mn irradiated with ultraviolet radiation from a low-pressure mercury lamp was investigated for possible utilization of CaF_2:Mn as an ultraviolet dosimeter. There were large sample-to-sample variations in response, and the response per unit irradiance of any one sample was found to be strongly dependent on irradiation history, particularly on the ultraviolet dose previously received by the sample.

Solid State Dosimetry—Measurements were made of the temperature and exposure-rate dependence of the photocurrents produced by x rays in silicon radiation dectectors of the p-n, p-i-n, and surface-barrier types. The short-circuit currents showed in some detectors a positive, and in some a negative, temperature dependence; while in still other detectors the currents showed a limited range of linear exposure-rate dependence. This varied behavior can be explained by differences in the internal series and junction resistances. In particular, it has been shown that with increasing ratio of internal series and junction resistances, the temperature coefficient of the short-circuit current at a given temperature decreases from positive to negative values. This information has immediate application in qualitative prediction of the temperature dependence of a given detector from measurements of its electrical properties, and may be of interest in the development of silicon radiation detectors with a very small temperature dependence.

Holographic Interferometry for Measuring Radiation Dose Distributions—A holographic interferometer has been constructed to determine the three-dimensional energy deposition profile produced by high-intensity pulsed radiation sources in transparent media. Coherent-light wave fronts passing through a liquid cell before and immediately after irradiation, cause an interference pattern to be constructed within a hologram. Reconstruction of the hologram, in the same geometry, produces a system of interference fringes representing the temperature profile caused by the liquid's absorption of radiation. This comes about because changes in refractive index of the liquid are approximately proportional to the local temperature variations. For the first time, relatively high-resolution depth dose and isodose contours can be determined for high-intensity pulsed radiation fields. (See figure on p. 160.)

High-Energy Electron and Photon Absorbed Dose Standards—Initial measurements of absorbed dose were made in a 50 MeV electron beam with the Bureau's graphite calorimeter and with a graphite ionization chamber having dimensions similar to the calorimeter core. A definitive intercomparison of the two detectors will provide the basis of new absorbed dose standards for electron and photon beams from 1 to 50 MeV.

X- and Gamma-Ray Instrument and Source Calibrations—The mechanical aspects have been completed in the updating of the calibration facility for the moderately and heavily filtered x-ray techniques. Information concerning the filter identity, diaphragm size, exposure time, and certain other factors is available in digital form. Ionization currents and other analog signals are digitized by a digital voltmeter, and all information is recorded by automatic typewriter and punched tape. After several interfacing problems have been solved,



Holographic interferometer for measuring three dimensional absorbed dose distributions from radiation beams supplied by such high-current pulsed machines as the domed instrument in the rear. The lower part of the figure shows fringe patterns made with the holographic interferometer. At left is seen a shadowgram of the unirradiated cell, while the middle and right photographs show the holographically generated interferograms representing the absorbed dose distribution following a pulse of electrons with average energies of about 1.5 and 2.0 Me V.

data reduction and report preparation will be carried out by computer.

Two new spherical graphite cavity ionization chambers have been constructed as additional exposure standards. These are being studied along with other chambers already available in order to provide additional information on the reliability of these detectors in the exposure standardization of gamma-ray beams.

Cobalt-60 Source Calibration—The power output of the cobalt-60 source furnished to NBS by the National Research Council, Ottawa, Canada, has been determined by an absolute counting method at the International Bureau of Weights and Measures, Sèvres, France. The value agrees within 0.3 percent with the power previously determined by calorimetry at NBS.

Pulse Radiolysis of Triphenylmethane Dye Cyanides—Triphenylmethane cyanide solutions have been found to be excellent dosimeters for pulse radiolysis because their response is dose-rate independent and because the formation of color by irradiation does not suffer a back reaction. A pulse radiolysis program has been initiated to study rate constants and intermediate species produced for short times by submicrosecond radiation pulses, in order to understand the unique properties of these dosimeter systems.

Dose Distributions Measured with Radiochromic Dyes—Thin radiochromic dye films, based on earlier NBS research, have recently become commercially available and are being used to depict, in detail, the dose profile of intense radiation beams in various phantoms and in a vacuum. This is possible because the response of the system is independent of dose rate and is the same in the presence of various gases and solids, and *in vacuo*. Depth-dose studies have been made for various types of material and varying angles of incidence, and are being compared with theoretical computations.

A conventional optical densitometer has been converted to a microdensitometer by adding certain optical, mechanical, and recording components. Various viewing slits as small as 16 μm are used with scanning speeds from 8 μm/s to 2 mm/s and with analog-to-digital tape readout for computer analysis. This new instrument has been used for measuring dose distributions determined with radiochromic dye films, and is generally useful for scaning images with low spatial contrast.

Energy Deposition in Surface Layers of Silicon by Monoenergetic Electrons—The energy deposition in surface layers of silicon by normally incident beams of monoenergetic electrons has been measured. The silicon layers studied were transmission-type, semiconductor detectors with a thickness less than the mean range of the incident electrons, which had energies of 0.25, 0.50, 0.75, and 1.0 MeV. The fraction of beam energy absorbed in a silicon layer was determined from absorbed-energy distributions derived from pulse-height distributions of the interaction of electrons with the detectors. Measurements were made for two different cases: the energy absorbed in a specific layer alone, and the energy absorbed in the same layer as part of a homogenous, semi-infinite medium, as for example, a surface layer. In the latter case, a larger fraction of the incident energy is absorbed in the layer. The measurement results compared well with Monte Carlo calculations.

NUCLEAR PHYSICS RESEARCH

Nuclear Structure Studies by Electron and Photon Excitation—A program designed to investigate the systematics of nuclei in the deformed region by electron and photon excitation has produced data

on the energy levels of the nuclei ^{167}Er, ^{191}Ir, ^{179}Hf, and ^{197}Au. Thirty-four levels have been observed in these nuclei with incident electron energies from 2.3 to 3.5 MeV; twenty-eight of these have been observed for the first time. The data are being fitted to existing theoretical models. Tentative analysis of the multipolarity of the transitions to these states indicates that all but three are of the electric quadrupole plus magnetic dipole type. Of the remaining three, one state in ^{197}Au is being classified as an electric dipole transition, while the other two states in ^{179}Hf give strong indication of being electric monopole transitions.

The Photonuclear Data Center—Compilation and abstracting activities have continued with the Center's files being maintained current to within two months of the published literature. These files now contain information on over 3,000 specific reactions published in over 1,500 research papers. The file of digitized cross section data has been expanded to include data from over two hundred individual curves. The latest completely annotated index to the literature in the field was issued in May 1970.

Extreme-angle Emission of Long-Range Alpha Particles in the Thermal Neutron Fission of ^{235}***U***—Study of the emission of long-range alpha particles in fission yields direct information on the initial stages of the fission process. An experiment has been performed to establish a correlation between the emission of long-range alpha particles at small angles with respect to the detected fission fragments and the fragments themselves. The results show that extreme-angle alpha particles have higher than average kinetic energy and are associated with symmetric and near symmetric division of the nucleus.

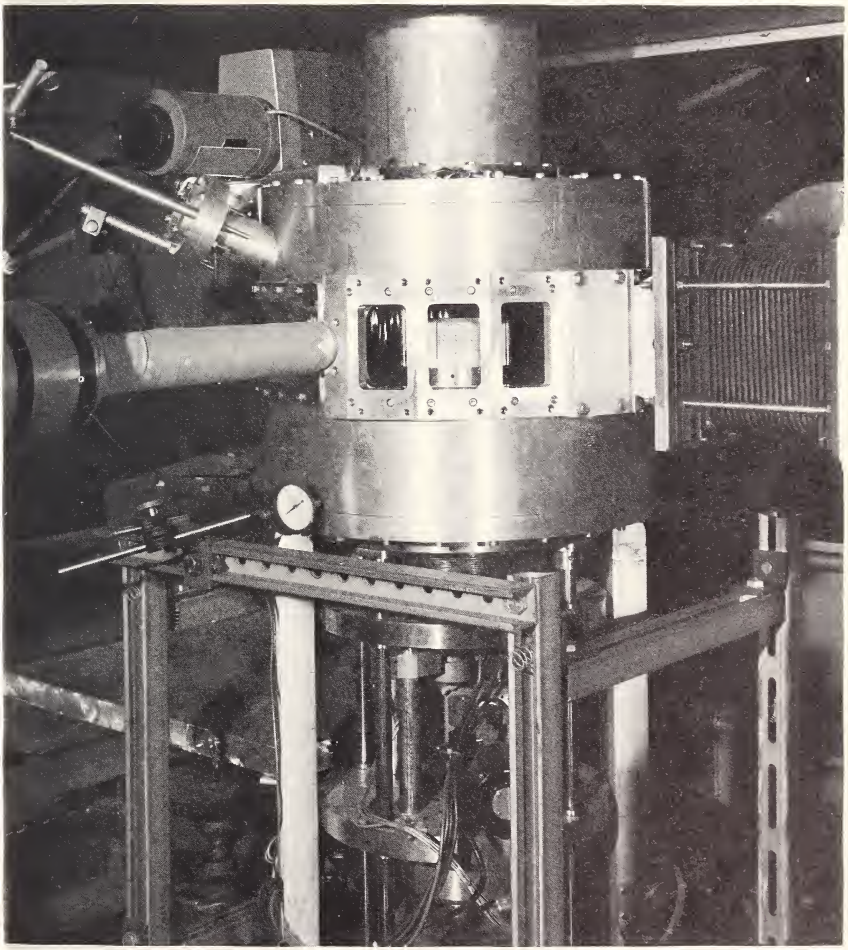
Two-Photon Emission in (n,p) Capture—A search for two-photon emission in thermal (n,p) capture is being conducted in collaboration with American University. The experiment aims at establishing the probability of occurrence of this process in an effort to help explain part of the apparent discrepancies between the measured and calculated values of the thermal (n,p) capture cross section.

Nuclear Spectroscopy—The angular distributions of beta, gamma, and conversion electronic radiations were measured for several cryogenically oriented radioactive isotopes. These oriented sources were produced by the NBS isotope separator, which was used to implant a particular isotope into a ferromagnetic material such as iron. The interaction between the nuclear magnetic moment of the isotope and the rather strong effective magnetic field, resulting from the electronic structure of the medium, allows most elements having a nonzero nuclear magnetic moment to be oriented to an appreciable degree in an adiabic demagnetization cryostat.

The multipolarity mixing ratios for twelve gamma-ray transitions in osmium-192 and platinum-192 have been determined, as well as for

four beta transitions from iridium-192. The sign of the magnetic moment of iridium is determined to be positive. The sign of the magnetic moment of praseodymium-142 is negative and the magnitude of the effective field is $60 \pm {}^{40}_{20}$ tesla. A study of bromine and krypton isotopes has been initiated; a preliminary result has shown the ground state magnetic moment of bromine-82 to be positive.

High Energy Electron Scattering—The high energy electron scattering program using the NBS electron linear accelerator proceeded at an accelerated pace during the past year because of an increased availability of beam time. Eight new experiments were begun, and the data-taking phases of nine experiments were completed during the year. The important new results of two experiments, studies of the ^{12}C giant resonance and of the low-lying states of ^{16}O, were published.



Electron scattering chamber. Bullseye seen through open port is used to aline the Linac's electron beam (which enters through tube at left) with a target. Scattered electrons enter the spectrometer at right. TV camera, upper left above chamber, views bullseye through an outside mirror (not visible).

The charge distribution parameters of the even titanium isotopes (46, 48, 50) were also measured. Other experiments are in progress to study: the 15.1 MeV level in ^{12}C; the giant resonance of ^{13}C; the energy level structure of ^{13}C, ^{14}C, ^{14}N, ^{16}O, ^{19}F, ^{48}Ti, ^{88}Sr, ^{89}Y, and ^{90}Zr. Most of these experiments are being done in collaboration with guest workers from a number of universities.

A number of improvements in the experimental apparatus are being made with the goal of measuring the electron-proton scattering cross section to an accuracy of well under one percent. For this purpose a new detector system is being built. The new system will provide improved knowledge of the detector efficiency, a method for direct background measurement, higher counting rates, and higher resolution.

Electrodisintegration Experiments—The energy and angular distributions of the $^4He(e,e'\,^2H)^2H$ reaction in the energy interval of 33 to 55 MeV were measured. Since the center of mass and charge of the system coincide, this reaction is expected to proceed via the absorption of the E-2 transition radiation. The measured angular distribution ($\sin^2 2\theta$) supports this multipolarity assignment. This is believed to be the first direct measurement of an E-2 electron disintegration cross section. Attempts to fit the data with wave functions that are not coupled to other modes of decay yield a cross section 10 to 100 times larger than these measurements.

Parity Violation in Strong Interactions—A program to study parity violation due to the weak interaction in the overall nuclear interaction is underway in collaboration with Harvard University and Brookhaven National Laboratory. At present the work is concentrating on a measurement of the circular polarization of gamma rays arising from thermal neutron capture in ^{113}Cd. The results of this program should lead to a better understanding of the weak interaction process.

STRUCTURE OF MATERIALS

Infrared and Raman Spectra of Simple Hydrogen Bonded Crystals—As part of a program to investigate the lattice dynamics and interatomic forces in strong hydrogen-bonded crystals, as well as the basic spectroscopic behavior of these systems, infrared and Laser-Raman spectra for $NaHF_2$ and KHF_2 have been measured and analyzed. In particular, the $q = 0$ lattice modes for these crystals have been identified and the infrared band shapes for the bending and stretching modes of the HF_2^- ions have been studied extensively by isotope dilution techniques. The isotope dilution results clearly indicate that the considerable width of the infrared absorption bands assigned to the asymmetric stretching and bending vibrations is associated with the coupling of near-neighbor HF_2^- oscillators having similar fre-

quencies or energy states. These studies are being extended to neutron spectral measurements.

Structure and Thermal Motion in PH_4Br and PH_4I—The crystal structure of PH_4 Br has been determined by a three-dimensional neutron diffraction study. The structures of both PH_4Br and PH_4I can be considered as tetragonal distortions of the CsCl structure. The phosphonium ion has a P–H distance of 1.4.4 Å and suffers the same slight distortion from a regular tetrahedron in both salts. The orientations of the ions in these salts are such that the P–H bond is pointed directly at the halide ion which is the *second* nearest neighbor of the phosphonium ion. This is in contrast to the analogous crystal phase of ammonium bromide in which the N–H bond points directly at the bromide ion closest to the ammonium ion. Thermal motions of the PH_4^+ ions in these salts have been derived from the diffraction data using a rigid-body treatment. Comparison of the amplitudes of librational and translational motions with previous spectroscopic data yields good agreement. The structural information obtained from these experiments will be integrated with information obtained from previous neutron, Raman, and NMR studies in an attempt to develop a generally consistent force model for both the ammonium and phosphonium halides.

Neutron Diffraction in Liquid Aluminum—The microscopic state of a liquid is described in terms of the pair correlation function. This function may be obtained by means of neutron diffraction. In the past the statistical theory of the liquid state had not advanced far enough to permit the calculation of the pair correlation. Recently, however, new theoretical approaches to this problem have been developed which are successful in the case of the alkali metals. Hopefully these techniques may also be applied to polyvalent metals for which pseudopotential theory applies. Measurements in aluminum have been carried out near the melting point (660 °C), and are presently being extended to higher temperature (1000 °C). Theoretical results will be compared with these measurements. This project is a cooperative effort of NBS, American University, and the Naval Ordnance Laboratory.

Molecular Dynamics in Plastic Crystals—Solids containing molecules with a spherical shape generally exhibit a crystal phase below the melting point in which the molecules begin to rotate rapidly with about the same freedom as in the liquid phase. This phase change is associated with a striking change in thermodynamic and other physical properties. The solid becomes soft and waxy and is designated as a "plastic" crystal. A neutron-scattering study of the plastic crystal phase transition in neopentane has been completed in collaboration with scientists from Argonne National Laboratory. The details of the changes in molecular dynamics in the plastic phase have been

examined by various theoretical fits to the changes in neutron quasi-elastic scattering with momentum transfer. A very low activation energy for molecular reorientation (3.8 J/mol.) in the plastic phase is derived from the temperature dependence of the neutron line-broadening. A systematic study of other plastic crystals is planned using the NBS reactor's cold-neutron facility, to better understanding the basic properties of these interesting materials.

Spin Canting In Rare Earth Iron Garnets ($R_3Fe_5O_{12}$)—The accepted model for the microscopic spin alinement in these materials has been a collinear arrangement, with a net moment resulting from unequal antiparallel rare earth and iron sublattices. However, due to the large component of the rare earth moment arising from the orbital electron motion, it was predicted that the rare earth moment would tilt away from the direction of the net moment under the influence of its non-cubic local environment. These arrangements have now been detected by low temperature neutron diffraction measurements in Dy, Tb, and Er iron garnets, and help in understanding the fundamental magnetic forces in these technologically important materials.

Crystal Structure of the TiNi Martensite—TiNi undergoes a crystallographic transformation just above room temperature that exhibits a novel "shape memory" effect, in which the material, deformed in the low temperature phase, will revert to its original shape if heated above the transition. Understanding this phenomenon requires a knowledge of the low temperature phase, which is extremely complicated. A model was proposed, based on x-ray diffraction measurements, in which certain shearing motions of the atoms cause strains whose relief provides the mechanism of the shape memory. Since Ti and Ni atoms look very different to x rays and neutrons, neutron diffraction measurements were taken throughout the transition region, and were found to confirm the model. This work was conducted through a cooperative program with the Naval Ordnance Laboratory.

Investigation of Vitreous Solids—Vitreous silica, a simple and basic material whose structure is representative of a large variety of substances in the glassy state, has found broad use in a variety of scientific applications. The structure of vitreous silica has been the subject of numerous investigations in recent years. Discrepancies have appeared in the published results of some investigations, depending upon whether the x-ray or neutron diffraction technique was used. An understanding of the source of these differing results and their resolution is essential for a thorough understanding and ultimate improvement of the various diffraction techniques employed in the analysis of glassy structures. Through a cooperative program between the Naval Research Laboratory and NBS, highly accurate data have been obtained on pure vitreous silica using both diffraction techniques. Newly developed methods of analysis have shown these data to be consistent

and have indicated structural features unobserved previously. It is expected that these methods will be further developed and used in a continuing program that seeks to explain the structure of widely used vitreous solids.

Crystal Structure of Metal Ion Complexes—A number of crystal structures of metal ion complexes have been investigated in the past year by means of x-ray and neutron diffraction techniques. The metal ions used in these studies include Cu^{++}, Cd^{++}, Co^{+++}, Ni^{++}, and the ligands include imidazole, pyrazole, 2,2′-bipyridine, 1,4-diazine and pyridine N-oxide, and nitrate groups. Each of these ligands is potentially multifunctional; that is, bonding to its environment is possible through more than one site. A crystal structure analysis of such complexes provides detailed information on the utilization of the active sites of the ligand molecules and about the type and the extent of the hydrogen bonding in the structure. Moreover, the analysis provides precise bond distances and angles. The data may be utilized to interpret the spectroscopic results and to establish a connection between crystallographic and chemical properties for these compounds.

Determination of Hydrogen Positions in the Crystal Structure of Apophyllite—Apophyllite is a hydrated potassium, calcium fluorosilicate mineral. Its crystal structure was refined by neutron diffraction techniques in order to try to explain why loss of weight occurs in two distinct steps on heating. The diffraction data were able to establish that a small fraction of the hydrogen was bonded to fluorine.

RADIATION THEORY

Electron and Photon Transport Theory—A set of methods and computer programs for calculating the penetration and diffusion of high-energy radiation through extended media has been further developed and refined. These methods involve a combination of random sampling with analytical multiple-scattering theory. Their reliability has been established through an extensive series of comparisons with experimental data on electron reflection and transmission coefficients, depth-dose distributions, gamma-ray buildup factors, thick-target bremsstrahlung and photo-neutron production coefficients, electron energy-loss straggling distributions, and electron and photon flux spectra. A set of programs for treating one-dimensional source-medium configurations has been distributed through the Oak Ridge Shielding Information Center, and is now in use in several other laboratories. Three-dimensional programs for configurations with spherical and cylindrical symmetry have also been developed. Many applications have been made to problems arising in a variety of fields. Typical examples are: the interpretation of cavity chamber measurements in water media irradiated with high-energy electron beams, in

order to establish the relation between the measured ionization in air and the corresponding absorbed dose in water; the determination of the response function of silicon, germanium and sodium iodide detectors, that is, the statistical relation between observed pulse height distributions and the actual photon or electron energy spectra; the calculation of absorbed dose distributions from beta-emitting radionuclide sources used for diagnostic purposes in nuclear medicine; the calculation of the flux of auroral electrons incident onto the earth's atmosphere from the knowledge of the secondary x rays observed in balloon experiments at heights of 30–40 km; and the prediction of three-dimensional auroral ionization and luminosity patterns.

High Energy Scattering Theorems—At very high energies E, the celebrated "Pomeranchuk Theorem" predicts *equality* of the total cross sections σ for the two scattering processes: (1) particle A strikes particle B and (2) particle $\overline{A}$ (the antiparticle of A) strikes particle B. (Example: $A = K^+$ meson, $B =$ proton (p), and $\overline{A} = K^-$ meson). Recent high energy data taken at the Serpukhov 70 GeV accelerator indicate that the σs for K^-p and K^+p have become independent of energy (a prerequisite for the theorem to apply), *but are unequal!* An NBS investigation of this problem resulted in (1) an input assumption of the theorem which can be relaxed while doing least violence to physics as we now know it, (2) discarding of this assumption, and (3) *prediction* that (i) the width of the forward peak of the differential elastic cross section $d\sigma/dt$ shrinks asymptotically as $(\log E)^2$ and (ii) at fixed energy in the asymptotic region, $d\sigma/dt$ *oscillates wildly* with t, the momentum transfer.

High Energy Reaction Cross Sections—A detailed description of high energy meson-baryon reactions has been carried out using SU(3) and $SU(6)_W$ invariant amplitudes. Some photoproduction processes have also been analyzed.

Elementary Particle Spectroscopy—The classification of mesons and baryons into SU(3) and SU(6) multiplets and the relations of their spectra to the quark model are fundamental problems of particle spectroscopy. An important question is whether exotic particles exist (those with quantum numbers different from what can be obtained in the three quark model for baryons and the quark-antiquark model for mesons). This is related to the possible splitting of the A_2 meson, and to the forward peaking of reaction cross sections in which exotic amplitudes may be exchanged. The properties of such particles, and tests for their existence, have been studied extensively and were reported in invited papers.

Estimates of Error in Moment Calculations of Radiation Penetration Data—Important tabulations of gamma-ray and neutron distributions exist whose accuracy, while thought to be high, has never been gaged quantitatively. Among these are distributions which have been re-

constructed from spatial moments, with the use of biorthogonal polynomial systems in the representation. Methods have been worked out for estimating limits to the error caused by the truncation of these series due to knowledge of only a finite set of moments.

Neutron and Gamma Ray Codes—Considerable progress has been made on computer codes using the moments method to calculate penetration of neutrons and gamma rays through matter. The gamma-ray code has been modified to include the contribution from fluorescent photons generated after photoelectric absorption, and annihilation photons generated after pair production. The neutron code has been modified to accept ENDF/B cross section data, to process cross sections for multielement materials such as air and concrete, and to include the termal neutron component. Calculations have been made for point isotropic sources of fission neutrons and 14 MeV neutrons in air, as well as for a plane source with an air-equilibrium spectrum of neutrons, incident perpendicularly on concrete.

Quartet Structure of Nuclei—The low energy spectra of all even-even nuclei with the mass number a multiple of four up to A = 60 have been shown to consistently have what is essentially a quartet structure, which is the shell model equivalent of the Rutherford α-particle model.

Short Range Correlations—The influence of the high momentum components of the nuclear wave function on definite processes has been investigated. It was shown that short range correlations of the type described by the Jastrow model increase the theoretical absorption probability of π^- mesons in light nuclei by about a factor 10^6 as compared with the value given by the uncorrelated shell model. The new value is essentially in agreement with experiment. A calculation of the (γ,pn) reaction, which is also sensitive to the short range correlations, has been completed for some specific cases.

X-Ray Attenuation Coefficient Information Center—Three decades of energy (100 MeV to 100 GeV) were added to previous evaluated data tabulations in this series with the publication of NSRDS-NBS 29: "Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 keV to 100 GeV" (for 23 elements ranging from hydrogen (Z = 1) to uranium (Z = 92) and 13 mixtures. Collaboration was continued with researchers at the Lawrence Radiation Laboratory, Livermore, Calif., resulting in the publication of Sec. I (Jan. 1970) and Secs. III and IV (August 1969) of UCRL–50174: "Compilation of X-Ray Cross Sections" (87 elements from hydrogen (Z = 1) to plutonium (Z = 94) for photon energies 1 keV to 1 MeV). An NBS-LRL contribution to the International Tables for X-Ray Crystallography was combined from Sections I and IV of UCRL–50174. In addition, a magnetic tape of photon cross section data (87 elements, 1 keV—100 MeV), combining pair production and high-energy Compton scattering data from NSRDS–NBS 29 with

atomic photoeffect and low-energy Rayleigh and Compton scattering data from UCRL–50174, has been made available in ENDF/B (Evaluated Nuclear Data File) format from the National Neutron Cross Section Center, Brookhaven National Laboratory, Upton, N.Y.

FACILITIES OPERATIONS

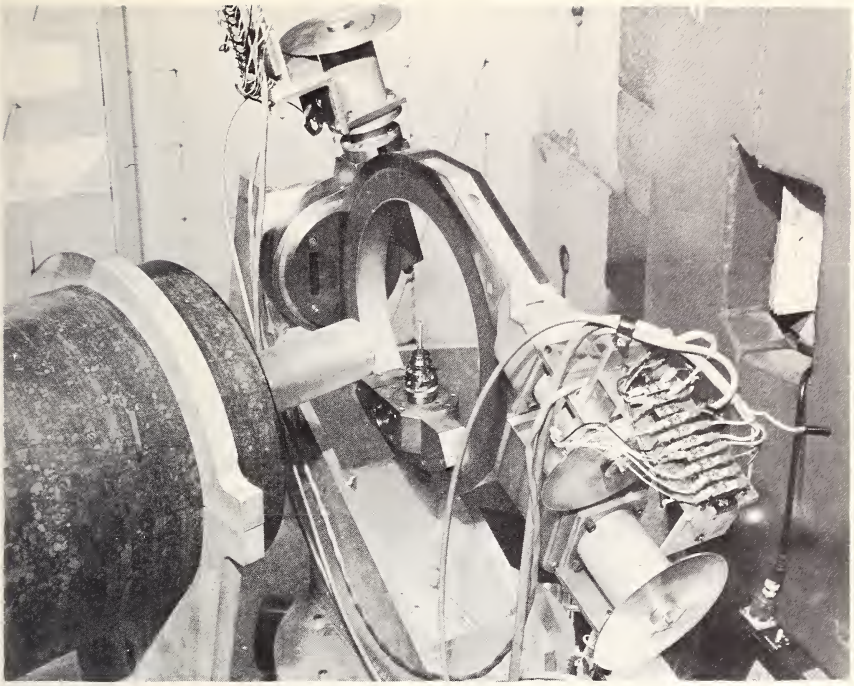
Reactor—The NBS reactor became fully operational during the year. All required reactor testing was completed and a full-term 15-year license was issued by the AEC. During this period more than 6,000 hours of reactor time were provided to users. This is equivalent to 60,000 megawatt-hours of energy produced. Currently operation is at the maximum rated power of 10 Mw on a continuous around-the-clock basis about two thirds of the time. This schedule permits operation with minimum staffing. Reactor performance to date has been excellent, and efficiency and time utilization have been very high. Very little time has been lost due to malfunctions or unscheduled shutdowns.

Seven of nine beam tubes, the thermal column, and one through-tube are fully instrumented and in constant use for a wide variety of research and application programs. The remaining two tubes, as well as the unique cryogenic facility, will be instrumented and operational next year.

Extensive use was made of the reactor in-core irradiation facilities. One long-term facility was added and several others are planned. More than 1,200 irradiations were made during the year. These included a wide variety of research and development programs ranging from biological and medical studies to activation analysis programs, radiation effects studies, and the production of numerous radioisotopes.

Use of the reactor by organizations outside CRR has increased significantly during the past year and continues to expand rapidly. Twenty-five scientists from other parts of the Bureau, representing 16 man-years of effort, used the reactor regularly, either directly or in cooperation with scientists in the Reactor Radiation Division. An additional 32 scientists from other agencies, universities, and industry spent 12 man-years of effort using the reactor.

In preparation for full power operation it was necessary to measure the maximum temperature reached by the fuel elements during the process of transferring spent fuel elements from the reactor to storage facilities. Since the fuel transfer system did not permit the attachment of thermocouples to the fuel plate itself, infrared pyrometry techniques were devised to measure the fuel plate temperatures. In addition to confirming that the fuel elements always remained at safe temperatures, the development of this technique provided a generally useful method for studying fuel element temperatures in a highly radioactive environment.



Crystal mounted on a rod and positioned within a goniometer (center) for analysis using a neutron scattering technique. Neutrons enter from right, scatter from the crystal, and are detected at left. All angle positioning of the goniometer is done through programming of an on-line computer.

Diffractometer Control System—A system for real-time computer control of four neutron diffractometers and an x-ray diffractometer has been put into routine operation at the reactor. The system is being used in structure studies of crystals (particularly crystals containing hydrogen or magnetic ions), glasses, and liquids. All programs for the collection, reduction, and collation of data are written in FORTRAN II language. A 15-minute film describing the system is available on free loan.

Linear Accelerator—During the year approximately 2600 hours of beam time were provided for experiments using the linac. This was 73.9 percent of the scheduled beam time and an increase of 54 percent over the beam time provided last year. Continued modifications to the accelerator and beam transport equipment have been made to improve beam quality and reduce maintenance. The fraction of the scheduled time during which beam was delivered to experiments was increased 10 percent. This increase was made possible by operation of the linac around-the-clock on a four day week schedule during most of the year.

Experiments using the accelerator include programs in electron scattering, photoneutron production, production of heavy ions, measurement of neutron total absorption cross sections, studies in beam monitoring, tests of accelerator theory, programs in activation anal-

ysis, production of radioactive sources for materials studies using Mössbauer sources, and for studies of photonuclear reactions, studies of direct production of specific fission products induced by energetic neutrons, studies of transient radiation effects in dye dosimeters and in dilute DNA solutions, development of monoenergetic polarized photon beams, and programs in electron and x-ray beam dosimetry. Programs to develop picosecond beam pulses are continuing. Construction of beam transport systems into new experimental areas continues.

During the year 46 workers from 15 outside institutions and from NBS groups outside of CRR used the linac. Most of the guest workers spent a relatively small fraction of their time at NBS, doing analysis of their data at their home institutions. During the year 4 doctoral degrees from three different universities were granted based on experimental work done using the linac. All or most data for 10 other doctoral candidate theses were taken during the year.

New Facility for High-Intensity High-Rate Electron and X Irradiations—A high-intensity pulsed electron beam source has been installed. This source, which is capable of producing 2-MeV electron beams having peak currents exceeding 5000 amperes in a pulse of 50 nanoseconds or less, can be used for investigations of electron or x-ray interactions at high rates, radiation chemistry, fluorescent decay studies, and other radiation effects requiring high rates or fast electron beam pulses. It should also be useful in developing dosimeters and dosimetric techniques for these high rates.

4-MeV Electron Accelerator—The 4-MeV electron accelerator is continuously being updated to insure the maximum utilization of its capabilities. Among the items added in the last year are a capacitive feedback system to stabilize the terminal potential. This system operates with considerably less maintenance than the corona discharge system previously utilized. In addition, the construction of a 180° electron scattering apparatus using a Si(Li) annular electron detector has begun, and should be operable in the next few months. This apparatus, with the previously available 18-in scattering chamber and the 180° photon scattering apparatus, will give the experimenter considerable latitude in the area of low-energy electron and photon experiments.

Isotope Separator—The ions $^{27}Al^+$ and $^{52}Cr^+$ were implanted into targets for the Naval Research Laboratory. In addition, $^{7}B^+$, $^{14}N^+$, $^{16}O^+$, and mass 28 ($^{12}C^{16}O^+$ and $^{14}N_2^+$) ions were implanted into various surfaces in collaboration with RCA. Ions of $^{20}Ne^+$ were implanted into niobium for coulomb excitation experiments at Pennsylvania State University. For NBS studies $^{82}Br^+$ ions were implanted into iron foil at an energy of 100 keV for nuclear orientation studies, and $^{85}Kr^+$ ions in natural krypton were implanted in alumi-

num foils for neutron activation in the NBS reactor and also for determining the ratio of $^{85}Kr^{+}$ and $^{85}Kr^{1}H^{+}$ at masses 85 and 86.

TECHNICAL ASSISTANCE TO OTHERS

Symposium on Electromagnetic Interactions in Two-, Three-, and Four-Nucleon Systems—An understanding of the properties of the s-shell nuclei is necessary to bridge the gap between the nucleon-nucleon interaction problem and the many-body problems of nuclear structure. During the last five years considerable progress has been made in the development of both experimental as well as theoretical techniques applicable to the study of these few-nucleon systems. A one-day symposium for experimentalists as well as theorists actively engaged in research on two-, three-, and four-body nuclei was held at the Center for Radiation Research on Sunday, April 26, 1970, just prior to the start of the Washington Meeting of the American Physical Society. Approximately seventy physicists from the United States and Canada spent the day discussing the most recent theoretical and experimental results as well as attempting to delineate the progress that has been made recently in understanding the properties of these light nuclei.

Scintillation and Semiconductor Counter Symposium—Sponsored jointly by NBS, the Nuclear Science Group of the Institute of Electrical and Electronics Engineers, and the Atomic Energy Commission, the 12th Scintillation and Semiconductor Counter Symposium was held in Washington, D.C. on March 11–13, 1970. An audience of more than 400 registrants heard scientists and engineers from the U.S. and five other countries present the latest developments in radiation detectors and their associated circuitry. The proceedings of this biennial event were published by the Nuclear Science Group of the IEEE.

CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY

The quarter century since the advent of the electronic computer saw the National Bureau of Standards as a leader in the early development of what is now the fastest growing technology in the world. The Bureau's program in this field, greatly expanded since the forties when early NBS research on computers was a partial function of the Ordnance Development Division and the National Applied Mathematics Laboratories, today is carried on by the Center for Computer Sciences and Technology (CCST) under a Congressional mandate embodied in the 1965 Brooks Bill (Public Law 89–306). This law and supporting policy guidance from the Bureau of the Budget assign to NBS the responsibility for:

(1) providing guidance in the promulgation of hardware and software standards, both for industry-wide voluntary standards and Federal standards,
(2) providing other government agencies with technical assistance and consultation in both hardware and software areas for the efficient use of computers,
(3) promoting training in various areas of computer applications,
(4) providing information services related to computer technology,
(5) providing computer services—involving the use of both equipment and programming—to NBS and to other government agencies, and
(6) engaging in exploratory research.

The CCST is a national center for research and development for the Government in the broad fields of computer sciences and technology. It employs a professional staff of about 150 people, consisting of mathematicians, engineers, chemists, physicists, operations research analysts, computer systems analysts, computer systems administrators, physical science administrators, and others. The work of the CCST interfaces with and is supported by the work of various other groups within the Bureau, within other agencies of the Federal Government, and within the affected organizations of the technical community outside government, such as the American National Standards Institute.

The technical work of CCST is carried out in the Office of the Center's Director, two special mission-oriented offices, and three technical divisions.

COMPUTER SERVICES

As part of its basic program, the Center operates a computer service that provides computer and related services to NBS and other government agencies on a cost-reimbursable basis. Primary emphasis is placed both on support of scientific, experimental and developmental applications and on assistance during the development and early implementation of systems that the user anticipates converting to his own computer within a specific period. Access to the main computer system, an intercoupled UNIVAC 1108/418, is provided to both on-site users and those at remote terminals connected via telephone lines.

An illustrative example is the assistance to the Economic Development Administration, which began using the NBS facility from a remote terminal in the summer of 1967 and, as planned, converted to its own computer in January 1970. This assistance permitted the orderly development of a broad economic data base and information-handling techniques at a minimum cost. Terminals at U.S. Forest Service offices in Washington, D.C., Atlanta, Milwaukee, Denver, and Albuquerque were connected to the system, enabling the Forest Service to experiment with centralized road design computations and collaborative development of new design techniques. At the same time, a saving was achieved by the Forest Service by not having to acquire additional computer equipment to support the decentralized operations.

The Bureau's computer facility works three shifts a day processing data for scientists and administrators of NBS and other government agencies.

Cost/benefit analyses obtained from experimentation with various terminal equipments and various communication facilities were used in selecting equipment and facilities. This resulted in a saving of $1200 per terminal and a performance improvement of 12 to 25 percent over leased devices. Adjustments and modifications to the operating software have resulted in increased operational efficiencies and have provided the experience necessary for evolving a fully modernized multiaccess, multiprocessor computer. Conversion from contractor to in-house maintenance of the 1108 system has improved the overall stability and responsiveness of the Bureau's computer system to user requirements.

User Communications—The Computer Services Division trys to keep users up-to-date on technical matters affecting computer utilization. The system itself is used to (1) print notices of current interest at the end of each printed output; (2) produce a comprehensive user's manual and maintain an up-to-date version in on-line mass storage, and (3) maintain a list of known software bugs and tips on how to avoid them. In addition, frequent newsletters are issued containing technical information and advance notice of proposed system changes, enabling users whose programs are affected to plan accordingly. Occasional seminars presented by the systems staff serve to pass along "tricks of the trade," stimulating users to think about more efficient ways of using the system. These communications are aimed both at better service to the users and at freeing systems programmers for more effective use by reducing demands for one-to-one user counseling.

COMPUTER INFORMATION

Office of Computer Information (OCI) has been set up in the Center to serve as a specialized information center in the computer field. It functions in several ways:

Developing an Information Management System—An information management system known as CHAOTIC (Computer and Human-Assisted Organization of a Technical Information Center) provides two significant outputs: an archival magnetic tape file of information describing each item of computer information which can be used for retrospective search in a batch-processing mode or eventually in an on-line interactive mode, and a magnetic tape file from which a set of indexes is produced for immediate use as search tools. The latter include KWIC (Key Word In Context) and KWOT (Key Word Out of Title) indexes, personal and corporate author indexes, subject category listings, and a master bibliographic list.

Classifying Computer Information—Participants representing government, industry, and the academic community developed a concept-oriented classification scheme for computer program documentation,

to be used by programmers and patent searchers. The outgrowth of this work is a computer-based classification system, programmed in COBOL, known as CAIC (Computer-Assisted Indexing and Classification), based on a statistical word association approach.

Information Service—Information was provided in response to requests from government, industry, the academic community, and international organizations on the following topics: NBS reports, availability of computer programs, identification reports on official guidelines or procurement policy for ADP systems, reference material on various types of ADP equipment, American literature on cost/benefit analysis, reference materials on the computer and microfilm applications, technical aspects of data banks and data communications, standards for tape format for information interchange, ADP glossary, use of EDP in security portfolio and stock market analysis, and classification schemes for computer information. Bibliographies were prepared on: computerized numerical control, litigation and computers, optical character recognition printing, and social implications of computers.

The first three volumes of a series of studies in research and development requirements in the computer and information sciences were issued, and NBS Monograph No. 91 was reissued with additions.

STANDARDS

FIPS PUBS—Ten Federal Information Processing Standards (FIPS PUBS) have been published, the last three during fiscal 1970. The ten are: FIPS PUB 0—General Description of the Federal Information Processing Standards Register; FIPS PUB 1—Code for Information Interchange; FIPS PUB 2—Perforated Tape Code for Information Interchange; FIPS PUB 3—Recorded Magnetic Tape for Information Interchange (800 CPI, NRZI); FIPS PUB 4—Calendar Date; FIPS PUB 5—States of the United States; FIPS PUB 6—Counties of the States of the United States; FIPS PUB 7—Implementation of the Code for Information Interchange and Related Media Standards; FIPS PUB 8—Metropolitan Statistical Areas; and FIPS PUB 9—Congressional Districts of the United States.

Six proposed Federal Information Processing Standards have been forwarded to the Office of Management and Budget for adoption and approval. These include standards for:

a. Bit Sequencing of the Code for Information Interchange in Serial-by-Bit Data Transmission
b. Character Structure and Character Parity Sense in Parallel-by-Bit Data Communication in the Code for Information Interchange
c. Character Structure and Character Parity Sense for Serial-by-Bit Communication in the Code for Information Interchange

d. Hollerith Punched Card Code
e. Rectangular Holes in 12-Row Punched Cards
f. Subsets of the Standard Code for Information Interchange.

In addition, the following proposed Federal Information Processing Standards are in the process of coordination with the Federal Departments and Agencies:

a. Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
b. Interface Between Data Terminal Equipment and Automatic Calling Equipment for Data Communication
c. Layout of Forms for OCR Input
d. Specifications for General Purpose Paper Cards for Information Processing
e. COBOL Programming Language
f. Recorded Magnetic Tape for Information Interchange (200 CPI, NRZI)
g. Recorded Magnetic Tape for Information Interchange (1600 CPI, NRZI)

To assist the Office of Information Processing Standards in deriving requirements and plans for Federal information processing standards development, a new committee, the Federal Information Processing Standards Coordinating and Advisory Committee, was established. Seven task groups have been established, under the sponsorship of this committee, to undertake development work in the following areas:

Task Group 1—Objectives and Requirements for Standards
Task Group 2—Data Terminal and Data Systems Requirements
Task Group 3—Character Sets, Sign Conventions and Packing Techniques
Task Group 4—Subsections on Standards for Use in Requests for Proposals
Task Group 5—Federal Information Processing Vocabulary
Task Group 6—Magnetic Tape and Recorded References
Task Group 7—Magnetic Tape Labels for Information Interchange

The first of several candidate Magnetic Disk Reference Surfaces was delivered to the Office of Information Processing Standards. This is an early step in the establishment of a National Reference Disk Standard.

The Office of Information Processing Standards has provided expertise and professional assistance in the development of American National Standards. This has resulted in numerous National Standards being proposed by ANSI over the past year. Many technical meetings of ANSI X3 and X4 groups were hosted by the National Bureau of Standards at its facilities in Gaithersburg.

NBS staff members have contributed to the development of International Recommendations in the area of information processing through ISO Technical Committee 97 and its subcommittees.

Arrangements have been made through the NBS Clearinghouse for Scientific and Technical Publications to have FIPS PUBS made available in microfiche form. In addition, arrangements have been made to provide the long list of data element standards having lists of items recorded in machine-sensible form on magnetic tape and punched cards.

Information pertinent to the Federal information processing standards program appears in a regular monthly column, entitled FIPS Notes, in the NBS Technical News Bulletin.

NBS Standard Reference Magnetic Tape—The CCST is now supplying the Office of Standard Reference Materials with SRM 3200—unrecorded secondary standard magnetic tape, which is now in use by the computer tape and equipment industries nationally and internationally. For the first time these Government-sponsored reference tapes are available to industry for use in evaluating the performance of magnetic computer tapes and maintaining control over their production. This standard tape resulted from research on tape characteristics, in the course of which the performance measurements laboratories had to develop new instrumentation, a tape evaluation system that measures the amplitude of signal pulses read from the tape. This instrumentation is now used in calibrating the standard

Adjusting circuitry that measures the amplitude of pulses recorded on reference magnetic tape in order to calibrate the tape.

tapes and in maintaining the primary and secondary reference tapes held in repository. The prototype instrumentation has been redesigned and a new model fabricated for the General Services Administration's Magnetic Surfaces Laboratory, which is now located at the Bureau's Gaithersburg laboratory complex. Here it is used in performing qualification and acceptance tests in procuring magnetic tape for use with computers in the Federal Government.

TECHNICAL ASSISTANCE AND ADVISORY SERVICES

As a part of its central mission, the Center provides consultation, technical assistance, and advisory services to other government agencies. The services range from brief consultations to such long-range projects as providing technical assistance in the design and development of computer systems, and other-agency sponsored exploratory research.

Consulting services have continued to the Lister Hill Center for Biomedical Communications of the National Library of Medicine on problems of optical character recognition, networking, compatibility, and health records. Consultation has been provided to the Patent Office with respect to handling patents for computer programs and in undertaking an experimental computer-assisted patent classification system. The Department of State was advised on the potential use of a large on-line information retrieval system. Assistance was rendered to the U.S. Office of Education in the evaluation of computer-related education research programs. The Department of Housing and Urban Development was assisted in evaluating contract proposals for urban information systems. Consultation was given the Post Office Department on a time-sharing system used to redirect mail to servicemen in Viet Nam whose duty stations have been changed. Other consulting services have been provided to the Department of Commerce, the Agency for International Development, the Department of State, the Department of Justice, and the National Commission for Product Safety.

Laboratory Automation—The CCST continued assistance to NBS laboratories in the design and development of laboratory automation equipment and in the design and programming of systems to accompany them. New instrumentation creates demands for real-time control of experiments, precision in computation, and the processing of masses of data. One such project is concerned with the system design and programming of a laboratory facility for the Analytical Chemistry Division of NBS. The computer is programmed to acquire signals on-line and in real time from several instruments simultaneously and to be responsive to the scientist's requests for service. Applications will include processing environmental sensor data, test-

ing combustion efficiency of auto engines, controlling urban transportation flow, and computing data from electrocardiograms.

NBS data automation scientists have assisted other scientists in setting up data acquisition systems, some using small, dedicated electronic computers. In one such installation at the Bureau, a Hall-effect experiment was connected, via special-purpose hardware, to a time-shared computer. The voltage sequence magnetic flux, and specimen temperature were under control of the remote computer. The interaction between the experiment control and the computer was stylized so that they could communicate as if a human operator were seated at the console.

In another application of data automation, a biological microscope at the National Institutes of Health was fitted with a mechanical stage which could be moved in three dimensions under control of an associated computer. The computer selects the illumination wavelength and intensity, controls the scan, measures light transmission at each point scanned, and writes the data on magnetic tape or sends it via telephone line to a large computer for processing. This system is being used for pattern recognition in identifying blood cells, for autoradiograph scanning, to produce three-dimensional representations of tissue scanned, for microspectrophotometric analyses, and as a design tool in creating new scanning systems.

A computer controls the scan and records data from this microscope.

Automated Accounting System—An automated accounting system has been developed during the past two years for the Agricultural Research Service. The complex multiphase system was originally designed for three terminals in distant cities. Subsequent reorganization modified the original concept and the system is now being completed for a computer in the Agriculture Library, where it will have a centralized input.

The U.S. Army TACFIRE Program—NBS consultants assisted the Army TACFIRE program by participating in monitoring contracts for both hardware and software required in this multiple, real-time computer system.

Remote Computer Graphics—A study of system design and support of remote computer graphics has been completed for the National Aeronautics and Space Administration. This activity included the development of a graphical text editor, which was used at the NBS research facilities to study the performance, in general, of graphical displays connected to time-shared systems by communication lines of limited bandwidth.

Microfilm Reader-Copier—A microfilm reader-copier called the Select-a-Frame has been developed for the National Library of Medicine to provide a rapid means of making automatically original-size prints of frames selected from rolls of microfilm.

RESEARCH AND DEVELOPMENT

Performance Measurement—A study was initiated to measure the performance of remote access computer systems. The computer programs being written will allow the in-house time-sharing research system to be used as a tool in measuring the performance of other time-sharing systems. The output of this work is expected to be useful to those individuals and groups having to select one of several time-sharing systems for remote terminal work.

Teletypewriter Terminal Design—A multiheaded teletypewriter terminal has been designed and constructed for use with in-house CCST programs. This terminal consists of three teletypewriter devices that are mediated by an electronic system to communicate over a single line with the remote computer system. The new terminal will permit simultaneous operation and printout of clean hard copy for later reference. It will also facilitate multiple terminal experiments using only the single line to the computer.

Pharmacological Information System—A computerized pharmacological information system designed with support from the National Institutes of Health is geared to the highly complex needs of drug researchers. Its purpose is to enable a small pharmacological research group having no knowledge of computers to set up its own data file. The system would place emphasis on the portion of the file having

interest to the group and would offer facilities for the drug researchers to query the file and receive answers. A sample file compiled of psychotropic drugs and related compounds includes information on names of compounds, chemical structures, physiological action in humans, and lethal doses of drugs in experimental animals. One major benefit of the system is the potential for rapid screening of large masses of data.

Communications Network Planning—The Defense Communications System controls large, complex switched networks that use the facilities of commercial communications carriers. The Defense Communications Agency (DCA) staff requires methodologies for effective and economical network planning, design, and management in order to reduce the network's susceptibility to large-scale attack, to improve reliability, and to optimize other facets within the constraints of availability, cost, and such factors. The CCST assisted the DCA in developing new methodologies and efficient computer programs, implementing them for application to the planning, design, and management of the Defense Communications System.

Two-Dimensional Graphic Structures—Recent years have seen an increased interest in computer graphics—both the entry of graphical data into a computer and in the computer generation of graphic displays for human viewing. Although there has been progress in hardware for graphic processing, the field remains in its infancy. One reason is the difficulty of processing or describing a graph in terms other than an assemblage of points and lines. Research is being conducted into the linguistics of two-dimensional graphic structures—the nature of relationships among elements, ways of determining well-formedness, and ways of translating between two- and one-dimensional representations. The areas of immediate interest are Chinese characters and molecular diagrams.

Data Definition Language—Work was begun on developing a data definition language (DDL) that will permit any data file to be described and the description interpreted by a programming language compiler. Such a DDL would promote the interchange of data and programs from one computer system or from one installation to another. The eventual goal is to incorporate the DDL into a system that can translate data files, structurally revising them to effect their movement from computer system to computer system.

Interactive Programming—An experiment is being conducted in the design of a computer program for interactive use by a program designer for producing other computer programs. The program with which the designer works is called a "generator program." Generators have their principal use in such applications as computer-assisted instruction, or in writing interrogation programs that might, for example, be used to elicit a medical history from a patient. Special-

ists in computer-related areas can relieve others of the need to specialize by making it less difficult and costly to write interactive computer programs and by improving the conversational fluency of such programs. Thus, a program generator might produce only true/false or multiple-choice computer-assisted instruction programs, with a systems programmer creating a generator which would then be used by a teacher or course author to produce the actual courses.

TRAINING

The Center attempts to maintain awareness in the profession of recent technical developments in electronic data processing. To this end, a course was sponsored in conjunction with the Personnel Division; it was called "Advanced Concept and Principle of Third Generation Computer Services."

Training has also been supplied at the Center to foreign nationals, under sponsorship of the Agency for International Development.

CONFERENCES AND SYMPOSIA

The Center conducts a colloquium series with the primary objective of fostering discussion on various aspects of computer applications, such as problems, policies, long-range plans, and new product developments. Half of the speakers come from industry and half from Government. The audience is restricted to seventy-five people in order to obtain highly responsive audiences.

On April 27 and 28, 1970, NBS hosted the ACM First Workshop on Terminals and Communications, sponsored by the Association for Computing Machinery.

The Workshop was attended by about 150 representatives, drawn largely from the terminal, computer, and communications industries and from Government. Presentations covered principles of basic data movement, standardization work in progress worldwide, the economic value of standardization, communication systems performance, control procedures, live discipline and protocol, networks, keyboards, cathode ray tube display terminals, interactive interfaces, and programming for communications processors.

Representatives from the Center participated with major ADP policy-making officials in Government and industry management at a conference held in Charlottesville, Virginia, September 15-17, to examine the impact of developments on the Government's policies and practices for selecting, procuring, and managing computer systems.

In December 1969 the Center cosponsored a conference for 450 registrants on image storage and transmission systems for libraries; the other sponsors were the Federal Library Committee's Task Force

on Automation, the Lister Hill National Center for Biomedical Communications, and the Panel on Information Science and Technology of the Committee on Science and Technology. Members of the Center also participated in Federal Library Committee task forces, including those for: (1) compilation of descriptions of mechanized information systems in Government agencies, (2) revision of the COSATI-sponsored standard for microfiche, (3) study of the status of automation activities in the Federal library community, and (4) preparation of a definitive report on the impact of information sciences technology on the economy and on policy implications.

Several members of the CCST are chairmen of active professional committees, such as the Special Interest Group on Computer Systems Installation Management of the ACM; they have chaired meetings and panel discussions at national conferences in addition to presenting papers at conferences. Several members of the Center's staff serve on important policy-making committees in the profession, both nationally and internationally, in connection with standards activities and with other functions in the data processing field.

OFFICE FOR INFORMATION PROGRAMS

This Office, established in 1969 under an Associate Director for Information Programs, has management responsibility for two operating programs, the National Standard Reference Data Program and the Clearinghouse for Federal Scientific and Technical Information, and four supporting functions, the Office of Technical Information and Publications, the Office of Public Information, the NBS Library, and the Office of International Relations.

Management of these diverse but related functions was consolidated to coordinate and harmonize all the elements of the NBS information system, from support of the experimentalist and theoretician, through dissemination of the technical information output of the Bureau and the Federal Government to meet the needs of the technical and general public, to building relations with the national and international technical communities. The principal accomplishments of these activities are described below.

NATIONAL STANDARD REFERENCE DATA SYSTEM

The formal existence of the National Standard Reference Data System dates from 1963, when the Federal Council for Science and Technology asked the National Bureau of Standards to assume primary responsibility in the Federal Government for promoting and coordinating the critical evaluation of numerical data in the physical sciences. The program was conceived as a decentralized national effort, with financial support coming from a variety of Government and private sources, but with NBS responsible for the overall planning and coordination. The existing data compilation activities supported by NBS and other Government agencies were to serve as the nucleus of the system. These activities were to be strengthened, new projects started in neglected technical areas, and the entire effort molded into a coherent program.

The technical scope of the program is restricted to well-defined physical and chemical properties of substances and systems that are well-characterized. While this definition leaves some borderline cases, the intent is to concentrate the effort on intrinsic properties that are clearly defined in terms of accepted physical theory. Properties which depend upon arbitrarily defined characteristics of the measurement technique are generally excluded. Likewise, materials of un-

certain or variable composition are not included. Biological properties and data relating to large natural systems also fall outside the program.

A primary aim of the program is to provide critically evaluated numerical data, in a convenient and accessible form, to the scientific and technical community. Certain secondary outputs, such as annotated bibliographies and procedures for computerized handling of data, are also prepared. A less tangible but equally important aim is to provide feedback into the generation of physical data that will raise the general standards of measurement. That is, by communicating the experience gained in evaluating the world output of data in the physical sciences, experimental techniques will hopefully be advanced and the reliability of physical measurements improved.

Management of the National Standard Reference Data System is provided by the Office of Standard Reference Data. Over 30 continuing data centers and other data evaluation projects are currently being supported by this Office. Many of these projects are located in NBS technical divisions; others are operated on a contract basis at universities, other Government laboratories, and industrial laboratories. The continuing data centers search the world literature for papers within their technical scope, organize and index these papers for convenient retrieval, and carry out critical evaluations of the data reported in them. In addition, the data centers provide bibliographic support for individuals writing critical reviews or carrying out critical evaluation on specific topics.

Current Activities

The NSRDS program of data evaluation is divided into six technical areas. Highlights of the current activities in these areas are given below, along with a summary of progress of groups concerned with information services and data systems design.

Thermodynamic and Transport Properties

During the year, the program in thermodynamics and transport properties of the Office of Standard Reference Data included ongoing projects in the following areas:

Chemical Thermodynamic Data on Inorganic Compounds
Thermodynamic Data on Organic Compounds
Properties of Molten Salts
Thermodynamic Properties of Polar Gases: Ammonia
Low Temperature Specific Heats
Systems at High Pressure
Vapor-Liquid Equilibrium in Binary Mixtures of Non-Electrolytes at Low Pressures

Binary Metal and Metalloid Constitution Diagrams
Thermal Conductivity of Selected Materials, in Particular the Elements
Transport Properties of Fluids
Properties of Electrolyte Solutions
Thermodynamic Properties of Cryogenic Fluids
Thermodynamic Properties of Nitrogen
Thermodynamic Data near the Critical Point of Binary Liquid Mixtures and the Néel Point of Magnets

These projects are sponsored by NBS although some are supported in part by other agencies.

Projects were added on excess thermodynamic properties of liquid mixtures of hydrocarbons and the heat capacity of water near the critical point. The first of these is closely related to the project on vapor-liquid equilibria in binary mixtures. The second is part of a series of projects, some sponsored by the Office of Standard Reference Data, others not, which provides an evaluation of data in the critical region on the basis of recent theoretical advances.

Three monographs containing evaluated data have appeared during the year. These are:

Molten Salts: Vol. 2, Section 1. Electrochemistry of Molten Salts: Gibbs Free Energies and Excess Free Energies From Equilibrium—Type Cells, by G. J. Janz, and Chr. G. M. Dijkhuis; Section 2. Surface Tension Data, by G. J. Janz, G. R. Lakshminarayanan, R. P. T. Tomkins and J. Wong. NSRDS–NBS–28, 1969.

High-Temperature Properties and Decomposition of Inorganic Salts, Part 2. Carbonates, by K. H. Stern and E. L. Weise. NSRDS–NBS–30, 1969.

Electrolytic Conductance and the Conductances of the Halogen Acids in Water, by Walter J. Hamer and Harold J. DeWane. NSRDS–NBS–33, 1970.

Two other publications might be mentioned. These are products of the GSSSD, the Russian national data system, which have been translated into English at the request of the Office of Standard Reference Data. They are·

Thermophysical Properties of Liquid Air and its Components by A. A. Vasserman and V. A. Rabinovich TT69–55092 [1]

Thermophysical Properties of Gases and Liquids No. 1 by V. A. Rabinovich, Editor TT69–55091

The Office of Standard Reference Data also provides support for the Bulletin of Thermodynamics and Thermochemistry, an annual annotated bibliography of the literature in the field.

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[1] The TT numbers are to be used in ordering from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.

On November 5–7, 1969, a symposium on "The Evaluation of the Thermodynamic Properties of Fliuds" was held at Airlie House, Warrenton, Va. The symposium was sponsored by the Numerical Data Advisory Board of the National Academy of Sciences-National Research Council at the request of the Office of Standard Reference Data. The primary themes of the symposium were:

(a) The estimation of the reliability of experimental, theoretical, and evaluated data, techniques for data evaluation, and related problems.

(b) Assessment of the needs for evaluated data in science and industry, and discussion of current programs carried out to meet these needs.

A report on the discussions of panels detailed to study data needs, resources, and programs in six technical areas is available from the Office of Standard Reference Data.

Atomic and Molecular Data

This program continues to emphasize the compilation, evaluation, and publication of atomic and molecular spectra, collision cross sections and other molecular properties. A new project was started on the development of criteria for obtaining and reporting laser Raman spectra. An ad hoc advisory meeting of the Joint Committee for Atomic and Molecular Physical Data was convened to encourage and promote the publication of high grade spectra in the fields of infrared spectroscopy, Raman spectroscopy, microwave spectroscopy, mass spectrometry, and nuclear magnetic resonance. A project to measure the absolute cross section for helium excitation by electron impact has also been initiated. This experiment is to provide a definitive value of the cross section plus an estimate of the limits of systematic error, so that it may be used as a model for making cross section measurements of other types.

The following publications have appeared during the last year:

1. NSRDS–NBS–22, Volume II, Atomic Transition Probabilities, Vol. II, Sodium Through Calcium, by W. L. Wiese, M. W. Smith, and B. M. Miles, 1969.
2. NSRDS–NBS–29, Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 keV to 100 GeV, by J. H. Hubbell, 1969.
3. NBS Special Publication 320, Bibliography on Atomic Transition Probabilities, Jan. 1916 through June 1969, by B. M. Miles and W. L. Wiese, 1970.
4. NBS Special Publication 306–4, Bibliography on the Analyses of Optical Atomic Spectra, Section 4 ^{57}La-^{71}Lu ^{89}Ac-^{99}Es, by Charlotte E. Moore, 1969.

5. Bibliography of Ion-Molecule Reaction Rate Data, JILA Information Center Report No. 9, by George A. Sinnott, August 1969.
6. Compilation of Low Energy Electron Collision Cross Section Data, Part II, JILA Information Center Report No. 7, by L. J. Kieffer, September 1969.
7. Bibliography of Low Energy Electron Collision Cross Section Data (1967–1969), JILA Information Center Report No. 10, by G. E. Chamberlain and L. J. Kieffer, February 1970.
8. Ion-Molecule Reactions, by E. W. McDaniel, V. Cermak, A. Dalgarno, E. E. Ferguson, and L. Friedman, June 19, 1970, John Wiley and Son, Inc.

Chemical Kinetics

This program area emphasizes the preparation of critical reviews in kinetics, particularly the compilation of rate constant data. A number of such reviews are presently in progress, some of which are pertinent to research on environmental problems. Similarly, a number of reviews and data compilations are being prepared in the area of radiation chemistry.

The following reports have been issued:

1. NSRDS–NBS–21, Kinetic Data on Gas Phase Unimolecular Reactions, by S. W. Benson and H. E. O'Neal, 1970.
2. NSRDS–NBS–31, Bond Dissociation Energies in Simple Molecules, by B. deB. Darwent, 1970.

Solid State Data

The activities in the solid state program continue to center on compilation of crystal data, alloy properties data, superconductive properties, and diffusion data. An ad hoc NAS–NRC advisory panel was held recently to examine and recommend a programmatic plan for compiling and publishing Mössbauer effect data. Data compilation projects dealing with static dielectric constants and energy gaps in semiconductors have been initiated. Considerable progress has been made on the Crystal Data Determinative Tables.

Colloid and Surface Properties

Currently there are six active projects in the field of colloid and surface properties. These are:

Surface Tensions of Molten Salts
Critical Micelle Concentrations of Aqueous Surfactant Systems
Surface Tensions of Substances Liquid in the Vicinity of Room Temperature and Below

Light Scattering by Liquids
Electrical Properties of Interfaces
Physical Data Pertaining to Phase Transition Kinetics

A monograph containing critically evaluated data in the field has also been published. This is:

Molten Salts: Vol. 2, Section 1. Electrochemistry of Molten Salts: Gibbs Free Energies and Excess Free Energies From Equilibrium-Type Cells, by G. J. Janz, and Chr. G. M. Dijkhuis; Section 2, Surface Tension Data, by G. J. Janz, G. R. Lakshminarayanan, R. P. T. Tomkins and J. Wong. NSRDS–NBS–28, 1969.

Several other reports are in the final stages of preparation.

Nuclear Data

In this field the Office of Standard Reference Data cooperates closely with the Atomic Energy Commission. Agreements have recently been reached for joint support of two important projects, the Particle Data Center and the *Tables of Isotopes* project, both located at the Lawrence Radiation Laboratory. The former center publishes regular summaries of fundamental particle properties and other data from high energy physics. The *Table of Isotopes* has gone through six editions, the last published in 1967; the group is being reactivated and a complete revision of the tables will be started shortly.

The following publication has appeared:

NBS Special Publication 322, Photonuclear Data Index Jan. 1965 through Jan. 1970, 1970.

Information Services

The four basic units of activity within the Information Services operation are: Data File, Compilation Publication Services, Inquiry Services, and Analysis and User Relations.

Data File—The mission of the Data File is to selectively acquire known world-wide data compilations and other reference documents and publications within the scope of the mission of the NSRDS and to organize the collection systematically. The Data File houses a collection of about 1300 reference data compilations, critical reviews, bibliographies, and other ancillary reference works.

An Annotated Listing of the documents in this collection is in press and will appear as an NBS Technical Note.

Compilation Publication Services—This activity serves as the editorial intermediary between the Office of Standard Reference Data and the associated data centers of the NSRDS and other individuals and groups producing data compilations on the one hand, and publishers on the other hand. The publishers are the Government Print-

ing Office, commercial publishers, and the Clearinghouse for Federal Scientific and Technical Information. One of the functions of the Compilation Publication Services is to produce the monthly newsletter, the NSRDS News.

NSRDS News—The program has produced, thus far, 32 publications in the NSRDS series of critically evaluated data compilations; 12 other compilations of data; 22 nondata publications from NSRDS related projects, as well as a number of publications published under the aegis of various of its associated data centers.

Inquiry Services—This unit provides replies to inquiries received by the Office of Standard Reference Data. At present, due to limited resources, information and data provided in response to queries are usually limited to that which are available within NSRDS and related publications. However, inquiries are frequently referred to competent sources in the NBS or elsewhere. At times, references are provided; if available, copies of publications or excerpts therefrom containing the requested information are provided. Inquiries have steadily been increasing from about 200 in 1966 to more than 1000 in 1969, with less than 30 in the latter instance receiving negative replies.

Analysis and User Relations—The mission of this unit is to provide the Office understanding of requirements, both present and future, of the NSRDS's actual and potential users. Among its efforts to determine user needs and means for developing feedback mechanisms have been several surveys. A survey is in process to learn what special librarians know about the NSRDS and how special librarians use NSRDS publications.

Data Systems Design

The Data Systems Design Group combines interest in computer programming, systems design and application, and data correlation. Earlier experience gained in design and application of a number of general-purpose computing programs is now providing guidelines for the preparation of general purpose computer programs for data storage and retrieval, for file manipulation, and for computer-assisted text preparation, editing, and printing. There is close collaboration with the NBS Electronic Printing Section in devising a variety of computer-based systems for more effective use of the Electronic Composing System at the Government Printing Office.

Work in this area can be grouped into three main activities:

1. Development of general-purpose computer programs required for the generation and updating of data files and the preparation of publications.
2. Design of computer-based data files and retrieval systems which provide accessibility to as wide a segment of the technical community as possible.

3. Consultation and advisory services to data centers adhering to NSRDS.

Computer-Assisted Text Preparation and Editing—Special effort is being given to the writing of general-purpose compatible computer programs to exploit the capabilities of the newest computer configurations. Programs and the subroutines they require are being written in ANSI Standard FORTRAN IV. The first release in this series is REFORM, a program that can be used to manipulate and edit fixed-field files containing as many as nine different card formats. It can select or abridge information from any of the cards and print that information or reformat new cards in any desired order or arrangement. Provision is made for introducing as many as 26 arbitrary strings of characters, thereby permitting the insertion of labels, headings, or comments into the file or the printer output. The program and its characteristics are described in NBS Tech. Note 444. The second release was EDPAC. This is a package of five programs that have been used extensively at NBS over the last four years. These are called JUSTIFY, SCRAMBLE, SEARCH, BLOCKSEARCH, and SUBSTITUTE. These programs and their characteristics are described in NBS Tech. Note 470. The REFORM and EDPAC programs have been put on magnetic tape and are being distributed by the Clearinghouse for Federal Scientific and Technical Information.

Automatic Typesetting and Composition of Data Tables—Experience has been gained in writing computer programs to convert existing data tapes for automatic typesetting of NSRDS publications. One goal has been to design the programs, insofar as possible, for general rather than specific applications. SETLST and KWIND are the first programs to be released in this series. These are ANSI FORTRAN IV programs that 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 phototypsetting devices. These programs and their characteristics are described in NBS Tech. Note 500.

CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION *

The Clearinghouse for Federal Scientific and Technical Information has continued its efforts to collect, announce, and disseminate unclassified U.S. Government-sponsored and other research and development reports, as well as translations of foreign technical literature, to the scientific and technical community, industry, commerce,

* On September 2, 1970, the Clearinghouse was transferred from NBS to the National Technical Information Service in the Office of the Assistant Secretary of Commerce for Science and Technology.

and the general public. The output of the Clearinghouse increased substantially during fiscal year 1970. Approximately 4 million copies of technical reports were distributed to more than 125,000 customers, a 25 percent increase over the previous year. The Clearinghouse journal, *U.S. Government Research and Development Reports*, (USGRDR) announced 42,000 titles, bringing the total Clearinghouse collection to more than 620,000 titles.

The Clearinghouse continued expansion of its coverage in acquiring technical information from Federal agencies and from private organizations. Arrangements were concluded with several federally supported information centers, resulting in documents being acquired from the National Air Pollution Control Administration, the National Center for Health Services Research and Development, the Public Land Law Review Commission, the Coastal Plains Regional Commission, the Wisconsin Bureau of State Planning, the Institute for Urban Information Systems, and from the Vancouver Forest Products Laboratory. In another area, translations from the China Mainland Press became available on a subscription basis beginning in January 1970. A principal source of information on academic research on the Chinese mainland, the subscription package includes selections from the daily press, selected articles from periodicals on a monthly basis, and a compilation of articles on particular topics issued irregularly.

During the year, special efforts were made to make the scientific and technical information held by the Clearinghouse available to larger audiences. Beginning with the January 10, 1970 issue, magnetic tapes of the USGRDR journal have been sold on a subscription basis. A magnetic tape (600-foot minireel) containing information equivalent to each USGRDR is issued on the journal publication date. Beginning in July 1969, the Clearinghouse initiated *Selective Dissemination of Microfiche* (SDM), a faster and more economical method for customers to obtain microfiche copies of the latest documents in several hundred categories. The SDM standing order concept eliminates the need to order each document individually, thus saving time and reducing the cost of the service.

Among the new products issued during the year was the third microfilm edition of the Cumulative Index to the Classification of Patents, containing the official listing of all patent numbers issued through December 31, 1968, covering more than 3,415,000 patents. The Index consists of 16 reels of 16 millimeter film—seven reels of original (primary) classifications and nine reels of cross-reference (secondary) classification. Also issued was a Patent Number Sequence Classification Record, a new microfilm publication during 1969, listing the original and cross-reference classifications together for each patent number, in patent number order. Another new item

was the Federal Stock Number Cross-Reference List, made available on magnetic tape. The list, on 38 reels, makes it unnecessary for manufacturers to thumb through thousands of pages to match company part numbers with stock numbers of the Federal Supply System.

The Clearinghouse has developed a 16 mm microfilm cumulative index of the U.S. Government Research and Development Reports from July 1964 to July 1969, covering more than 150,000 titles. This index is being used experimentally for handling general reference searches received by the Clearinghouse. Experiments are now underway for an interactive, integrated, real-time, on-line search system to link the Clearinghouse, the Commerce Field Offices, and the users of the Clearinghouse.

LIBRARY

The NBS Library contains holdings of approximately 120,000 titles and receives about 300 periodical titles regularly. During the past year it has enlarged its services to the staff by providing on-the-spot copying services and by improving circulation activities. Special support to the flammable fabrics research program has been provided by the preparation of bibliographies on selected topics.

The Library is now enlarging the scope of its holding to support the larger responsibilities assigned to the Bureau in areas such as systems analysis, fire research and safety, and fabric flammability research, as well as the larger range of activities which the Bureau conducts for other Federal agencies responsible for areas such as urban planning, housing, vehicle safety, transportation, and crime studies. At the same time the Library is conducting a vigorous weeding-out program of its holdings in order to become more responsive to these increasing staff needs.

It has embarked upon a long-range self-study for the enhancement of its capabilities and services for the future, with special attention to the benefits that automation and new media can provide for greater support of the staff of the Bureau, and for its own internal activities.

INTERNATIONAL RELATIONS

The NBS Office of International Relations offers services in connection with staff travel abroad, international organizations and conferences, foreign visitors to NBS (about 700 from 48 countries in the past year), guest workers and trainees from abroad working on NBS projects, and liaison with the State Department and the international affairs offices of other federal agencies.

A major responsibility is that of managing the Bureau's contract program utilizing foreign excess currencies of the U.S. in India, Israel, Pakistan, and just beginning in Yugoslavia. Under this program, the Bureau supports proposals that are contributory to the

main interests of NBS, are of high scientific or technological excellence, and are of mutual benefit to the two countries and institutions involved. During the year work was in progress on 25 contracts in India, 37 in Israel, 1 in Pakistan, and 2 in Yugoslavia, involving a total of $1,075,000.

NBS plays a part in bilateral agreements existing between the U.S. and France, Iran, Italy, Japan, and Rumania. Increased activity has taken place between the U.S. and France, involving exchanges of information and mutual visits in the areas of building technology and metrology. NBS continues its association with the National Industrial Research Institute of the Republic of Korea, and relations with other national institutions concerned with measurement science, such as the National Physical Laboratory of Great Britain and the National Standards Laboratory of Australia are long standing and vigorous.

PUBLICATIONS PROGRAM

The Bureau's technical work, no matter how good, is of little value unless made available to those who can use it. Formal publications are a traditional means of disseminating results of NBS work. Authors have the option of publishing in an NBS periodical or nonperiodical series (of which there are currently 10 series), or in the journals of professional societies or in other media. During the past year the Bureau staff produced 858 papers, totalling 15,518 printed pages. Complete citations to these papers begin on page 221.

To a steadily increasing extent NBS publications are being prepared by computer controlled photocomposition. A group skilled in the techniques of computer assisted printing works with the technical staff in preparing documents for processing by the Linotron at the Government Printing Office (GPO). The essence of the system is that both text and formatting instructions are put on tapes at NBS and used by GPO to control an automatic photocomposition process. This system is especially useful in the printing of lengthy computer generated tables, as the output tape from the computer can be used as the input for photocomposition. During the year a total of 2600 pages were prepared by photocomposition.

CONFERENCES

The face-to-face communication that takes place at scientific meetings has become an important part of the Bureau's interactions with the technical, academic, and industrial communities. Recognizing this, NBS cosponsored, managed, or hosted the following 32 major meetings during the year:

ASTM Committee on Consumer Standards
ACCG Conference on Crystal Growth
ISA Continuous Weighing Short Course
Government Microcircuit Application Conf. (GOMAC)
Precoordination—The Basic for Industrialized Building
ISO/TC 106 Dentistry
Dental Materials Research Symposium
American Cybernetics Society
Electronic Warefare Symposium
Marine Mapping, Charting, & Geodesy
Third Materials Research Symposium
Thermodynamic Properties of Fluids
Society for Personnel Administration
Image Transmissions
Senior Aided Combat Systems
ANSI Committee S–4
Masonry Structures Conference
Force Measurements (PMS)
American Society for Information Sciences
Solid State Sciences Panel
FIPS Task Group 5
ASTM Committee A–1
ANSI Committee X–3
American Physical Society
ANSI X–3.2.7 Meeting
IEEE Transducer Conference
Radiation Quantities
Economic Stabilization
Silicon Device Processing
National Conference of Standards Laboratories
Precision Measurement Association
Association of Computing Machinery

APPENDIXES

ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS [1]

The Bureau is headed by a Director who is appointed by the President with the advice and consent of the Senate. The Director is assisted in the overall management of the Bureau by a Deputy Director. An Associate Director for Administration is responsible for the planning and operation of facilities and of administrative management services in support of the Bureau's technical programs. An Associate Director for Information Programs is responsible for the dissemination and accessibility of scientific and technological information.

Technical program activities are conducted in three Institutes and two Centers. Each is headed by a Director who is responsible for the development and direction of research programs and central national services essential to the fulfillment of a broad segment of the Bureau's mission. These major organizational units are:

(1) The Institute for Basic Standards, which includes the Office of Measurement Services and 10 technical divisions (5 in Boulder, Colorado) each serving a classical subject matter area of science and engineering; also in IBS are 3 administrative divisions serving the technical divisions located at Boulder;

(2) The Institute for Materials Research, which consists of 6 divisions, organized primarily by technical field;

(3) The Institute for Applied Technology, which includes 10 divisions oriented to high technology industries;

(4) The Center for Radiation Research, which includes 4 divisions concerned with the theory and application of radiation; and

(5) The Center for Computer Sciences and Technology, which includes 5 divisions concerned with the selection, acquisition, and utilization of automatic data processing equipment.

[1] As of June 30, 1970.

DIRECTOR

Lewis M. Branscomb

DEPUTY DIRECTOR

L. M. Kushner

OFFICE OF THE DIRECTOR

Assistants to the Director
G. E. Auman
C. N. Coates
R. V. Stapleton

Legal Advisor
A. J. Farrar

Office of Academic Liaison
S. Silverman

Staff Units Reporting to the Deputy Director

Office of Industrial Services ---------- G. S. Gordon
Office of Engineering Standards Liaison ---------- A. A. Bates

OFFICE OF ASSOCIATE DIRECTOR FOR ADMINISTRATION

R. S. Walleigh

Deputy Associate Director
P. H. Schrader

Patent Advisor
D. Robbins

Accounting Division ---------- J. P. Menzer
Administrative Services Division ---------- G. W. Knox
Budget Division ---------- J. E. Skillington
Management and Organization Division ---------- J. T. Hall
Personnel Division ---------- G. R. Porter
Plant Division ---------- H. Graham
Supply Division ---------- N. H. Taylor

OFFICE OF ASSOCIATE DIRECTOR FOR INFORMATION PROGRAMS

E. L. Brady

Assistant for Program Coordination and Evaluation
P. H. Kratz

Office of Standard Reference Data ---------- D. R. Lide, Jr.

Atomic and Molecular Data	Data Systems Design
Chemical Kinetics	Mechanical Properties
Colloid and Surface Chemistry	Nuclear Data
Information Services	Solid State Properties

Thermodynamics and Transport Data

Clearinghouse for Federal Scientific and Technical Information ---------- H. E. Sauter

Document Distribution and Reproduction	Joint Publications Research
Automated Systems and Services	Document Processing

Administrative Operations

Office of Technical Information and Publications ---- W. R. Tilley

Special Activities	Photographic Services
Editorial	Graphic Arts
Publications	Computer Assisted Printing

Library Division ---------- E. L. Tate

Resources Development	Reader Services

Library Auxiliaries

Office of Public Information ---------- A. V. Gentilini
Office of International Relations ---------- H. S. Peiser

INSTITUTE FOR BASIC STANDARDS

Director
E. Ambler

Assistant Director
R. J. Corruccini

Deputy Director, Institute for Basic Standards/Boulder [1]
B. W. Birmingham

Senior Research Fellow
C. Eisenhart

Office of Measurement Services
J. M. Cameron

Applied Mathematics ---------- E. W. Cannon
- Mathematical Analysis
- Statistical Engineering
- Operations Research

Electricity Division ---------- C. H. Page
- Electrical Reference Standards
- High Voltage
- Electrochemistry
- Absolute Electrical Measurements
- Electrical Instruments

Mechanics Division ---------- L. K. Irwin
- Sound
- Hydraulics
- Vibration Measurements
- Aerodynamics
- Humidity Measurements
- Engineering Mechanics
- Rheology
- Fluid Meters

Heat Division ---------- R. P. Hudson
- Heat Measurements
- Statistical Physics
- Cryogenics Physics
- Temperature
- Equation of State
- Radiation Thermometry
- Pressure Measurements

Optical Physics Division ---------- K. G. Kessler
- Spectroscopy
- Plasma Spectroscopy
- Infrared Spectroscopy
- Vacuum Measurements
- Far Ultraviolet Physics
- Mass, Length, and Volume
- Molecular Spectroscopy
- Photometry
- Electron Physics
- Engineering Metrology
- Quantum Metrology
- Image Optics and Photography
- Spectrophotometry

Quantum Electronics Division [1] ---------- H. S. Boyne
- Laser Measurement Techniques
- Quantum Electronics
- Plasma Physics

Electromagnetics Division [1] ---------- R. C. Sangster
- Senior Research Scientists
- Power-Current-Voltage Standards
- Pulse and Time Domain
- Noise and Interference
- Automation
- Fields and Antennas
- Circuit Standards
- Systems and Instrumentation
- Electromagnetic Metrology Information Center

Time and Frequency Division [1] ---------- J. A. Barnes
- Frequency-Time Dissemination Research
- Frequency-Time Broadcast Services
- Atomic Frequency-Time Standards

Laboratory Astrophysics Division [1] ---------- S. J. Smith, Acting

[1] Located at Boulder, Colorado.

Cryogenics Division [1] ---------- D. B. Chelton
- Cryogenic Technical Services
- Cryogenic Data Center
- Cryogenic Properties of Solids
- Cryogenic Fluid Transport Processes
- Properties of Croygenic Fluids
- Cryogenic Systems
- Cryogenic Metrology
- Cryoelectronics

Administrative Services Division [1] ---------- B. F. Betts
- Supply
- Office Services
- Guard Services

Instrument Shops Division [1] ---------- W. A. Wilson
- Instrument Shops 1, 2, and 3
- Glass Shop

Plant Division [1] ---------- E. A. Yuzwiak
- Construction-Maintenance
- Special Services
- Custodial Services

INSTITUTE FOR MATERIALS RESEARCH

Director
J. D. Hoffman

Assistant Director
E. Horowitz

Office of Standard Reference Materials ---------- J. P. Cali, Acting

Analytical Chemistry Division ---------- W. W. Meinke
- Radiochemical Analysis
- Spectrochemical Analysis
- Electrochemical Analysis
- Analytical Coordination Chemistry
- Microchemical Analysis
- Analytical Mass Spectrometry
- Organic Chemistry
- Activation Analysis
- Separation and Purification

Polymers Division ---------- R. K. Eby
- Polymer Dielectrics
- Polymer Chemistry
- Polymer Crystal Physics
- Dental Research
- Thermophysical Properties
- Polymer Interfaces
- Molecular Properties and Characterization

Metallurgy Divison ---------- E. Passaglia
- Engineering Metallurgy
- Alloy Physics
- Lattice Defects and Microstructures
- Corrosion
- Metal Physics
- Electrolysis and Metal Deposition
- Crystallization of Metals

Inorganic Materials Division ---------- J. B. Wachtman, Jr.
- Inorganic Chemistry
- Inorganic Glass
- Solid State Chemistry
- Physical Properties
- Crystallography
- Solid State Physics

Physical Chemistry Division ---------- J. R. McNesby
- Thermochemistry
- Surface Chemistry
- Photo Chemistry
- Radiation Chemistry
- Elementary Processes

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[1] Located at Boulder, Colorado.

INSTITUTE FOR APPLIED TECHNOLOGY

Director
H. E. Sorrows, Acting

Deputy Director
M. W. Jensen

Fire Research and Safety
Flammable Fabrics
Colorimetry

Office of Engineering Standards Services ---------- D. R. Mackay
Product Standards Section
Information Section
Mandatory Standards Section

Office of Weights and Measures ---------- T. M. Stabler, Acting
Office of Invention and Innovation ---------- D. V. DeSimone
Innovation Studies Program
Invention Programs
Metric Study

Office of Vehicle Systems Research ---------- P. J. Brown
Tire Systems
Occupant Restraint Systems
Braking Systems

Product Evaluation Division ---------- M. R. Meyerson, Acting
Plastics and Textiles
Viscoelastic Materials
Fibrous Systems
Paper Evaluation

Building Research Division ---------- J. R. Wright
Structures
Materials Durability and Analysis
Fire Research
State Codes and Standards
Scientific and Professional Liaison
Building Systems
Sensory Environment Branch

Environmental Engineering
Psycho-physics
Building Transport Systems

Electronic Technology Division ---------- M. G. Domsitz
Semiconductor Characterization
Instrumentation Applications
Electron Devices
Semiconductor Processing

Technical Analysis Division ---------- W. E. Cushen
Management Information and Economic Studies
Post Office Studies
Simulation and Transportation Studies
Mathematical Modeling
O. R. in Behavioral Sciences
Systems Engineering
Urban Systems and Environmental Studies

Instrument Shops Division ---------- W. L. Drissel, Acting
Instrument Shops 1-5
Optical Shop
Glassblowing
Tool Crib
Welding and Sheet Metal
Electroplating Shop

Measurement Engineering Division ---------- G. F. Montgomery
Electronic Instrumentation
Electronic Optical Development
Microwave and Mechanical Instrumentation

CENTER FOR RADIATION RESEARCH

Director
C. O. Muehlhause

Deputy Director
R. S. Caswell

Radiation Theory
Health Physics

Reactor Radiation Division ---------- R. S. Carter
Reactor Operations
Engineering Services
Neutron Solid-State Physics
Radiation Effects

Linac Radiation Division ---------- J. E. Leiss
Linac Operations
Radiation Physics Instrumentation
Photonuclear Physics
Electronuclear Physics

Nuclear Radiation Division ---------- H. H. Landon
Neutron Physics
Radioactivity
Nuclear Spectroscopy

Applied Radiation Division ---------- J. W. Motz
X-Ray Physics
Dosimetry

CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY

Director
J. P. Nigro, Acting

Pattern Recognition and Description

Office of Information Processing Standards ---------- J. O. Harrison, Jr.
Planning and Coordination
Hardware Standards
Software Standards
Applications and Data Standards
ADP Management Standards

Office of Computer Information ---------- M. R. Fox
Computer Services Division ---------- W. B. Ramsay
Business Applications
Scientific Applications
Computer Operations
Systems Programming and Training

Systems Development Division ---------- C. T. Meadow
Programming Support Systems
Information Science
Management Systems
Communications and Control Systems

Information Processing Technology Division ---------- J. P. Nigro
Measurement Automation
Computer Systems
Performance Measurements

FIELD ESTABLISHMENTS

Institute for Basic Standards

Metrology Division Field Station:
Visual Landing Aids Field Laboratory — Arcata, California
Time and Frequency Division Field Station:
Standard Frequency Station WWV–WWVL–WWB — Fort Collins, Colorado
Standard Frequency Station WWVH — Maui, Hawaii
Laboratory Astrophysics Division Field Station:
Poor Man's Relief Mine, Four-Mile Canyon — Boulder, Colorado

Institute for Applied Technology

Office of Weights and Measures Field Stations:
Master Railway Track Depot — Clearing, Illinois

ORGANIZATIONAL CHANGES

For approximately one year the Metrology Division and the Atomic and Molecular Physics Division of the Institute for Basic Standards participated in a management experiment to improve their organization and programmatic response. The objective of the experiment was to promote close cooperation between the two divisions leading toward improved applications of theoretical and experimental physics to problems in advanced metrology such as applications of stabilized lasers to dimensional metrology and applications of radiometric techniques to photometry. The two divisions operated under joint management after the experiment began. One of the first acts of the joint management was to form Advanced Project Groups to strengthen research efforts of the above type. The new approach proved valuable in stimulating interchanges of ideas and progress in dealing with measurement problems. In order to formalize improvements in technical supervision and coordination of effort, the two divisions have been combined into a new single division entitled the Optical Physics Division.

A reorganization of the Electricity Division has incorporated several interrelated management improvements. Updating of work in absolute electrical measurements and electrical instruments has been accomplished by strengthening work on the Josephson effect, and a streamlining of the High Voltage programs has been achieved by relocating staff at Gaithersburg, while keeping the old facilities at Van Ness Street in a standby state. A plan to extend partially developed new high voltage calibration techniques should permit an improvement in service to the electrical power industry.

On September 2, 1969, Dr. Branscomb, as newly appointed Director of NBS, established an Executive Board to assist him in managing Bureau affairs. The Board membership consisted of the Institute, Center, and Associate Directors. The Executive Board meets with the Director to make decisions on such matters as Bureau program planning, budget allocations, and policies. An Executive Council was also established to formulate policies and develop plans for Bureau programs. The membership of the Executive Council includes that of the Executive Board except for the Director, NBS, and the Deputy Director, IBS/Boulder. During the fiscal year 1970 Dr. Ambler served as chairman of the executive council.

SUMMARY OF NBS STAFF AS OF JUNE 27, 1970

	Washington	*Boulder*	*Total*
Full-Time Permanent Staff	2816	550	3366
Other Staff [1]	599	88	687
Total Paid Staff	3415	638	4053
Research Associates and Guest Workers	118	13	131
Total NBS Staff	3533	651	4184
Professional Staff with Academic Degrees [2]			
Physicists	393	108	501
Chemists	254	12	266
Engineers	192	80	272
Mathematicians	52	4	56
Other	167	9	176
Total	1058	213	1271

[1] Summer, Post Doctoral Research Fellows, Summer Aids, Part-Time, Intermittent and Temporary.

[2] Full-Time Permanent Professional Staff.

FINANCIAL DATA FOR FISCAL YEAR 1970

Program and source of financing

	Obligations incurred in thousands of dollars (rounded)
Supported by NBS Appropriations	
Operating programs:	
Research and technical services	$39,804
Special foreign currency program	1,020
Construction and facilities programs:	
Plant and facilities	1,127
Construction of facilities	495
Total obligations, NBS appropriations	42,446
Supported by other funds: [1]	
From other Federal agencies	27,530
From other sources	5,915
Total obligations, other funds	33,445
Total program	75,891

[1] Work supported by other funds consists of research and development programs for other Government agencies; consultative, advisory, and technical services, the performance of various tests and calibrations, and the manufacture and sale of standard reference materials for other Government agencies and the public; and the sale of technical documents to the public.

RESEARCH ASSOCIATES AND THEIR SPONSORS DURING FISCAL YEAR 1970

American Dental Association

Argentar, Mr. Harold
Bowen, Mrs. Joy C.
Bowen, Dr. Rafael L.
Brown, Dr. Walter E.
Brunetti, Dr. Anthony P.
Carolson, Mr. Elmer T.
Caul, Mr. Harold J.
Chandler, Mr. Harry H.
Chow, Mr. Laurence
Gregory, Mr. Thomas M., Jr.
Kingsbury, Mrs. Pamela R.

Mabie, Mr. Curtis P., Jr.
Manuszewski, Mr. Richard C.
McDowell, Mr. Hershel
Moreno, Dr. Edgard C.
Norwood, Miss L. Dianne
Paffenbarger, Dr. George C.
Patel, Mr. Praful
Rupp, Dr. Nelson Woodward
Wallace, Mrs. Betty M.
Waterstrat, Mr. Richard M.
Young, Mr. Larry C.

American Petroleum Institute

Hine, Mr. Donald J.

*American Society for Testing and Materials**

Bell, Mrs. Jacqueline Y.
de Groot, Mr. Johan H.
Evans, Mrs. Eloise H.
Grimes, Mr. John W., Jr.
McMurdie, Mr. Howard F.
Morris, Mrs. Marlene C.

American Society for Testing and Materials (Concrete and Concrete Reference Laboratory)

Anderson, Mr. Harry G., Jr.,
Atkinson, Mr. George O., Jr.
Dise, Mr. John R.
Johnson, Mr. Marlin C.
Katz, Mrs. Anne K.
Liskey, Mr. John F.
McCarthy, Mr. Dennis D.
Spring, Mr. Curtis B.
Sturm, Mr. William F.
Wallace, Mr. Dennis R.

American Viscose Division (FMC Corporation)

Oneal, Mr. Glen, Jr.

Bell Aerosystems

Rogers, Ernest E.

Children's Hospital

Borasky, Dr. Rubin

Cornell University (NBS Boulder, Colorado)

Stouffer, Dr. James Ray

Corn Refiners Association, Inc.

Thomas, Mr. James H.
Vomhof, Dr. Daniel W.

Dow Chemical Company

Hamilton, Mr. Robert M.

Electrical Testing Laboratories, Inc.

Mohan, Mr. Kshitij

International Business Machines Corporation

Cleveland, Mr. Norman G.
Phillips, Dr. Sidney L.

Kennecott Copper Corporation

Harvey, Mr. W. William

*Sponsorship assumed as of December 5, 1969 by Joint Committee on Powder Diffraction Standards (JCPDS), a non-profit organization.

Manufacturing Chemists Association
Clark, Dr. Joseph E.
Gill, Mr. Paul C.
Herndon, Mr. John L., III
Slater, Mr. James Alan

Owens-Corning Fiberglas Corporation
Fitch, Mr. William E.

Porcelain Enamel Institute
Burdick, Mr. Milton D.
Baker, Mrs. Margaret A.
Gugeler, Mr. Lauren A.

Underwriters Laboratories, Inc.
Castino, Mr. Guy T.

U.S. Naval Ship Research & Development Center
Hammond, Mr. Barry L.

GUEST WORKERS

The Bureau makes its facilities available to scientists, including retired NBS employees, who are working on a problem that is of interest to NBS, and who have need for NBS equipment and competences. These "guest worker" arrangements are quite flexible, ranging from an occasional interaction to a full-time long-term basis. Listed below are the identifiable guest workers who worked with technical programs during the year.

Institute for Basic Standards

Name	*Affiliation*
Balcom, M. M.	NBS
Benedict, W. S.	Johns Hopkins University
Bohlander, R. A.	University of Colorado
Brombacher, W. G.	NBS
Chang, S.	Oak Ridge National Laboratory
Clatworthy, W. H.	American University
Dellepiane, G.	University of Genoa
Finnegan, T. F.	University of Pennsylvania
Fystrom, D. O.	University of Colorado
Girard, G.	International Bureau of Weights and Measures, France
Graham, B. J.	U.S. Naval Academy
Hammar, C. L.	Sweden
Harris, M. G.	Harry Diamond Laboratories
Haupt, G. W.	NBS
*Johns, J. W. C.	National Research Council, Canada
McDonald, J. K.	Fort Detrick
Mockler, R. C.	University of Colorado
Mohler, F. L.	NBS
Otto, E. M.	NBS
Pardoe, G. W. F.	University of Colorado
*Schmidt, H. H.	University of California, Riverside
Schubauer, G. B.	NBS
Simpson, P. D.	Howard University
Stimson, H. F.	NBS
Stouffer, J. R.	Cornell University
Stricker, S.	Technion Israel Institute of Technology
Youden, W. J.	NBS

* Selected as IBS Visiting Scientist for 1969.

Institute for Materials Research

Name	*Affiliation*
Angeles, R. M.	American University
Bald, J.	Harry Diamond Laboratories
Barton, J. A. Jr.	U.S. Air Force
Belkas, E.	Nuclear Research Center "Democritos"—Athens, Greece
Benoit, C.	National Bureau of Metrology—France
Benzinger, T.	Naval Medical Research Institute
Brooks, C.	University of Montreal
Coleman, L. B.	Johns Hopkins University
Donnay, J. D. H.	Johns Hopkins University
Druck, S. J.	Catholic University
Froix, M.	Howard University
Goldich, S. S.	Northern Illinois University
Hayman, R.	Winston Churchill High School
Henoc, J. R.	Delegation General A'la Rechereche Scientifique Et Technique, Paris, France
Jones, P. E.	Washington Technical Institute
Keyes, P. H.	University of Maryland
King, R. C.	York College
Kuroha, T.	Japan—The Furukawa Electric Co., Ltd.
Lesclaux, R. P.	University of Bordeaux—France
Malmberg, M.	University of Maryland
Marr, G. A.	Washington Technical Institute
Mattamal, G. J.	American University
McCurdy, W.	University of Delaware
Newton, M. J.	Washington Technology Institute
Olin, J. S.	Smithsonian Institution
Osinskiy, V. I.	Institute of Physics, Romania
Peterson, N. C.	Polytechnic Institute of Brooklyn
Petrescu-Prahova, J.	Institute of Physics, Romania
Price, E.	Howard University
Roestamsjah	American University
Rotariu, G.	Atomic Energy Commission
Sandoval, H. R. L.	University of Chile
Scott, A. H.	NBS
Shoup, R.	National Institute of Health
Silver, G. D.	Winston Churchill High School
Smith, C. E.	Howard University
Stein, A.	Temple University
Stern, T. W.	U.S. Geological Survey
Stolovy, A.	Naval Research Laboratory
Wood, D.	Winston Churchill High School

Institute for Applied Technology

Name	*Affiliation*
Cheslow, M. D.	
Curtis, T. P.	National Security Agency
Fairbairn, D. G.	South Africa
Gbadamosi, L. A.	Washington Technical Institute
Goldman, D.	MITRE Corporation
Harnett, J. P.	Rixon
Kohayakawa, Y.	Japan, Canon Optical Company
Myklebost, S.	Norway
Scales, J. L.	Harry Diamond Laboratories

Center for Radiation Research

Name	*Affiliation*
Alberi, J. L.	Harvard University
Barber, W. C.	Massachusetts Institute of Technology
Bergstrom, J. C.	Catholic University
Bertozzi, W.	Massachusetts Institute of Technology
Byrden, A. J.	Bureau National De Metrologie, Paris
Chertok, T. B.	American University
Cooper, T. J.	Massachusetts Institute of Technology
Crannell, C. J.	Catholic University
Davis, C. M.	Naval Ordnance Laboratory
Donaldson, Dr. G. W.	Armed Forces Radiobiology Research Institute
Drechsel, D.	University of Virginia
Dunning, J. R.	Howard University
Ensslin, N.	Massachusetts Institute of Technology
Faist, M. B.	Armed Forces Radiobiology Research Institute
Ferry, P.	Armed Forces Radiobiology Research Institute
Glynn, J. C.	Atomic Energy Commission
Grammer, G.	Virginia Polytechnic Institute
Hallowell, P. L.	Massachusetts Institute of Technology
Herrero, F. A.	Armed Forces Radiobiology Research Institute
Hill, F. X.	Washington Technical Institute
Hussman, E. K.	NATO Fellowship, Federal Republic of Germany
Jarzynski, J.	Naval Ordnance Laboratory
Johnson, W. T.	American University
Kline, F. J.	Catholic University
Kowalski, S.	Massachusetts Institute of Technology
Maruyama, X. K.	Massachusetts Institute of Technology
McGarry, E. D.	Harry Diamond Laboratories
Meaburn, G. M. A. C.	Defense Atomic Support Agency
Mihailovic, M.	Yugoslavia
Miller, H. C.	National Aeronautics and Space Administration
Mills, M. T.	Massachusetts Institute of Technology
More, M. L.	Harry Diamond Laboratories
Morris, W. J.	Naval Facilities Engineering Command
Murphy, J. J.	University of Illinois
Nagle, P. C.	Center for Naval Analyses
Neuhausen, R.	West Germany
O'Brien, J. T.	Catholic University
Parke, W. C.	George Washington University
Romberg, E. F.	University of Maryland
Rosenstein, M.	Bureau of Radiological Health
Sargent, C. P.	Massachusetts Institute of Technology
Schneider, C. S.	U.S. Naval Academy
Shmuklarsky, M. J.	U.S. Naval Engineering Command
Smirnow, J. R.	American University
Stallard, J. M.	Naval Ordnance Laboratory
Trower, W. P.	Virginia Polytechnic Institute
Turchinetz, W. E.	Massachusetts Institute of Technology
Wall, N. S.	
Weber, R. B.	American University
Williams, R. H.	Naval Ordnance Laboratory
Williamson, C. F.	Massachusetts Institute of Technology

Center for Computer Sciences and Technology

Name	*Affiliation*
Fineran, C.	
Kawai, H.	Japan
Penzak, W.	FBI
Podgorski, J. P.	Patent Office

Clearinghouse

Name	*Affiliation*
Hirschy, R. E.	AIRES Corporation

Office of Standard Reference Data

Name	*Affiliation*
Fuller, G.	Oak Ridge National Laboratory

STATUTORY VISITING COMMITTEE

The Statutory Visiting Committee was established by Act of Congress to advise the Secretary of Commerce and the Director of NBS. This committee is appointed by the Secretary of Commerce. It meets at the call of its chairman. Dates indicate expiration of appointment.

Dr. Robert L. Sproull, President, University of Rochester, Chairman (1971)
Prof. Norman F. Ramsey, Dept. of Physics. Harvard University (1970)
Dr. E. R. Piore, Vice President and Chief Scientist, International Business Machines Corporation (1972)
Dr. Elmer V. Engstrom, Chairman, Executive Committee, Radio Corporation of America (1973)
Dr. J. E. Goldman, Senior Vice President, Research and Development, Xerox Corporation (1974)

EVALUATION PANELS

In 1953 the Secretary of Commerce established an ad hoc committee to evaluate the functions and operations of the National Bureau of Standards. In their report, one of the recommendations of the Committee was that NBS establish several advisory committees to provide a continuing contact between the scientists and engineers of the academic and industrial communities and the Bureau staff. The ad hoc committee believed that such committees could render many valuable services, particularly in coupling Bureau staff more closely and effectively to the technical and scientific people of industry and the universities.

The Bureau, in implementing this recommendation, established panels of experts as advisers to each of its technical divisions. Replacing this arrangement in 1959, at the request of the Bureau, the National Academy of Sciences was asked to provide the continuing evaluation of the functions and operations of the Bureau. In discharging this responsibility, panel members are selected and appointed by the National Academy of Sciences—National Academy of Engineering—National Research Council.

Panel members are drawn from among the leaders in the fields of research and administration in industry and universities. Administratively, they are attached to the National Research Council, Division of Physical Sciences.

It is the responsibility of the panel members to review and evaluate the functions and operations of NBS. They consider importance and relative priority of projects, quality of staff, equipment needs, finance, and the relation of the program to the mission of the Bureau.

There are panels for each of the five major organizational units: the Institutes for Basic Standards, Materials Research, and Applied Technology, and the Centers for Radiation Research and for Computer Sciences and Technology.

These panels examine broad policy and program areas of the Institutes and Centers, and review and coordinate the work of a number of "Division" panels selected to evaluate specific program areas in each of the Institutes and Centers. The combined evaluations and recommendations of these panels, after appropriate review, are submitted as an annual report by the Academy to the Director of NBS.

The chairmen of the Institute and Center panels also constitute an Executive Committee for the Academy under the chairmanship of Dr. W. O. Baker. This committee considers problems, issues, and policies which are common to more

than one area of Bureau activity, and serves to single out and order the more important findings of the panels. It meets with members of the Secretary's Statutory Visiting Committee at their annual meeting, providing members of the Visiting Committee with an opportunity to discuss the work of the Bureau with a group of senior scientists and engineers who in total have spent many days in reviewing the functions and operations of the Bureau. This meeting also provides a mechanism whereby assessments of Bureau capabilities relative to national needs can be brought to the attention of the Secretary of Commerce at his annual meeting with the Visiting Committee.

Institute for Basic Standards

Evaluation Panel for Institute for Basic Standards
Dr. John A. Hornbeck, Sandia Laboratories, Chairman
Dr. William G. Amey, Leeds & Northrup Company
Professor Marvin L. Minsky, Massachusetts Institute of Technology
Mr. S. C. Richardson, Scotia, New York
Professor Cyril M. Harris, Columbia University
Dr. E. F. Hammel, University of California
Professor W. E. Spicer, Stanford University
Dr. Erwin G. Loewen, Bausch & Lomb Incorporated
Dr. George J. Zissis, University of Michigan
Dr. R. G. Meyerand, Jr., United Aircraft Corporation
Mr. Theodore S. Saad, Sage Laboratories, Inc.
Mr. Nathan Cohn, Leeds & Northrup Company
Dr. Wayland C. Griffith, Lockheed Palo Alto Research Laboratory
Professor Donald N. Langenberg, University of Pennsylvania

Evaluation Panel for Applied Mathematics Division
Professor Marvin L. Minsky, Massachusetts Institute of Technology, Chairman
Dr. C. A. Bennett, Battelle-Northwest
Dr. Richard W. Hamming, Bell Telephone Laboratories
Professor H. O. Hartley, Texas A&M University
Mr. Murray S. Klamkin, Ford Motor Company
Professor M. H. Martin, University of Maryland
Professor John Riordan, The Rockefeller University
Professor John Todd, California Institute of Technology

Evaluation Panel for Electricity Division
Mr. S. C. Richardson, Scotia, New York, Chairman
Mr. R. W. Flugum, Ohio Brass Company
Professor Raymond M. Fuoss, Yale University
Mr. William J. Johnson, Philadelphia Electric Company
Professor W. H. Parker, University of California, Irvine
Dr. Edward W. Schwarz, Sangamo Electric Company
Mr. DeWayne B. Sharp, IBM Corporation
Mr. Douglas C. Strain, Electro Scientific Industries, Inc.

Evaluation Panel for Mechanics Division
Professor Cyril M. Harris, Columbia University, Chairman
Professor Lynn S. Beedle, Lehigh University
Mr. James T. Bergen, Armstrong Cork Company
Professor James W. Daily, University of Michigan
Professor Rodger B. Dowdell, University of Rhode Island
Professor Daniel C. Drucker, University of Illinois
Dr. Wayland C. Griffith, Lockheed Palo Alto Research Laboratory
Dr. John C. Snowdon, Ordnance Research Laboratory

Evaluation Panel for Heat Division
Dr. E. F. Hammel, University of California, Chairman
Professor G. B. Benedek, Massachusetts Institute of Technology
Dr. Francis P. Bundy, General Electric Company
Dr. H. Tracy Hall, Brigham Young University
Professor John E. Kilpatrick, Rice University
Dr. David L. McElroy, Oak Ridge National Laboratory
Professor James E. Mercereau, California Institute of Technology
Mr. Fred E. Nicodemus, Naval Weapons Center

Evaluation Panel for Optical Physics Division (Atomic & Molecular Physics)
Professor W. E. Spicer, Stanford University, Chairman
B. B. Dayton, The Bendix Corporation
Dr. James E. Drummond, Boeing Scientific Research Laboratories
Professor Ronald Geballe, University of Washington
Professor Vernon W. Hughes, Yale University
Dr. John Otvos, Shell Development Company
Dr. Abraham Savitzky, Perkin-Elmer Corporation

Evaluation Panel for Optical Physics Division (Dimensional Metrology)
Dr. Erwin G. Loewen, Bausch & Lomb Incorporated, Chairman
Dr. Arnold L. Bloom, SPECTRA-PHYSICS, INC.
Mr. James Bryan, Lawrence Radiation Laboratory
Mr. Louis Polk, Dayton, Ohio
Dr. F. Dow Smith, Itek Corporation

Evaluation Panel for Optical Physics Division (Photometry & Radiometry)
Dr. George J. Zissis, University of Michigan, Chairman
Professor Charles A. Barth, University of Colorado
Mr. B. R. Buus, General Electric Company
Dr. F. Dow Smith, Itek Corporation
Professor William L. Wolfe, University of Arizona

Evaluation Panel for Quantum Electronics Division
Dr. R. G. Meyerand, Jr., United Aircraft Corporation, Chairman
Dr. Arnold L. Bloom, SPECTRA-PHYSICS, INC.
Professor A. Javan, Massachusetts Institute of Technology
Dr. Joshua Menkes, University of Colorado
Dr. Robert W. Terhune, Ford Motor Company
Professor Charles B. Wharton, Cornell University

Evaluation Panel for Electromagnetics Division
Mr. Theodore S. Saad, Sage Laboratories, Inc., Chairman
Mr. Ray Y. Bailey, Newark Air Force Station
Mr. Stuart L. Bailey, Atlantic Research Corporation
Professor Herbert J. Carlin, Cornell University
Professor Paul D. Coleman, University of Illinois
Dr. Richard W. Damon, Sperry Rand Research Center
Mr. Phillip H. Entz, The Boeing Company
Mr. Archie Gold, U.S. Army Advanced Ballistic Missile Defense Agency
Mr. David M. Goodman, New York University

Evaluation Panel for Time and Frequency Division
Mr. Nathan Cohn, Leeds and Northrup Company, Chairman
Dr. L. S. Cutler, Hewlett-Packard Company
Dr. John M. Holt, Collins Radio Company
Mr. Chesley Looney, Jr., National Aeronautics and Space Admin.
Dr. A. O. McCoubrey, Varian Associates
Dr. Allen M. Peterson, Stanford University
Dr. F. O. Vonbun, National Aeronautics and Space Admin.
Dr. Gernot M. R. Winkler, U. S. Naval Observatory

Evaluation Panel for Laboratory Astrophysics Division
Dr. Wayland C. Griffith, Lockheed Palo Alto Research Laboratory, Chairman
Professor Ronald Geballe, University of Washington
Professor Dudley Herschbach, Harvard University
Dr. John T. Jefferies, University of Hawaii
Professor Robert P. Kraft, University of California

Evaluation Panel for Cryogenics Division
Professor Donald N. Langenberg, University of Pennsylvania, Chairman
Dr. L. Warren Brandt, U. S. Bureau of Mines
Mr. Gordon R. Deppe, Aerojet Liquid Rocket Co.
Professor Rodger B. Dowdell, University of Rhode Island
Dr. Frederick J. Edeskuty, Los Alamos Scientific Laboratory
Dr. John L. Mason, AiResearch Manufacturing Company

Institute for Materials Research

Evaluation Panel for Institute for Materials Research

Dr. William P. Slichter, Bell Telephone Laboratories, Inc., Chairman
Professor John Bardeen, University of Illinois
Dr. Arthur Bueche, General Electric Company
Dr. N. B. Hannay, Bell Telephone Laboratories
Dr. Raymond F. Boyer, The Dow Chemical Company
Dr. Richard A. Oriani, United States Steel Corporation
Dr. George J. Bair, Corning Glass Works
Dr. Sidney W. Benson, Stanford Research Institute

Evaluation Panel for Analytical Chemistry Division

Dr. N. B. Hannay, Bell Telephone Laboratories, Chairman
Dr. Jules Blake, Mallinckrodt Chemical Works
Dr. George N. Bowers, Jr., Hartford Hospital
Dr. T. S. Burkhalter, Texas Instruments Inc.
Dr. Vincent P. Guinn, University of California, Irvine
Professor Herbert A. Laitinen, University of Illinois
Dr. L. M. Melnick, United States Steel Corporation
Professor L. B. Rogers, Purdue University
Professor Sidney Siggia, University of Massachusetts

Evaluation Panel for Polymers Division

Dr. Raymond F. Boyer, The Dow Chemical Company, Chairman
Dr. Frederick M. Fowkes, Lehigh University
Dr. Fred Leonard, Walter Reed Army Medical Center
Professor Carl S. Marvel, University of Arizona
Dr. Anton Peterlin, Research Triangle Institute
Dr. Ralph W. Phillips, Indiana University School of Dentistry
Professor William O. Statton, University of Utah
Professor Walter H. Stockmayer, Dartmouth College
Professor Bruno H. Zimm, University of California

Evaluation Panel for Metallurgy Division

Dr. Richard A. Oriani, United States Steel Corporation, Chairman
Dr. Douglas S. Billington, Oak Ridge National Laboratory
Dr. Harris M. Burte, Air Force Materials Laboratory (MAM)
Dr. Herbert I. Fusfeld, Kennecott Copper Corporation
Professor John P. Hirth, Ohio State University
Dr. Elliot S. Nachtman, La Salle Steel Company
Professor David Turnbull, Harvard University
Dr. J. H. Wernick, Bell Telephone Laboratories, Inc.

Evaluation Panel for Inorganic Materials Division

Dr. George J. Bair, Corning Glass Works, Chairman
Dr. Neil Bartlett, University of California
Dr. Paul W. Gilles, University of Kansas
Dr. J. S. Kasper, The General Electric Company
Dr. Robert W. Keyes, IBM Research Center
Dr. R. A. Laudise, Bell Telephone Laboratories, Inc.
Dr. William R. Prindle, Ferro Corporation
Dr. R. J. Stokes, Honeywell, Inc.
Professor J. H. Van Vleck, Harvard University

Evaluation Panel for Physical Chemistry Division

Dr. Sidney W. Benson, Stanford Research Institute, Chairman
Dr. Harold A. Dewhurst, Owens Corning Fiberglas Corporation
Dr. Warren E. Falconer, Bell Telephone Laboratories
Professor H. J. Morowitz, Yale University
Professor T. N. Rhodin, Cornell University
Professor Joseph T. Vanderslice, University of Maryland
Professor John E. Willard, University of Wisconsin
Professor Richard N. Zare, Columbia University

Institute for Applied Technology

Evaluation Panel for Institute for Applied Technology
Mr. Michael Witunski, McDonnell Douglas Corporation, Chairman
Dr. Raymond A. Bauer, The White House
Dr. John S. Brod, The Procter & Gamble Company
Professor Howard W. Emmons, Harvard University
Mr. Morris Kaplan, Consumers Union of the U. S., Inc.
Mr. Francis L. LaQue, Verona, New Jersey
Mr. Jacob Rabinow, Bethesda, Maryland
Dr. Gordon K. Teal, Texas Instruments Incorporated
Mr. Alfred C. Webber, E. I. du Pont de Nemours & Co.
Mr. William L. Hooper, Boise Cascade Housing Development
Dr. Leon Podolsky, Pittsfield, Massachusetts
Professor Hugh J. Miser, University of Massachusetts

Evaluation Panel for Product Evaluation Division
Mr. Alfred C. Webber, E. I. du Pont de Nemours & Co., Chairman
Dr. William H. Aiken, Union Camp Corporation
Dr. J. M. Calhoun, Eastman Kodak Company
Mr. Fred Fortess, Celanese Fibers Marketing Company
Mr. Morris Kaplan, Consumers Union of the U. S., Inc.
Mr. G. C. Maassen, R. T. Vanderbilt Company
Mr. Herbert Phillips, The Association of Home Appliance Manufacturers (AHAM)
Mr. E. J. Stavrakas, J. C. Penney Company

Evaluation Panel for Building Research Division
Mr. William L. Hooper, Boise Cascade Housing Development, Chairman
Mr. George B. Begg, General Services Administration
Mr. Herman Blum, Herman Blum Consulting Engineers, Inc.
Mr. William W. Caudill, Caudill Rowlett Scott
Professor Ray Clough, University of California
Mr. Fred Good, National Roofing Contractors Association
Mr. Andrew R. Lolli, Meyerson & Co., Inc.
Mr. Alfred A. Perry, Department of Housing and Urban Development
Mr. Herbert H. Swinburne, Nolen, Swinburne and Associates
Dr. Calvin W. Taylor, The University of Utah
Mr. John A. Wacker, J. W. Bateson Company, Inc.
Mr. Frank Waters, McGraw-Hill Information Systems Company

Evaluation Panel for Electronic Technology Division
Dr. Leon Podolsky, Pittsfield, Massachusetts, Chairman
Mr. Ralph E. Clarridge, IBM Corporation
Mr. Ivan G. Easton, General Radio Company
Mr. H. J. Luer, Bell Telephone Laboratories, Inc.
Dr. Remo Pellin, Monsanto Company
Mr. Peter R. Perino, Statham Instruments, Inc.
Dr. Thomas A. Perls, Martin Marietta Corporation
Dr. Robert L. Pritchard, General Electric Company
Mr. Robert I. Scace, General Electric Company
Mr. Samuel H. Watson, RCA Corporation

Evaluation Panel for Technical Analysis Division
Professor Hugh J. Miser, University of Massachusetts
Dr. William E. Bradley, Puredesal
Professor Robert Dorfman, Harvard University
Mr. Leslie C. Edie, The Port of New York Authority
Mr. Martin L. Ernst, Arthur D. Little, Inc.
Dr. Robert Herman, General Motors Research Laboratories
Dr. David B. Hertz, McKinsey and Company, Inc.
Dr. William Linvill, Stanford University
Dr. William H. Mitchel, University of Oregon
Professor E. W. Montroll, University of Rochester
Professor Philip M. Morse, Massachusetts Institute of Technology
Professor Gustave J. Rath, Northwestern University
Mr. Robert H. Shatz, Sikorsky Aircraft

Center for Radiation Research

Evaluation Panel for Center for Radiation Research
Dr. Walter H. Zinn, Combustion Engineering, Inc., Chairman
Dr. S. C. Abrahams, Bell Telephone Laboratories, Inc.
Mr. Frank Attix, Naval Research Laboratory
Dr. Marshall R. Cleland, Radiation Dynamics, Inc.
Dr. Peter T. Demos, Massachusetts Institute of Technology
Mr. Robert Kettner, Nuclear Assurance Corporation
Dr. R. B. Leachman, Kansas State University
Professor E. W. Montroll, University of Rochester
Dr. George F. Pieper, National Aeronautics and Space Admin.
Professor C. G. Shull, Massachusetts Institute of Technology

Center for Computer Sciences and Technology

Evaluation Panel for Center for Computer Sciences and Technology
Dr. Jack Moshman, Moshman Associates, Inc., Chairman
Mr. H. G. Asmus, American Federation of Information Processing Societies
Mr. T. E. Climis, IBM Corporation
Dr. Edward E. David, Jr., Bell Telephone Laboratories, Inc.
Dr. Robert R. Johnson, Burroughs Corporation
Mr. J. Don Madden, Compata, Inc.
Dr. Charles A. Phillips, Business Equipment Manufacturers Assn.
Mr. F. Gordon Smith, Executive Sciences, Inc.

AWARDS AND HONORS

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from Government, academic, professional, and industrial groups. The following list reflects such recognition bestowed on Bureau staff members during fiscal year 1970.

Armstrong, Richard W.	Honorable Mention. Belgian Fund for Study Research Concerning the Problem of Road Safety
Bates, A. Allan	Award for Meritorious Service in the Field of Standardization, Standards Engineering Society and American Society for Testing and Materials
Bowen, Ray	Bumblebee Award, American Academy for Plastics Research in Dentistry
Branscomb, Lewis M.	Member, President's Committee on the National Medal of Science
Deslattes, Richard S.	Arthur S. Flemming Award
Diller, Dwain E.	Russell B. Scott Memorial Award
Eisenhart, Churchill	President-Elect, American Statistical Association
Fatiadi, Alexander	Certificate of Merit from the Dictionary of International Biographies for Distinguished Service to Organic Chemistry
Gatterer, Lawrence E.	Awarded Science and Technology Fellowship, Department of Commerce
Kessler, Karl G.	President, Optical Society of America
Koonce, Calvin S.	Maryland Academy of Sciences Distinguished Young Scientist of 1969
Lashof, Theodore W.	Elected TAPPI Fellow, Technical Association of the Pulp and Paper Industry
Lloyd, E. C.	Member, Research Policy Board, American Society of Mechanical Engineers
Michaelis, Robert	ASTM Award of Merit
Phillips, Clinton W.	Distinguished Service Award, American Society of Heating, Refrigerating and Air-Conditioning Engineers
Robinson, Henry	ASTM Award of Merit
Roder, Hans M.	Russell B. Scott Memorial Award
Schoen, Louis J.	Awarded Science and Technology Fellowship, Department of Commerce

Seward, Richard W.	Blue Pencil Award, Federal Editors Assn., for the September 1969 issue of the NBS Technical News Bulletin
Silverman, Shirleigh	1970 Award for Outstanding Publication in the Field of Standardization. Presented by the Standards Engineers Society
Sitterly, Charlotte M.	Honorary Doctorate, University of Kiel, Germany
	Membre Correspondant of the Societe Royale des Sciences de Liege
Spencer, Lewis V.	L. H. Gray Medal, International Commission on Radiation Units and Measurements
Tate, Douglas	ASTM Award of Merit
Taylor, John K.	Service Award, Chemical Society of Washington
Waters, Hal P.	Honorable Mention, Belgian Fund for Study Research Concerning the Problem of Road Safety
Wiederhorn, Sheldon M.	Made Fellow of the American Ceramic Society
Youden, W. J.	1969 Shewhart Medal, American Society for Quality Control
	1969 Samuel S. Wilks Memorial Award, American Statistical Association

EUGENE C. CRITTENDEN AWARD
(National Bureau of Standards)

For superior performance by support personnel.

Recipient	*Area*
Curry, Flenard	Packing and Crating Services
Greene, James L.	Publications Services
Jones, James S.	Instrument-making Services
Mendenhall, Jo R.	Cryogenic Data Center Services
Mont, Charles E.	Excess Property and Storage
Rogers, Fayette E.	Planning and Estimating Modifications
Wichman, Gerald L.	Technical Progress of the Boulder Laboratories
Williams, Harry B.	Cutting and Polishing of Crystals and Glasses

DEPARTMENT OF COMMERCE EXCEPTIONAL SERVICE AWARDS
(Gold Medal)

Recipient	*Technical Area*
Bennett, John A.	Metallurgical Research
DeSimone, Daniel V.	Invention and Innovation
Dibeler, Vernon H.	Mass Spectrometry
Hall, John Lewis	Laser Technology
Penner, Samuel	Nuclear Structure Studies
Scribner, Bourdon F.	Spectroscopic Techniques

DEPARTMENT OF COMMERCE MERITORIOUS SERVICE AWARDS
(Silver Medal)

Recipient	*Technical Area*
Berendt, Raymond D.	Noise Abatement and Control
Caswell, Randall S.	Science Administration in Radiation Physics
Dunfee, Bernadine L.	Voltage-ratio and Current-ratio Measurements
Freeman, David H.	Determination of Ultra-Traces
Hardland, Leonard S.	Inventions Program
McLaughlin, William L.	Dosimetry and Radiation Imaging Methods

Melmed, Allan J.	Metal Surfaces
Napolitano, Albert	High-temperature Viscometry
Olver, Frank W. J.	Numerical and Asymptotic Analysis
Pope, Chester I.	Paper and Photographic Chemistry
Rosenblatt, Joan R.	Advanced Statistical Methodology
Schaffer, Robert	Synthetic and Structural Organic Chemistry
Schleter, John C.	Spectrophotometric Data
Skillington, James E.	Budgeting Practices
Straus, Sidney	Volatilization of Polymers
Sze, Wilbur C.	Inductive Voltage Divider
Tate, Douglas R.	Absolute Value of Acceleration Due to Gravity
West, Estal D.	Accurate Heat Measurements
Wiederhorn, Sheldon M.	Crack Propagation

DEPARTMENT OF COMMERCE SUPERIOR SERVICE AWARDS
(Bronze Medal)

Recipient	*Technical Area*
Bottamiller, Wilbert O.	Instrument Shops
Darr, Martha M.	Spectrochemical Analysis
Kaeser, Robert S.	Cryogenic Physics and Thermometry
Kumpula, John W.	Dental Research
Martin, W. Perry	Administration
Schaefer, Karl E.	Administration
Shure, Sylvia M.	Administration
Smith, Joseph M.	Scientific Apparatus
Taylor, Charles E.	Instrument Shops
Wegner, Edwin A.	Administration

EDUCATION, TRAINING, AND UNIVERSITY LIAISON

A comprehensive employee development program, ranging from broad surveys to very detailed treatment of a new or specialized area of research, is available to all staff members and to members of other Government agencies and industrial personnel on a space-available basis. Courses and seminars are implemented primarily through the NBS Graduate School and special educational programs for subprofessional and non-professional employees, through non-Government educational and training facilities, and through interagency offerings. The programs range from adult basic education through postdoctoral research, and are offered at both the Boulder and Gaithersburg Laboratories. The primary objectives are to increase employee knowledge, skills, and efficiency in assigned duties in the categories more fully described below, and to prepare Bureau staff members to respond to the rapidly changing technology at all levels. Programs also include emphasis on maintaining liaison with the public, industry, commerce, and science.

In accord with Federal policy the Bureau is increasing its participation in projects aimed at stimulating community interest. Instruction by our scientists in the fields of their expertise, and facilities are being made available to the universities, public schools, professional societies, and the industrial and scientific community. In addition to numerous seminars offered through the Graduate School program and in cooperation with other Government and industrial agencies at the division and institute levels, there is the weekly National Bureau of Standards Scientific Colloquium at which current topics of broad interest to the Bureau are presented. These are open to the public and are attended by members of the university, industrial and Government communities, as well as by NBS personnel. Speakers are drawn from the outside community and from the NBS staff. Monthly colloquia under the joint sponsorship of the National Institutes of Health and the National Bureau of Standards are also offered, with each institution alternating as host.

NBS Graduate School

The NBS Graduate School curriculum includes graduate and undergraduate courses in the physical sciences, mathematics and specialized branches of engineering. A series of scientific colloquia and seminars designed to update and continue the education of the postdoctoral scientist are led by research leaders from the Bureau and from other research centers and universities. In addition, general staff development courses are offered, such as Supervision and Management, Reading Improvement, Technical Report Writing, and administrative and clerical conferences, workshops and courses.

Surveys periodically redetermine course offerings and keep the program in step with the changes and variations in educational requirements and the changing technology. Graduate degrees based partly on credit obtained for courses or thesis research carried on under the NBS Graduate School Program have been earned by 6 Bureau employees this year, bringing the total to 356 graduate degrees earned at 46 different universities since the establishment of the educational program in 1908.

The educational program at Boulder is associated with the University of Colorado in a Joint Course program and Adjunct Professor Plan. Courses are offered by the Bureau and the University which mutually benefit the Government and the University.

Postdoctoral Research Associateships

The National Bureau of Standards offers a number of awards for postdoctoral research. These awards provide young scientists of unusual ability and promise an opportunity for fundamental research in various branches of the physical, engineering, and mathematical sciences. Applications are evaluated by a Board of Selection appointed by the National Research Council. The Postdoctoral Research Associateship program has been in existence since 1954. There have been 203 awards made during these years.

Name	*University*	*NBS Advisor*
Alderman, Donald W.	Cornell University	R. J. Mahler
Borie, Edith F.	U. of North Carolina	L. C. Maximon
Cohen, Gerald B.	Carnegie-Mellon University	F. C. Brenner
Day, Gordon W.	U. of Illinois	L. M. Matarrese
Debye, Nordulf W.	Cornell University	J. J. Spijkerman
Epstein, Gabriel L.	U. of California (Berkeley)	J. Reader
Franzen, Douglas L.	U. of Minnesota	H. S. Boyne
Gibson, Benjamin F.	Stanford University	M. Danos
Gramlich, John W.	U. of Hawaii	I. L. Barnes
Greer, William L.	U. of Chicago	R. J. Rubin
Handy, Larry B.	U. of Wisconsin	F. E. Brinckman
Haney, Max A.	Rice University (Texas)	T. C. Farrar
Haynes, William M.	U. of Virginia	D. E. Diller
Jacob, Elizabeth J.	U. of Michigan	D. Lide
Julienne, Paul S.	U. of North Carolina	F. H. Mies
Kaldor, Andrew	Cornell University	A. Maki
Kelly, George E.	Northwestern University	M. Klein
Kessler, Ernest G., Jr.	U. of Wisconsin	W. C. Martin
Kranbuehl, David E.	U. of Wisconsin	P. Verdier
Kurylo, Michael J.	Catholic University	J. R. McNesby
Ledbetter, Hassell M.	U. of Illinois	R. P. Reed
Lehman, Donald R.	George Washington University	M. Danos
Lovas, Frank J.	U. of California (Berkeley)	D. R. Lide
Marchetti, Michael A.	Georgetown University	F. H. Mies
Merris, Russell L.	U. of California (Berkeley)	M. Newman
Mitchell, William C.	Washington University (Wisc.)	B. Robertson
Morrissey, Bruce W.	Rensselaer Polytechnic Inst.	R. R. Stromberg
Ott, William R.	U. of Pittsburgh	W. Wiese
Pierce, Stephen J.	U. of Calif. (Santa Barbara)	M. Newman
Redding, Rogers W.	Vanderbilt University	J. T. Hougen
Regula, Donald W.	Wayne State University	G. Kulin
Rosasco, Gregory J.	Fordham University	H. P. R. Frederikse
Sanchez, Isaac C.	U. of Delaware	E. O. DiMarzio

Schroeder, LeRoy	Northwestern University	J. J. Rush
Schuyler, Michael W.	Indiana University	R. A. Keller
Searles, Stuart K.	U. of Alberta (Canada)	P. Ausloos
Semmelroth, Carl C.	U. of Michigan	D. B. Judd
Sharp, Kenneth G.	Rice University (Texas)	T. D. Coyle
Sheingorn, Mark E.	U. of Wisconsin	M. Newman
Shelton, Carroll A.	U. of Pittsburgh	S. Block
Stewart, Selden L.	U. of Texas (Austin)	S. J. Tauber
Thornton, Donald D.	Syracuse University	B. W. Mangum
Treu, Siegfried	U. of Pittsburgh	C. T. Meadow

Other Employee Development Programs

In addition, the National Bureau of Standards recognizes the need to develop and upgrade the nonprofessional staff, which plays an essential role in the support of the scientific staff. Therefore, courses in adult basic education are offered in cooperation with the Montgomery County Public Schools, designed to help the individual in his work. Also, foreign-born individuals who need improvement in oral and written English can enroll in classes being taught by experienced adult teachers who are aware of the problems facing the non-English speaking individual.

Recent accomplishments in the area of nonprofessional training include the appointment of a full-time vocational counselor in the Employee Development and Relations Section to assist nonprofessional employees in career planning. The Bureau is working on moving employees out of dead-end jobs through training. Plans are being developed for the distribution of communications about the program including guidelines to supervisors and employees for use in nonprofessional development. A special Subcommittee has been appointed to oversee and plan special programs for nonprofessionals, work on career ladders, training for job changes and develop other opportunities for nonprofessionals, particularly the disadvantaged.

Classes in operation now are 2 High School Review classes and 3 Adult Basic Education classes. These classes are designed to prepare the individual for the High School Equivalency examination and for skills training classes in typing. The present and proposed training will serve to assist the employee in moving from limited education to skills and technical training.

Non-Government Education

Non-Government education falls into three categories . . . full-time (3 to 12 months) graduate study and research assignments at universities and research centers; full-time (less than 3 months) attendance at institutes, seminars, short concentrated courses and workshops; and part-time, job-related academic courses at universities and in industry. In the last year 861 staff members at Washington and Boulder were trained through non-Government facilities, and 4 career employees were selected for full-time graduate study or research assignments at universities and research centers. Participants in approved full-time training programs receive full salary and expenses, including tuition, fees, travel, and per diem, as well as transportation of family and household effects. In addition, 857 staff members, mostly from technical divisions, attended job-related courses on a semester basis, and shorter concentrated courses at universities and in industry.

Interagency Training

Courses made available through the Interagency Training Programs are an additional effective means of improving program operations for NBS personnel. Courses are offered at Government facilities in Supervision, Management, Office Skills and Practices, and specialized programs. This pooling of agency resources offers broader employee development opportunities at a saving to the Government. During the year 255 Bureau employees took advantage of the interagency offerings.

PUBLICATIONS*

PUBLICATIONS IN THE BUREAU'S SERIES

During the year NBS publications totaled 858 published papers and documents.

Of the formal publications, 90 appeared in the Journal of Research, and 504 in the journals of professional and scientific societies. Also, 143 summary articles were presented in the Bureau's Technical News Bulletin.

In the nonperiodical series, 121 documents were published: 8 in the Monograph series, 2 in the Handbook series, 18 in the Special Publication series, 10 in the Building Science series, 57 in the Technical Note series, 9 in the National Standard Reference Data Series, 1 in the Applied Mathematics series, 2 in the Federal Information Processing Standard series, and 14 in the Product Standards series.

Journal of Research. Reports National Bureau of Standards research and development in physics, mathematics, chemistry, and engineering. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts.
Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $9.50; foreign, $11.75. Single copy price varies. SD Catalog No. C13.22/sec.A:74.
Section B. Mathematical Sciences. Issued quarterly. Annual subscription: Domestic, $5; foreign, $6.25. Single copy price varies. SD Catalog No. C13.22/sec.B:74.
Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $5; foreign, $6.25. Single copy price varies. SD Catalog No. C13.22/sec.C:74.

Journal of Research

Section A. Physics and Chemistry

***J. Res. Nat. Bur. Stand.* (U.S.), 73A *(Phys. and Chem.)*, No. 4 (July–Aug. 1969), SD Catalog No. C13.22/sec.A:73/4. $1.25**

Negas, T., and Roth, R. S., Synthesis of barium ferrates in oxygen.
Negas, T., and Roth, R. S., The system SrO—"chromium oxide" in air and oxygen.
Smith, E. W., Vidal, C. R., and Cooper, J., Classical path methods in line broadening. I. The classical path approximation.
Smith, E. W., Vidal, C. R., and Cooper, J., Classical path methods in line broadening. II. Application to the Lyman series of hydrogen.
Woolley, H. W., The second virial coefficient for the realistic pair potential.

***J. Res. Nat. Bur. Stand.* (U.S.), 73A *(Phys. and Chem.)*, No. 5 (Sept.–Oct. 1969), SD Catalog No. C13.22/sec.A:73/5. $1.50**

Douglas, T. B., Conversion of existing calorimetrically determined thermodynamic properties to the basis of the International Practical Temperature Scale of 1968.

* Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (foreign postage, one-fourth additional). The NBS nonperiodical series are also available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151. Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

Douglas, T. B., and Payne, W. H., Measured enthalpy and derived thermodynamic properties of alpha beryllium nitride, Be_3N_2, from 273 to 1200 K.
Douglas, T. B., and Payne, W. H., Measured enthalpy and derived thermodynamic properties of solid and liquid lithium tetrafluoroberyllate, Li_2BeF_4, from 273 to 900 K.
Goodwin, R. D., Nonanalytic vapor pressure equation with data for nitrogen and oxygen.
Stimson, H. F., Some precise measurements of the vapor pressure of water in the range from 25 to 100 °C.
Roth, C., The configurations $(3d+4s)^n4p$ in neutral atoms of calcium, scandium, and titanium.
Catanzaro, E. J., Murphy, T. J., Carner, E. L., and Shields, W. R., Absolute isotope abundance ratio and atomic weight of terrestrial rubidium.

***J. Res. Nat. Bur. Stand.* (U.S.), 73A *(Phys. and Chem.)*, No. 6 (Nov.–Dec. 1969), SD Catalog No. C13.22/sec.A:73/6. $1.25**

Goodwin, R. D., Formulation of a nonanalytic equation of state for parahydrogen.
McMurdie, H. F., de Groot, J., Morris, M., and Swanson, H. E., Crystallography and preparation of some $ABCl_3$ compounds.
Mountain, R. D., Dynamical model for Brillouin scattering near the critical point of a fluid.
Robbins, C. R., and Levin, E. M., Phase transformation in barium tetraborate.
Roth, C., Odd configurations in singly-ionized copper.
Siu, M. C. I., Capillary depressions for nearly planar menisci.
Vicentini-Missoni, M., Sengers, J. M. H. L., and Green, M. S., Scaling analysis of thermodynamic properties in the critical region of fluids.

***J. Res. Nat. Bur. Stand.* (U.S.), 74A *(Phys. and Chem.)*, No. 1 (Jan.–Feb. 1970), SD Catalog No. C13.22/sec.A:74/1. $1.75**

Cezairliyan, A., Morse, M. S., Berman, H. A., and Beckett, C. W., High-speed (subsecond) measurement of heat capacity, electrical resistivity, and thermal radiation properties of molybdenum in the range 1900 to 2800 K.
Houck, J. C., Temperature coefficient of the Bismuth I-II transition pressure.
Judd, D. B., and Yonemura, G. T., CIE 1960 UCS diagram and the Muller theory of color vision.
Loftus, T. P., Standardization of cesium-137 gamma-ray sources in terms of exposure units (Roentgens).
Martin, W. C., and Kaufman, V., New vacuum ultraviolet wavelengths and revised energy levels in the second spectrum of zinc (Zn II).
Martin, W. C., and Sugar, J., Calculations of Zn II $3d^9 4s 5s$ and Ag I $4d^9 5s 6s$, and some new levels in these spectra.
Moreno, E. C., Patel, P. R., and Brown, W. E., Isothermal diffusion in the dilute range of the system $Ca(OH)_2$–H_3PO_4–H_2O—Theory.
Orcutt, R. H., Generation of controlled low pressures of nitrogen by means of dissociation equilibria.
Pope, C. I., Blemish formation in processed microfilm. II.
Scheer, M. D., Positive and negative ionsublimation from transition metal surfaces: A review of some recent results.
Weber, L. A., P–V–T, Thermodynamic and related properties of oxygen from the triple point of 300 K at pressures to 33 MN/m^2.

***J. Res. Nat. Bur. Stand.* (U.S.), 74A *(Phys. and Chem.)*, No. 2 (Mar.–Apr. 1970), SD Catalog No. C13.22/sec.A:74/2. $2.00**

Distefano, G., Photoionization study of $Fe(CO)_5$ and $Ni(CO)_4$.
Goodwin, R. D., Estimation of critical constants T_c, p_c from the $p(T)$ and $T(p)$ relations at coexistence.
Robbins, C. R., Synthesis and growth of fresnoite ($Ba_2TiSi_2O_8$) from a TiO_2 flux and its relation to the system $BaTiO_3$–SiO_2.
Roth, C., A theoretical investigation of the configurations $(3d+4s)^4 4p$ in neutral vanadium (V I).
Roth, C., A theoretical investigation of the configurations $(3d+4s)^5 4p$ in neutral chromium (Cr I).
Roth, C., A theoretical investigation of the configurations $(3d+4s)^7 4p$ in neutral iron.

Weeks, J. J., and Sullivan, P. K., The intensity as a function of temperature of the low-angle x-ray diffraction maxima of the *n*-paraffins: hexatriacontane, tetratetracontane, and tetranonacontane.

Papers presented at the Conference, Electronic Density of States, National Bureau of Standards, Gaithersburg, Md., Nov. 3–6, 1969.

Beeby, J. L., The electronic structure of disordered alloys.

Cardona, M., Optical properties and electronic density of states.

Ehrenreich, H., Summary of the conference on electronic density of states.

Mahan, G. D., Excitonic effects in x-ray transitions in metals.

Rooke, G. A., Soft x-ray band spectra and their relationship to the density of states.

Ziman, J. M., The band structure problem.

***J. Res. Nat. Bur. Stand.* (U.S.), 74A *(Phys. and Chem.)*, No. 3 (May–June 1970), SD Catalog No. 13.22/sec.A:74/3. $1.75**

Dickens, B., The crystal structure of hydrazinium trinitromethide $(N_2H_5^+[C(NO_2)_3]^-$ at ~—160 °C.

Dickens, B., Mauer, F. A., and Brown, W. E., A refinement of the crystal structure of $Na_2CO_3 \cdot H_2O$.

Hanley, H. J. M., McCarty, R. D., and Intemann, H., The viscosity and thermal conductivity of dilute gaseous hydrogen from 15 to 5000 K.

Horton, W. S., Anisotropic reaction kinetics of oxygen with pyrolytic graphite.

King, A. S., Conway, J. G., Worden, E. F., and Moore, C. E., Temperature classification of the spectra of dysprosium (Dy I, Dy II).

Papers presented at the Conference, Electronic Density of States National Bureau of Standards, Gaithersburg, Md., Nov. 3–6, 1969.

Beck, P. A., and Claus, H., Density of states information from low temperature specific heat measurements.

Butler, W. H., and Kohn, W., Local theory of disordered systems.

Hagstrom, H. D., Ion-neutralization spectroscopy.

Hedin, L., Lundqvist, B. and Lundqvist, S., Beyond the one-electron approximation: Density of states for interacting electrons.

Spicer, W. E., Optical density of states ultraviolet photoelectric spectroscopy.

Section B. Mathematical Sciences

***J. Res. Nat. Bur. Stand.* (U.S.), 73B *(Math. Sci.)*, No. 3 (July–Sept. 1969), SD Catalog No. C13.22/sec.B:73/3. $1.25**

A table of integrals of the exponential integral. Murray Geller and Edward W. Ng.

Principal ideals in matrix rings. Morris Newman and Stephen Pierce.

The second orthogonality conditions in the theory of proper and improper rotations. IV. Solution of the trace and secular equations. Harry Gelman.

Minimax error selection of a univariate distribution with prescribed componentwise bounds and ranking. A. J. Goldman.

Minimax adjustment of a univariate distribution to satisfy componentwise bounds and/or ranking. A. J. Goldman.

On the application of some interpolating functions in physics. A. J. Jerri.

Commutator groups and algebras. L. Greenberg.

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. 4 (Oct.–Dec. 1969), SD Catalog No. C13.22/sec.B:73/4. $1.25**

Goldman, A. J., and Meyers, P. R., Simultaneous contractification.

Gupta, H., Highly restricted partitions.

Horn, W. A., A theorem on convex hulls.

Mandel, J., The partitioning of interaction in analysis of variance.

Sadowski, W. L., and Ruthberg, Z. G., Selective excitation of harmonics in a collisionless plasma by two counterstreaming electron beams.

Sadowski, W. L., and Ruthberg, Z. G., Temperature renormalization in the non-linear Vlasov problem.

J. Res. Nat. Bur. Stand. (U.S.), 74B *(Math. Sci.)*, No. 1 (Jan.–Mar. 1970), SD Catalog No. C13.22/sec.B:74/1. $1.25

Brualdi, R. A., and Newman, M., An enumeration problem for a congruence equation.
Gross, F., Entire functions of exponential type.
Gupta, H., Partitions—a survey.
Merris, R., Partitioned hermitian matrices.
Pierce, S., Orthogonal decompositions of tensor spaces.
Rivlin, T. R., Bounds on a polynomial.
Sinha, T. N., A relation between the coefficients and roots of two equations and its application to diophantine problems.

J. Res. Nat. Bur. Stand. (U.S.), 74B *(Math. Sci.)*, No. 2 (April–June 1970), SD Catalog No. C13.22/sec.B:74/2. $1.25

Greenberg, L., and Newman, M., Normal subgroups of the modular group.
McKinney, J. E., and Oser, H. J., Acoustic propagation and stability within an inviscid, heat-conducting fluid.
Meyers, P. R., On contractive semigroups and uniform asymptotic stability.
Ng, E. W., and Geller, M., On some indefinite integrals of confluent hypergeometric functions.
Witzgall, C., On complementary polar conical sets.

Section C. Engineering and Instrumentation

J. Res. Nat. Bur. Stand. (U.S.), 73C *(Engr. and Instr.)*, Nos. 3 and 4 (July–Dec. 1969), SD Catalog No. C13.22/sec.C:73/3 & 4. $1.25

Ballard, L. D., Epstein, W. S., Smith, E. R., and Edelman, S., Optical FM system for measuring mechanical shock.
Bowman, H. A., and Gallagher, W. H., An improved high-precision calibration procedure for reference standard hydrometers.
Linzer, M., The nuclear quadrupole resonance magnetometer: A new method for the precision measurement of the magnitude and direction of magnetic fields.
Marzetta, L. A., and Flach, D. R., Design features of a precision ac-dc converter.
Index to Volume 73C, January to December 1969.

J. Res. Nat. Bur. Stand. (U.S.), 74C *(Engr. and Instr.)*, Nos. 1 and 2 (Jan.–June 1970), SD Catalog No. C13.22/sec.C:74/1 & 2. $1.25

Production of near-perfect interferograms of variable visibility. J. B. Saunders.
Locked nuclear quadrupole resonance spectrometer for pressure measurements. Ronald C. Frisch and David L. VanderHart.
Precise continuous optical attenuator. G. Ruffino.
An A–C resistance thermometer bridge. Robert D. Cutkosky.
On the flow induced by a Maxwell-Chartoff rheometer. Elliot A. Kearsley.
Mechanical compliance measurements of single-edge-notch tension specimens. Mary Jane Orloski.
Effect of notch geometry and temperature on the creep-rupture behavior of a titanium alloy. William D. Jenkins and William A. Willard.

Technical News Bulletin. The best single source of information concerning the Bureau's research, developmental, cooperative and publications activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—for engineers, chemists, physicists, research managers, product-development managers, and company executives. Readers use the TNB to learn of new developments with practical applications, to fill in background, to get ideas for further investigations, and for information on NBS calibration services, publications, and conferences. Annual Subscription: Domestic, $3; foreign, $4. Single copy price 30 cents. Available on a 1-, 2-, or 3-year subscription basis. SD Catalog No. C13.13:54.

Monographs. Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Swanson, H. E., McMurdie, H. F., Morris, M. C., and Evans, E. H., **Standard x-ray diffraction powder patterns,** Nat. Bur. Stand. (U.S.), Monogr. 25, Section 7, 188 pages (Sept. 1969), $1.50, SD Catalog No. C13.44:25, Sec. 7.

Engen, G. F., **An introduction to the description and evaluation of microwave systems using terminal invariant parameters,** Nat. Bur. Stand. (U.S.), Monogr. 112, 27 pages (Oct. 1969), 35 cents, SD Catalog No. C13.44:112.

Stevens, M. E., **Research and development in the computer and information sciences. 1. Information acquisition, sensing, and input: A selective literature review,** Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 1, 170 pages (Mar. 1970), $1.50, SD Catalog No. C13.44:113/Vol. 1.

Stevens, M. E., **Research and development in the computer and information sciences. 2. Processing, storage, and output systems: A selective literature review,** Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 2, 125 pages (May 1970), $1.25, SD Catalog No. C13.44:113/Vol. 2.

Stevens, M. E., **Research and development in the computer and information sciences. 3. Overall system design considerations: A selective literature review,** Nat. Bur. Stand. (U.S.), Monogr. 113, Vol. 3, 147 pages (June 1970), $1.25, SD Catalog No. C13.44:113/Vol. 2.

Brombacher, W. G., **Survey of Micromanometers,** Nat. Bur. Stand. (U.S.), Monogr. 114, 62 pages (June 1970), 60 cents, SD Catalog No. C13.44:114.

Hougen, J. T., **The Calculation of Rotational Energy Levels and Rotational Line Intensities in Diatomic Molecules,** Nat. Bur. Stand. (U.S.), Monogr. 115, 52 pages (June 1970), 55 cents, SD Catalog No. C13.44:115.

Vidal, C. R., Cooper, J., Smith, E. W., **Hydrogen Stark Broadening Calculations With the Unified Classical Path Theory,** Nat. Bur. Stand. (U.S.), Monogr. 116, 143 pages (May 1970), $1.50, SD Catalog No. C13.44:116.

Handbooks. Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.

Screw-thread standards for federal services. Part I. Unified UNJ unified miniature screw threads, Nat. Bur. Stand. (U.S.), Handb. 28, 237 pages (Dec. 1969), $2.00, SD Catalog No. C13.11:28. (Superseding H28 (1957) Part I and that applicable to Part I in the 1963 Supplement to H28.)

American National Standard. **Radiological Safety in the design and operation of particle accelerators,** Nat. Bur. Stand. (U.S.), Handb. 107, 22 pages (June 1970), 30 cents, SD Catalog No. C13.11:107.

Special Publications. (Formerly Miscellaneous Publications) This series includes proceedings of high-level national and international conferences sponsored by NBS, precision measurement and calibration volumes, NBS Research Highlights, and other special publications appropriate to this grouping, such as administrative pamphlets, wall charts and bibliographies.

NBS frequency and time broadcast services. Radio stations WWV, WWVH, WWVB, and WWVL, Nat. Bur. Stand. (U.S.), Spec. Publ. 236, 16 pages (1969), (Supersedes NBS Spec. Publ. 236, 1968 edition), 25 cents, SD Catalog No. C13.10:236.

Standard Reference Materials, Catalog and price list of standard materials issued by the National Bureau of Standards, Nat. Bur. Stand. (U.S.), Spec. Publ. 260, 1969 Edition, 44 pages (July 1969), (Supersedes NBS Misc. Publ. 260—1968 edition), 50 cents, SD Catalog No. C13.10:260.

Catanzaro, E. J., Champion, C. E., Garner, E. L. Marinenko, G., Sappenfield, K. M., Shields, W. R. **Standard reference materials: Boric acid; isotope and assay standard reference materials,** Nat. Bur. Stand. (U.S.), Spec. Publ. 260–17, 70 pages (Feb. 1970), 65 cents, SD Catalog, No. C13.10:260–17.

Geller, S. B., Mantek, P. A., Cleveland, N. G., **Standard reference materials: Calibration of NBS secondary standard magnetic tape (computer amplitude reference) using the reference tape amplitude measurement "Process A,"** Nat. Bur. Stand. (U.S.), Spec. Publ. 260–18, 41 pages (Nov. 1969), 50 cents, SD Catalog No. C13.10:260–18.

Paule, R. C., Mandel, J., **Standard reference materials: Analysis of interlaboratory measurements on the vapor pressure of gold (certification of standard reference material 745),** Nat. Bur. Stand. (U.S.), Spec. Publ. 260–19, 21 pages (Jan. 1970), 30 cents, SD Catalog No. C13.10 :260–19.

Estin, A. J., Editor, **Precision Measurement and Calibration, Selected NBS Papers on Electricity—Radio Frequency,** Nat. Bur. Stand. (U.S.) Spec. Publ. 300, Vol. 4, 456 pages, (June 1970), $5.50, SD Catalog No. C13.10 :300/ Vol. 4.

Ginnings, D. C., Editor, **Precision measurement and calibration. Selected NBS papers on heat,** Nat. Bur. Stand. (U.S.), Spec. Publ. 300, Vol. 2, 387 pages, $5.00, SD Catalog No. C13.10 :300/Vol. 6.

Moore, C. E., **Bibliography on the analyses of optical atomic spectra Section 4. ^{57}La–^{71}Lu and ^{89}Ac–^{99}Es,** Nat. Bur. Stand. (U.S.), Spec. Publ. 306, Section 4, 55 pages (Aug. 1969), 55 cents, SD Catalog No. C13.10 :306, sec. 4.

Durst, R. A., Editor, **Ion-selective electrodes.** Proceedings of a symposium held at the National Bureau of Standards, Gaithersburg, Md., January 30–31, 1969, Nat. Bur. Stand. (U.S.), Spec. Publ. 314, 474 pages (Nov. 1969), $3.50, SD Catalog No. C13.10 :314.

Diamond, J. J., Ed., **Bibliography on the high temperature chemistry and physics of materials, April, May, June 1969,** Nat. Bur. Stand. (U.S.), Spec. Publ. 315–2, 74 pages (July 1969), 75 cents, SD Catalog No. C13.10 :315–2.

Diamond, J. J., Editor, **Bibliography on the high temperature chemistry and physics of materials, July, August, Sept. 1969,** Nat. Bur. Stand. (U.S.), Spec. Publ. 315–3, 90 pages (Oct. 1969), $1, SD Catalog No. C13.10 :315–3.

Diamond, J. J., Editor, **Bibliography on the high temperature chemistry and physics of materials, October, November, December 1969,** Nat. Bur. Stand. (U.S.), Spec. Publ. 315–4, 85 pages (Jan. 1970), 75 cents, SD Catalog No. C13.10 :315–4.

Diamond, J. J., **Bibliography on the high temperature chemistry and physics of materials, January, February, March 1970,** Nat. Bur. Stand. (U.S.), Spec. Publ. 315–5, 82, pages (Apr. 1970), 75 cents, SD Catalog No. C13.10 :315–5.

Koeser, R. L., ed., **Report of the 54th national conference on weights and measures 1969,** Nat. Bur. Stand. (U.S.), Spec. Publ. 318, 270 pages (Nov. 1969), $1.50, SD Catalog No. C13.10 :318.

Miles, B. M., Wiese, W. L., **Bibliography on atomic transition probabilities, January 1916 through June 1969,** Nat. Bur. Stand. (U.S.), Spec. Publ. 320, 111 pages (Feb. 1970), (Supersedes NBS Misc. Publ. 278 and Supplement) $1.25, SD Catalog No. C13.10 :320.

Fuller, E. G., Gerstenberg, H. M., Collins, T. M., **Photonuclear data index, January 1965 through January 1970,** Nat. Bur. Stand. (U.S.), Spec. Publ. 322, 86 pages (May 1970), 75 cents, SD Catalog No. C13.10 :322. (Supersedes Supplement 1 to Misc. Publ. 277).

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), $1.25, SD Catalog No. C13.10 :325.

Michaels, S., Green, M. S., Larsen, S. Y., **Equilibrium Critical Phenomena In Fluids and Mixtures: A Comprehensive Bibliography With Key-Word Descriptors,** Nat. Bur. Stand. (U.S.), Spec. Publ. 327, 235 pages (June 1970), $4.00, SD Catalog No. C13.10 :327.

National Standard Reference Data Series. Includes the evaluated reference data and critical reviews of long-term interest that are produced by data centers within the NSRDS network. The National Standard Reference Data System is a Government-wide effort to provide the U.S. technical community with effective access to the quantitative data of physical science, critically evaluated and compiled for convenience.

Benson, S. W., O'Neal, H. E., **Kinetic data on gas phase unimolecular reactions,** Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 21, 645 pages (Feb. 1970), $7.00, SD Catalog No. C13.48 :21.

Wiese, W. L., Smith, M. W., Miles, B. M., **Atomic transition probabilities. Volume II. Sodium through calcium, a critical data compilation,** Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 22, 306 pages (Oct. 1969), $4.50, SD Catalog No. C13.48 :22.

Janz, G. J., and Dijkhuis, Chr. G. M., **Molten salts: Volume 2, Section 1. Electrochemistry of molten salts: Gibbs free energies and excess free energies from equilibrium-type cells** (Combined with Section 2), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 28, 116 pages (Aug. 1969), $2.75, SD Catalog No. C13.48 :28, vol. 2, sec. 1.

Janz, G. ., Lakshminarayanan, G. R., Tomkins, R. P. T., and Wong, J., **Molten salts: Volume 2. Section 2. Surface tension data** (Combined with Section 1), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 28, 116 pages (Aug. 1969), $2.75, SD Catalog No. C13.48:28, vol. 2, sec. 2.

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PATENTS

During the year 14 U.S. Patents were awarded to NBS inventors. Eight were assigned to the United States of America as represented by the Secretary of Commerce; the remaining 6 were assigned—also to the United States of America—as represented by the Secretary of the Navy, the Administrator of NASA, and the Secretary of the Army, as indicated below.

COMMERCE

Greenspan, L., Wexler, A., Instrument for measuring the adiabatic saturation temperature (thermodynamic wet-bulb temperature) of a vapor-gas mixture, No. 3,515,001 (June 2, 1970).

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Marton, L. L., System for producing two simultaneous records of high energy electrons in an electron microscope, No. 3,510,649 (May 5, 1970).

Motz, J. W., Apparatus for measuring the energy and current of an accelerator electron beam including apertured incident and exit electrodes, No. 3,477,023 (November 4, 1969).

Saylor, C. P., Purification by selective crystallization and remelt, No. 3,449,087 (June 10, 1969).

Saylor, C. P., Continuous gas-liquid chromatography method utilizing annular open columns, No. 3,511,028 (May 12, 1970).

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ARMY

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SP 340

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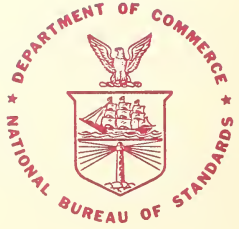
- 1949 The Atomic Clock—The initial NBS developments paved the way for later versions at NBS and elsewhere capable of keeping time to an accuracy of 1 second in 30,000 years.
- 1949 Gyromagnetic Ratio of the Proton—The first direct measurement of an important physical constant, leading to the revision of accepted values for other significant quantities in physics.
- 1950 Discovery of the Isotope Effect in Superconductivity—An important advance in the theory of superconductivity.
- 1950 SEAC (Standards Electronic Automatic Computer) Dedicated—First automatically sequenced, high speed, electronic digital computer in the United States.
- 1953 A spectrometer was developed to measure the energy of X-rays in the range between 0.5 and 50 million volts. Detection efficiency 100,000 times better than previously possible led to important new high energy X-ray investigations.
- 1956 A Bureau experiment first demonstrated that the quantum mechanical law of parity conservation does not hold in beta decay. This experiment disproved a widely accepted fundamental concept of nuclear physics, thus clearing the way for a reconsideration of existing theories.
- 1958 The gyromagnetic ratio of the proton was redetermined by measuring the precession rate of protons in a magnetic field. The new value made possible more accurate values of many fundamental constants such as electron charge-to-mass ratio, e/m, the magnetic moment of the proton, and Planck's constant, *h*.
- 1962 NBS published the first production line book in which the tables were composed by a photocomposition machine controlled by the output of a digital computer.
- 1962 A diamond pressure cell was used to make the first direct visual observations of phase transitions in transparent solids and liquids subjected to pressures of more than a million lbs/sq. in.
- 1963 The National Standard Reference Data System was established to disseminate critically evaluated data on the physical and chemical properties of materials authoritatively documented as to reliability, accuracy, and source.
- 1964 New broadcast facilities were dedicated (WWVB 60 kHz and WWVL 20 kHz) giving the most accurate and stable frequency transmission in the world. The frequency transmissions enabled laboratories to calibrate their precision sources to an accuracy of better than 1 part in 10^{11} (one thousandth of a second in 3 years).
- 1966 NBS dedicated major new facilities at Gaithersburg, Maryland.
- 1968 A 3-year Metric Study was begun to determine the effect upon the U.S. of increased worldwide use of the Metric System.
- 1969 A new technique for stabilizing He-Ne laser-saturated absorption in methane vapor gives promise of a new length standard 1000 times as reproducible as the present krypton 86 standard.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