DEPARTMENT
OF
COMMERCE

MISCELLANEOUS
PUBLICATIONS
OF THE
NATIONAL
BUREAU
OF
STANDARDS

NOS. 277 SUPPL. 1,
278 - 280

1965

TECHNICAL HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

Annual Report for:

INSTITUTE FOR BASIC STANDARDS

INSTITUTE FOR MATERIALS RESEARCH

INSTITUTE FOR APPLIED TECHNOLOGY

CENTRAL RADIO PROPAGATION LABORATORY

UNITED STATES DEPARTMENT OF COMMERCE
John T. Connor, *Secretary*
J. Herbert Hollomon, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

1965
Technical Highlights
of the
National Bureau of Standards

Annual Report, Fiscal Year 1965

May 1966

Miscellaneous Publication 279

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D. C., 20402 — Price 65 cents

Library of Congress Catalog Card Number: 6-23979

CONTENTS

I

THE DIRECTOR'S STATEMENT

NBS — AN EVOLVING INSTITUTION

Ever since its establishment by Congress in 1901 the Bureau has been characterized by a dynamic adaptation of its programs to the changing needs of science and industry.

The Organic Act of 1901 as revised in 1950 authorized the Bureau to carry out the following basic functions:

1. Development and maintenance of the National standards of measurement and the provision of means for making measurements consistent with those standards:
2. Determination of physical constants and properties of materials;
3. Development of methods for testing materials, mechanisms, and structures, and the making of such tests as may be necessary, particularly for Government;
4. Cooperation with other governmental agencies and with private organizations in the establishment of standard practices incorporated in codes and specifications;
5. Advisory service to Government agencies on scientific and technical problems;
6. Invention and development of devices to serve special needs of the Government.

Subsequent legislation, Executive Orders, and other actions added to these functions and assigned new responsibilities.

Although the measurements-standards mission has remained fundamental to the Bureau's programs since its inception, the Bureau has engaged in a wide variety of activities which did not directly stem from its measurement responsibilities. Generally, these programs have been undertaken to meet the specialized needs of other Government agencies, or to provide scientific and engineering data for various segments of private industry and commerce which were not in a position, at the time, to maintain research activities of their own.

The exponential growth of U. S. scientific and technological activity has increased the Bureau's workload in measurement and related fields many fold. At the same time, several new responsibilities have recently been assigned to it.

Among these are:

• *To serve as the focal point within the Federal Government for stimulating the application of science and technology to the economy.* Apart from fostering a viable national measurement system, this function involves an increased effort in the dissemination of technical information and in the development of engineering measurements and standards, which provide the technical base for performance criteria of goods and services.

• *To set up and operate the National Standard Reference Data System.* NBS has been assigned the task of directing the centralized collection, evaluation, organization, and distribution of standard reference data.

• *To establish and expand a Clearinghouse for Federal Scientific and Technical Information.* Here, the product handled is not data as such but R&D documents, the entire unclassified output of the considerable Federal scientific and technological complex. These documents help keep industry abreast of current technological developments.

• *To set up and operate a central technical analysis service* to conduct cost-benefit studies for our own, and other Commerce bureaus and Federal agencies on request.

• *To establish a central and major Government resource in the automatic data processing field.* Under this heading we will be providing the technical base for standardization in the computer field and developing ways of using computers for new tasks and for using them more efficiently on old tasks.

The last two responsibilities were assigned to us during fiscal year 1965.

• Our *Central Radio Propagation Laboratory* in Boulder, Colorado has also been given major additional responsibilities. It has been asked to provide the nation with space environment information and prediction services and to extend its support to the nation's telecommunications industry to cover the infra-red and optical portions of the electromagnetic spectrum. On the other hand, this important part of the NBS is scheduled, during fiscal year 1966, to become a key component of a new agency, the Environmental Science Services Administration, created by the President's Reorganization Plan No. 2, which was presented in fiscal year 1965. The Bureau once again has made a major contribution in the creation of a new scientific facility.

All of these recently assigned or expanded missions are described in greater detail in Section 3.

These assignments are in addition to our traditional measurement responsibilities, which in the meanwhile have grown extensively. There are

demands for increased accuracy and range of measurements, as well as for expansion of our various measurement services—calibration, testing, standard materials. Moreover, with the increasing complexity and sophistication of the science and engineering associated with measurement and standards there has been a corresponding increase in costs—both of laboratory facilities and equipment and of professional manpower.

The Nation's scientific and technical capability depends in large part on the capability of our measurement system. In a literal sense, measurement is the pacemaker of progress. In this Age of Science and Technology, more and more of our activities depend upon the work of the scientist and the engineer. This applies to economic activities no less than to the glamorous advances in space and defense programs.

Other nations of the world are harnessing the power of science and technology. If we are to maintain our world position we will have to expand our science and technology, and if we are to do that, we must have a national measurement system that unleashes our full potential for technological growth.

MANAGEMENT PROGRESS

Maintaining a proper balance between our resources and our responsibilities has been particularly crucial this past year because of the coincidence of new or added responsibilities and added demands on the national measurement capability with very limited fiscal resources.

Several steps were taken to assess our resources, evaluate the relative urgency of our responsibilities, and deploy the resources to achieve optimum results.

An important move was the reorganization of the Bureau into four Institutes, an action that had been taken 6 months before the fiscal year, but which did not fully operate until fiscal year 1965. The reorganization facilitated a systems approach to problems by grouping related programs under unified direction and by decentralizing management to permit closer evaluation and direction of program progress.

Projects and programs were studied in the context of identified major needs and in terms of their relationship to each other, to available resources, and to the probable requirements of the foreseeable future. As a result, extensive reprogramming was planned in fiscal 1965, to be completed in fiscal year 1966, with the object of canceling or curtailing low priority programs and of expanding those that would meet the most critical needs. About one million dollars was thus re-directed.

One of the prime objectives of management during the year was to accelerate the reduction of activities performed by the Bureau which could be done by private industry and other laboratories. This applied particularly to calibration services, where we seek to provide other laboratories with self-calibration capability, thus making them less directly dependent upon the Bureau. Self-calibration capability was also fostered by increased

emphasis on standard reference materials, independently reproducible standards, and standard reference data.

Improvement of measurement techniques and the dissemination of those techniques to industry and others was another prime management target. This was primarily reflected in the increased effort to provide engineering measurements and standards, the means by which industry can adapt laboratory measurement techniques to field measurement problems in comparatively difficult environments.

Still another objective was increased emphasis on development of engineering standards based on performance criteria rather than on a particular configuration and use of materials, and of test methods to measure conformance with the standards. This was especially important in the field of building and construction.

A major example of the use of a broad approach to management problems and agency goals was the decision, arrived at during fiscal 1965, to transfer the Central Radio Propagation Laboratory to the newly established Environmental Science Services Administration. The decision was based on an analysis of CRPL's programs and the resultant determination that they were more closely related to environmental research than to measurement and standards.

Another example is our program on atomic energy levels. As the result of the effects of the NBS Atomic Physics Division, various workers in the field throughout the world have combined their resources and voluntarily divided up the work, each taking parts in his own area of competence, all operating under the leadership of NBS. This example illustrates how the systems approach can be applied not only to the management of programs carried on within the Bureau but to coordination with activities going on outside the Bureau and throughout the world.

The Research Associate Plan, which has made its contributions over the years by making it possible for industry to obtain direct access to the staff and facilities of the National Bureau of Standards for the solutions of problems of industrial and National significance is currently being re-emphasized and revitalized. Under the program, industrial and professional organizations send their representatives to NBS for collaborative research with our staff.

The current objectives of the Research Associate Program are twofold. First, establish joint NBS-industry task forces where the special competences and measurement facilities of NBS make this environment especially well suited to the solution of selected problems. Second, to make NBS more quickly responsive to new needs that arise in industry that the Bureau can meet.

During the fiscal year new Research Associate plans were begun in fire research, the early detection of the deterioration of plastics, the use of the laser for length measurements, the causes and prevention of blemishes on microfilm, and cavitation problems in cryogenic fluids.

During the coming year, additional Research Associate plans are being developed in the fields of metallurgy, cryogenics, radio standards, textile standards and automatic data processing. The last will receive special emphasis in view of the Bureau's role in assisting the Federal Government in making optimum use of ADP equipment.

The LaQue Panel of the Commerce Technical Advisory Board, an advisory group to the Secretary, recommended that a new Federally-chartered institute be established to coordinate voluntary standardization activities in the United States. The proposed institute would be based on a reconstituted American Standards Association, and would include a Division of Consumer Affairs.

The Panel recommended continuation of the Commodity Standards Program at the Bureau, with the suggestion that procedures be improved. The Panel also urged more effective participation by the United States in the development of international standards. It further suggested a comprehensive study of building codes.

The Panel report has been circulated to trade associations, industrial groups, and others for comment. No action was taken on its recommendations during the year except that the Commodity Standards Program was strengthened to provide for more critical review and better technical back-up of voluntary standards.

NBS AS A SCIENTIFIC LABORATORY

Because of the all-pervasive importance of measurement, it was inevitable that the Nation's central measurement laboratory would become a focus of wide-ranging scientific and technical competence, covering the entire spectrum of the physical and engineering sciences.

NBS is the largest Government general-purpose laboratory in the physical sciences and engineering, and one of the largest public or private installations in the world. Its competence in certain fields is recognized and respected the world over.

The Bureau's scientific activity has been particularly distinguished in recent decades in the fields of: Atomic and molecular physics and spectroscopy, a whole new field of intermediate energy atomic physics opened by NBS, chemical physics, thermodynamics, theoretical physics, statistical mechanics, crystallography, analytical chemistry, polymers, metallurgy, cryogenics.

The Bureau's scientists and engineers. which constitute a high percentage of total staff. perform many research projects for other Government agencies. The extent of the demand for the Bureau's scientific and technical services is evidenced by the fact that about 40 percent of the Bureau's annual expenditures involve payments to it by other agencies for services rendered. See page 124.

Even more important than the *extent* of the Bureau's work, however, is the *quality* of its work and the reputation it builds.

All of the major programs of the Bureau require the utmost in skill and competence. Otherwise the programs will not fill the needs they are designed to meet. For example: The accuracy with which measurement standards can be reproduced and disseminated limits the reliability and accuracy of all exchanges derived from the standards. Thus the laboratory responsible for establishing and disseminating the measurement standards must provide leadership in the science of measurement. Similarly the Bureau's Standard Reference Materials program requires excellence in materials preparation and characterization; the Standard Reference Data

Aerial view of new NBS site at Gaithersburg, Md.

program requires extreme skill in data analysis and coordination, and the Engineering Standards program must have unusual competence in the development of product performance criteria and methods of testing. This need for excellence was well summarized in 1953 by the ad hoc committee which evaluated the function and operation of the National Bureau of Standards in relation to national needs: "It is not sufficient to have fairly good standards of measurement, fairly good methods of testing materials, mechanisms, or structures, or reasonably good determinations of important physical constants. The standards, the measurements, the test procedures must be the very best, the most accurate, the most reliable that can possibly be achieved at any given time, limited only by the state of the art at the time. It is thus more than a play on words to say that the 'standards' by which the Bureau is judged must be the very highest and best."

The Bureau's record of achievement is well known, probably more so to the scientific and technical community than to the general public. As an example of the range and importance of our current work, here are a few scientific developments of the past year:

Improving the Time Standard.—A thallium beam clock, undergoing tests and evaluation, may replace the cesium beam clock. The same principle applies to both clocks, yet, thallium's atomic resonance is less sensitive to magnetic fields and has a simpler spectrum. Improvement by an order of magnitude is possible.

Paralleling this effort is the promising research on the hydrogen maser. Initial tests produced unexcelled stability over short time periods. Importantly, the hydrogen atom acts as an oscillator and not a resonator —putting out its own signal. It also has an extremely fine spectral line and is independent of magnetic fields. Nevertheless, the frequency stability for long time periods must be evaluated before the usefulness as a time standard is known.

New Theory for Predicting Atomic and Molecular Parameters.—A theoretical framework was devised to predict atomic and molecular parameters previously unobtainable or extremely difficult to obtain experimentally. Many experiments to determine electronic wave functions and speeds of chemical reactions can now be removed from the laboratory and constructed in the computer.

Automatic Length Measurements with Laser Successful.—NBS successfully calibrated a line standard of length against the wavelength of light given off by a laser in its automatic fringe-counting interferometer. The accuracy obtained was 1.8 parts in 10^9. This is believed to be the first time a laser was used in length measurement, and the accomplishment opens the way for programmed machine tools based on the laser as a length-measuring device.

First Superconducting Oxide-type Semiconductor.—The first superconductivity of an oxide-type semiconductor was observed in a low temperature experiment on the semiconductor, strontium titanate. The discovery is of immediate value in the development of high-field industrial magnets and compact superspeed computers. In addition, the capability of predicting which semiconducting materials will be superconductive is enhanced.

Ultra-purification.—A new purification technique was developed which appears to make possible for the first time the preparation of what would in effect be absolutely perfect and pure crystals. Impurity is reduced by a factor of as much as 10^4 in each half-hour stage of operation, and it is believed that any number of stages can be employed with the same degree of improvement and no recontamination.

The purest copper ever achieved has been prepared by NBS scientists. The large single crystals are so pure that no impurities can be detected by any measurement method now available. They are about 30 times purer than any copper prepared previously.

Because of the Bureau's eminence in the scientific community, its participation and advice are sought by a variety of technical bodies.

Such groups as Congressional and executive scientific committees, and ad hoc groups formed to advise the Government on some specific problem often use the Bureau as a resource. Congress often looks to the Bureau as the source of Federal scientific and technical competence in such legislative proposals as studies of the Metric System, automatic data processing, etc.

Various professional societies depend on NBS participation in their work. Much of the material published by such groups as the American Standards Association and the American Society for Testing and Materials rests on a base of NBS research and technical data, and NBS people are important workers on the committees through which such organizations make their decisions.

NBS is host and sponsor to many scientific meetings each year. Such gatherings not only meet under Bureau auspices, but also profit from the contributions of NBS people to the actual program.

To spread its measurement competence to the production line—to dispense know-how as well as standards—NBS instituted measurement seminars. At these seminars, held at the Bureau, representatives from science and industry who are making and using measurements on the firing line, are instructed by NBS experts in the subtleties of their field.

The staff of the National Bureau of Standards is a major influence throughout the world of science and technology. The papers of NBS workers are a major contribution to this country's scientific and technical literature, whether they appear in the Bureau's own publications or in the outside technical journals. Through their activities in personal contacts with other scientists at meetings, in the laboratory, even through such informal work as lecturing at schools on all levels, NBS people provide this important and diffused "leadership" so necessary to the health of the national measurement system and the advance of the Nation's science and technology.

A burgeoning new field of opportunity for the Bureau is in direct cooperation with the academic community on problems of mutual interest. An outstanding example of this type of cooperation is the Joint Institute for Laboratory Astrophysics, a project of NBS and the University of Colorado. JILA, using the staff of both institutions, carries on both research and instruction in the field of laboratory astrophysics. It has drawn scientists for work and study from all over the world, as well as inquiries on its operations from many countries who wish to use this cooperative principle on projects of their own. Now the Bureau is exploring the possibilities of

establishing a similar project with the universities of the Washington, D. C., area to cover a much wider range of topics.

With its mandate and concern for the leadership of the Nation's measurement system, it is only natural for the Bureau to take the highest interest in the development of its staff, and in scientific education in general. NBS was a pioneer in the training programs which are now fairly common throughout the Government. The NBS Graduate School offers both graduate and undergraduate courses in the physical sciences, mathematics, and engineering. The Graduate School operations in both Washington and in Boulder, Colo., are in cooperation with local universities. NBS also sponsors training for its employees in outside institutions, where the study is job-related, under the Government Employees Training Act of 1958.

In its own laboratories, the Bureau serves a specific educational function in addition, of course, to the normal development expected for a technical worker on the job. NBS offers Postdoctoral Research Associateships to young scientists of exceptional ability, enabling them to further their research and education by working with outstanding men in their own field at the Bureau.

On yet another level, the Bureau opens its laboratories to undergraduate students through its Student Trainee Summer Program. This program offers an integrated work-study program for college students majoring in the physical sciences, mathematics, and engineering.

NBS is also active in various interagency training programs. An example is the Department of Commerce's Science and Technology Fellowship Program, which enables employees to broaden their backgrounds through special courses and special assignments in agencies other than their own. Through this program, the Department produces scientifically-oriented managers with the broad outlook necessary for top management positions. (See page 132 in the Appendix for the year's developments in staff training and education programs.)

At the end of fiscal year 1965, the operation of the Bureau's programs under Institutes had been underway for a year and a half.

II

INSTITUTE FOR BASIC STANDARDS

In support of the general mission of the National Bureau of Standards, the Institute for Basic Standards (IBS) provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce.

This central base consists of a complete, consistent set of units and national standards for physical measurement having precision and accuracy matched to national needs. It is accompanied by a chain of measurement extending to such multiples and submultiples as are needed for continued technological advancement.

The coordination of this measurement system with the systems of other nations is based upon NBS participation in various international groups such as the General Conference on Weights and Measures or its International Committee on Weights and Measures. In addition, NBS conducts official liaison with the International Bureau of Weights and Measures. Actual system compatability is achieved legally by securing necessary U. S. legislation to implement the international agreements and technically by insuring that our own standards are consistent with such agreements.

The essential IBS services providing accurate uniform measurement fall into four main categories:

I. Provision for direct or indirect calibration services leading to a calibration chain throughout the Nation such that all measuring instruments may be consistent with the national standards.

II. Provision for measurements and services leading to a coordinated national activity producing critically evaluated, accurate, consistent, reliable data on the physical constants and properties of substances.

III. Publication and dissemination of the results of research and development to provide information on how to make meaningful, consistent, accurate and precise physical measurements.

IV. Service to the rest of Government providing consulting and advisory services and special research assistance on those problems for which IBS has unique competence.

In this context the goal of IBS activity becomes quite clear. It should, and must, undertake the necessary fundamental and applied research and development to maintain, extend and improve the national standards to meet current needs, to be active and knowledgeable at the frontiers of measurements in order to forsee impending needs in time to meet them, to provide effective, efficient coupling mechanisms to insure that the necessary uniformity and accuracy are available throughout the Nation and to do all this in the minimum number of areas and ranges required by the Nation's citizens, scientists, engineers, industry, commerce, and national programs.

Improved measurement leads to new advances in science; in turn, new advances in science lead to improved measurement capability. Thus we expect, and find, among the accomplishments delineated in this report those which reflect immediate advances to the measurement system and those which reflect not only improvements in measurement but at the same time improvements in our basic knowledge and fundamental contributions to science itself.

PHYSICAL QUANTITIES, CONSTANTS AND CALIBRATION SERVICES

Six basic international qualities—those for length, mass, time, temperature, electrical current and luminous intensity—are the foundation of the International System of Units. From these six are derived approximately thirty-six additional quantities; the total of forty-two quantities are the basis of our system of physical measurement.

At present, the major items in the Bureau's measurement and calibration services cover the forty-two basic and derived quantities. As new horizons appear in science and technology, there will be continual shifts of emphasis in the Bureau's R&D program to provide measurement and calibration services for new quantities, to extend ranges, and to improve accuracies.

The Institute for Basic Standards maintains U. S. national reference standards for these units. Since the standards for some of them are established on the basis of physical constants and agreed on relationships, it is theoretically possible for any laboratory to establish its own reference standards independently. However, for the sake of maintaining consistency among various laboratories operating throughout the Nation, it is preferable to establish these standards on a national basis and to calibrate reference standards for the various laboratories throughout the Nation on the basis of the national standards. IBS takes responsibility for this task.

The dissemination of a uniform system of standards for measurement takes many forms, from calibrating material objects, such as meter bars, steel tapes, and gage blocks owned by the various laboratories involved, to furnishing laboratories with samples of material calibrated in terms of the standards, or to describing the properties of readily reproduced materials that can furnish a basis for measurement.

Inevitably, challenging research and development problems arise as a result of efforts to accomplish these missions. Some problems involve the application of new scientific tools to particular measurement capabilities, and their solution calls for cooperative efforts, both within NBS and with other laboratories.

The following specific program accomplishments and improved calibration services related to five of the six basic international quantities were realized in 1965:

INTERNATIONAL BASE UNITS

Length

The standard for length was established in 1960 by redefining the meter in terms of the wavelength of a spectral line of the isotope krypton 86. Shortly thereafter, it was experimentally demonstrated that proper application of the laser principle could further extend the precision of length measurements.

Laser Stability Studied.—Pursuing this new possibility a method was devised and perfected to measure the wavelength stability of lasers by direct interferometric comparison with a standard mercury lamp. The stability of NBS-built and commercial gas lasers was tested with this method under various environmental and operational conditions.

Laser Characteristics.—The optimum gas pressures and mixtures for rf-excited infrared and visible helium-neon lasers were determined. The characteristics and some of the optimal operation conditions of d-c-excited lasers were also established.

Laser Length Standard.—A visible helium-neon laser illuminating a fringe-counting Michelson interferometer was used to explore the possibility of extending the useful range of that interferometer to the full one-meter length for which it was originally designed. The laser wavelength was measured by comparative length measurement over a decimeter distance using the interferometer with both the laser and a standard mercury-198 source. The length of a meter line standard was then measured with the laser used as light source; the value obtained agreed with the assigned length of the line standard to 18 parts in 100 million.

New Laser Wavelength Measurement.—A precision spectroscopic measurement of laser wavelengths by direct comparison with primary krypton-86 standard of wavelength was initiated.

Gage Blocks.—This year's gage block calibration activity increased 36 percent from last year and confirms a continuing increase in demand for the

highest calibration accuracy. Continued demand could seriously stress these facilities in the future; a gage block R&D effort was continued this year in an effort to avoid such a problem.

Increased Measurement Accuracy.—Improved accuracy in measurement of NBS standards will allow calibrations to be made routinely. Research and development toward this goal has continued this year. Polarization methods, theoretically capable of providing such improvement, have been investigated. Necessary refinements in instrumentation and techniques have been defined and are being introduced. Automation of calibration instrumentation has been achieved by the development of the first fully automated polarimeter.

Better Gage Block Material.—Another R&D approach to calibration problems is being undertaken through a continuing search for more stable gage block material. Greater stability of material will reduce the need for recalibrations, and thus lower the national demand on IBS.

Out-of-House Calibration Activities.—With the development of the new light-wave standard of length, it is considered feasible for large out-of-house calibration activities to duplicate present IBS measurement facilities. This activity has been promoted by providing laboratory training and consultative, advisory, and committeeman work for metrological groups. In some cases, a 90 percent reduction of NBS calibration requirements can be realized by such action.

Improved Length Scale Calibration.—Although length scales are widely used on precision instrumentation throughout the Nation, IBS receives few requests for their calibration, probably due to the inadequacy of present calibration facilities. An automatic length scale interferometer designed to correct this inadequacy was completed this year. The range capability of the instrument was enhanced by incorporation of a laser source, and initial performance tests of the complete system indicate the probability of its use in routine calibration activity in the next fiscal year.

Measurement of Long Gage Blocks.—The accuracy of length measurement on gage blocks between 5 and 50 inches is limited by the ability to obtain accurate measurements of temperature and pressure. Because of the great variation in thermal coefficients in blocks made by different manufacturers, temperature uncertainties of 0.005 °C cannot be tolerated. Consequently, the temperature measuring equipment for interferometric comparisons and absolute stepping measurements are being modernized. A Hass barometer has been purchased and will permit more reliable pressure measurements.

Mass

A platinum iridium kilogram kept in the vault at Sevres, France is the International Standard of Mass. IBS has two platinum iridium replicas of this standard, as well as numerous additional mass standards of baser

metals. No promising proposals have been made to substitute a more modern standard for this unit nor does there seem to be any real need for such. Efforts are therefore devoted toward improving the method of disseminating this international standard within the United States.

New Weighing Technique.—Improvements in the technique of elastic weighing are giving results comparable with those obtainable with the best platform balances. The elastic weighing procedure is particularly applicable to the measurement of large masses in the 10 to 20 thousand pound range, where platform balances are cumbersome and expensive. With this technique, highly portable equipment can be placed in any laboratory where it is desired to compare large masses. This is particularly useful in calibrating dead weight machines which in turn are used to calibrate load cells for measuring rocket motor thrust.

Calibration of Mass Standards.—A pilot program in the calibration of mass standards has recently been initiated, in accordance with the NBS policy of providing calibration services only when they are not readily available elsewhere. This program extends a uniform methodology which will allow the maximum utilization of currently installed measurement equipment.

Frequency and Time

The NBS frequency standard uses as a reference a particular frequency of the cesium atom. This standard also provides a basis for measuring time, since one can use the frequency of the atom as a highly accurate clock "pendulum"—an electronic system which essentially counts the "ticks" or oscillations of the cesium atom. A recent evaluation of this frequency standard revealed that it has an accuracy of 5 parts in 10^{12}—equivalent to a loss of no more than one second in 6,000 years.

The Atomic Frequency Standard.—The NBS frequency standards and atomic clocks achieved new importance during the past year because of an agreement reached at the 12th General Conference of Weights and Measures which met in Paris during October of 1964. This conference recognized that while the basic unit of time—the second—is defined in astronomical terms (as a fraction of a particular year), national standards laboratories customarily measure this unit with atomic frequency standards because they are faster and more accurate. In view of this, the International Committee of Weights and Measures agreed that cesium beams could be officially used to determine the unit of time. This is, however, a temporary decision, pending further developments in the field of atomic frequency standards. The NBS Radio Standards Laboratory contributed strongly to this new agreement both by developing what are probably the most accurate and carefully evaluated frequency standards in the world and by contributing directly to the discussions in Paris.

Atomic Standard Broadcasts on WWVB.—On January 1, 1965, the Radio Standards Laboratory began broadcasting, via radio station WWVB, the

international unit of time as determined by the NBS cesium beam frequency standards. Thus the NBS cesium beam frequency standards are now serving as the national standard of both time and frequency, and for the first time, users can receive time signals based on an atomic time scale.

Hydrogen Maser a Possible Frequency Standard.—A hydrogen maser built at NBS was put into operation at the Radio Standards Laboratory and is being evaluated as a primary standard of frequency. It is also being used to study multiple quantum transitions.

Atomic Beams.—An experiment with an atomic beam apparatus, involving comparison of cesium-beam devices, hydrogen masers, and a thallium beam device, gave strong evidence that thallium may give better accuracy than cesium.

Oscillator Noise Investigated.—A self consistent treatment and a statistical model of "flicker" noise (one type of noise that is characteristic of quartz crystal oscillators) have been developed, along with elaborate methods of spectral classification of other types of noise.

U. S. Frequency Standard Reevaluated.—An extensive error analysis has been performed on the cesium-beam resonator (NBS-III) which is the U. S. Frequency Standard (USFS). This analysis revealed that frequency can be measured with a 99.9 percent confidence to an accuracy of 5 parts in 10^{12} with the USFS. A portable clock experiment performed by the Hewlett-Packard Company, which compared the USFS with similar standards of other laboratories, substantiated this figure.

Atomic Beam Phase Shifts.—A theoretical study of radiation-field-dependent frequency shifts in atomic beam resonances has provided an important method of determining phase shifts in the atomic beam frequency standards. This improved method and understanding should provide higher accuracy determinations for the USFS.

WWV, WWVB, WWVH Expand and Improve Services.—With reference to the dissemination of time and frequency standards, WWVB was shifted to a frequency with zero offset in the spirit of the new definition of time in terms of an atomic standard. In response to questionnaires to the users of WWVB, more than 2,000 replies were received indicating the popularity of this station. Plans for a new station WWV, at Fort Collins, Colo. were developed during the year, and some of the contracts for its construction have been completed. Also 2.5 MHz transmissions were added to WWVH in Hawaii.

Very-Low-Frequency Experiments.—In an effort to devise a satisfactory technique for precise timing at very low frequencies, using the highly stable propagation characteristics of these frequencies, NBS has been experimenting with multiple-frequency transmissions in the vicinity of 20kHz. Two or more frequencies are transmitted alternately, and when received, these signals may be reconstituted to produce a beat frequency equal to the difference between the two signals transmitted. This beat then provides

markers which may be used to identify the cycle of the carrier which is "on-time."

Transmission problems have also been studied. Of primary concern is the control of carrier phases so they are precisely related to each other at all times as they are transmitted. The characteristics of the receivers necessary to decipher these signals have also been studied.

Low Frequency Broadcasts.—WWVB (60kHz) at Fort Collins, Colo. has been prepared for more continuous service by the addition of a new stand-by antenna capable of radiating about 1 kilowatt of power. When this facility is completely established it will be possible to shift from main to stand-by facilities in a matter of several minutes, thus permitting sub-

View from the top of one of the 400-ft towers which support antennas of the 60 and 20kHz WWVG and WWVL transmitting stations at Fort Collins, Colo.

stantially continuous service. To exploit this continuous type of service, a new time code suited to low-frequency transmissions has been designed and equipment procured for its generation. This time code will allow the identification of time markers to be directly recorded on chart recorders.

Dissemination Research.—Studies of the propagation characteristics of stations WWVB (60 kHz) and WWVL (20 kHz) were recently begun to determine the accuracy with which frequency and time signals may be disseminated to any given site within each station's respective service area. (WWVB is designed to serve the continental United States, and WWVL to meet U. S. needs in much of the rest of the world.)

High Frequency Broadcasts.—A new frequency (2.5 MHz) was added to the broadcast of WWVH located in Maui, Hawaii. This frequency provides ground wave coverage of the Hawaiian Islands with improved accuracy capabilities.

WWV, now in Greenbelt, Md., will be relocated at Fort Collins, Colo. From this more central location, it will be able to provide better coverage at higher accuracy for most of its customers. The move is planned for July 1, 1966.

Temperature

The thermodynamic temperature scale is defined by assigning a value to the triple point of water. Then using thermodynamic relations and appropriate techniques, the scale is realized at points in other temperature ranges. To provide a common basis for defining temperatures, IBS works to realize the International Practical Temperature Scale (IPTS), the lower limit of which is defined at 90 °K (–183 °C). Other scales have been established at NBS to extend the practical range down to 2 °K.

Improved Temperature Scale.—A photoelectric pyrometer has been developed with which the International Practical Temperature Scale (IPTS) above the gold point, 1063 °C, is realized about ten times more accurately than with the standard disappearing filament visual pyrometer. The instrument has a temperature resolution of 0.2 °C, about 20 times better than the visual pyrometer.

The significantly greater resolution of the new pyrometer has served to reveal unpredicted sources of inaccuracy that were obscured in the visual pyrometer by the lack of observer precision. Pyrometer lamp instabilities remain the major limitation to accuracy, and their effect is minimized by frequent recalibration.

The IPTS has been realized with an estimated uncertainty (95 percent confidence) of 0.07 °C at 1063 °C, 0.35 °C at 1650 °C, and 1.9 °C at 3730 °C. To correct for lamp drift, the pyrometer is recalibrated at the gold point after each 100 hours of use, and further recalibrated at other points in the low range after every 200 hours of use.

Platinum Resistance Thermometer.—In an attempt to provide a more accurately realizable International Practical Temperature Scale, the platinum resistance thermometer is being studied as a possible instrument for interpolating between fixed points in the range 630.5 to 1063 °C. Thermometers have been designed and techniques worked out which show that these instruments should in fact be proposed for international adoption as the specified means of interpolation.

New 4-20 °K Calibration Service.—A calibration service for germanium resistance thermometers in the 4-20 °K range was initiated. The new NBS temperature scale, obtained with the acoustic thermometer, has been transferred to six germanium thermometers which are used to check the customers' units.

Work is continuing to establish the absolute integrity of the new scale and to develop means for more accurately interpolating the resistance-temperature curve between calibration points.

Luminous Intensity

Early research at NBS led to the development of an international standard for luminous intensity based upon the radiation from a black body at the temperature of freezing platinum. This unit—the candela—is defined as the visible radiation from 1/60 of a square centimeter of this source.

The development of higher temperature incandescent, fluorescent, and vapor lamps has caused this standard to be less suitable than when it was originally developed. Investigation of alternate methods of realizing this standard are thus under way. One proposal being investigated is to define the standard of luminous intensity by absolute photometry in terms of the radiation in watts from a source multiplied by the response of the average human eye to radiation. The radiation produced by the source would be measured by comparing its thermal effect with the thermal effect of a known electric current passed through a known electrical resistor.

Absolute Photometry.—Two instruments intended for the direct measurement of irradiance in terms of electrical units are being studied. The first is a thermoelectric instrument of the type designed by Guild of the National Physical Laboratory; the second is a resistance-type instrument of IBS design which uses a blackened cone as a receiver. In each instrument the temperature rise produced by the incident radiant energy is duplicated by a temperature rise produced with an internal electric heater. The electric power required to produce this rise is then measured by conventional methods, the incident radiant power being equal to the electric power, subject to correction. This power can then be converted to luminous units. The two instruments have been assembled, and preliminary tests have been completed.

Electric Current

Activities in this area are described along with the other electrical quantities.

MECHANICAL QUANTITIES

Force

Force is a derived mechanical quantity equal to the product of mass times acceleration. In the International System, the unit of force is the Newton, defined as that force which, when acting on a one kilogram mass, will give the mass an acceleration of one meter per second per second. At present in the United States it is customary to use the units of pound force or kilogram force. These are the forces which, acting on masses of one pound or one kilogram, will produce an acceleration of 9.80665 meters per second per second, which is the acceleration due to gravity.

Dead Weight Machines.—The most convenient method of obtaining accurately reproducible forces for the calibration of transfer standards is by means of dead weight machines. In such instruments, the force of the earth's attraction on the dead weight masses is applied to the device being calibrated. It is desirable to adjust the dead weight masses to take account of air buoyancy and the difference between the acceleration due to

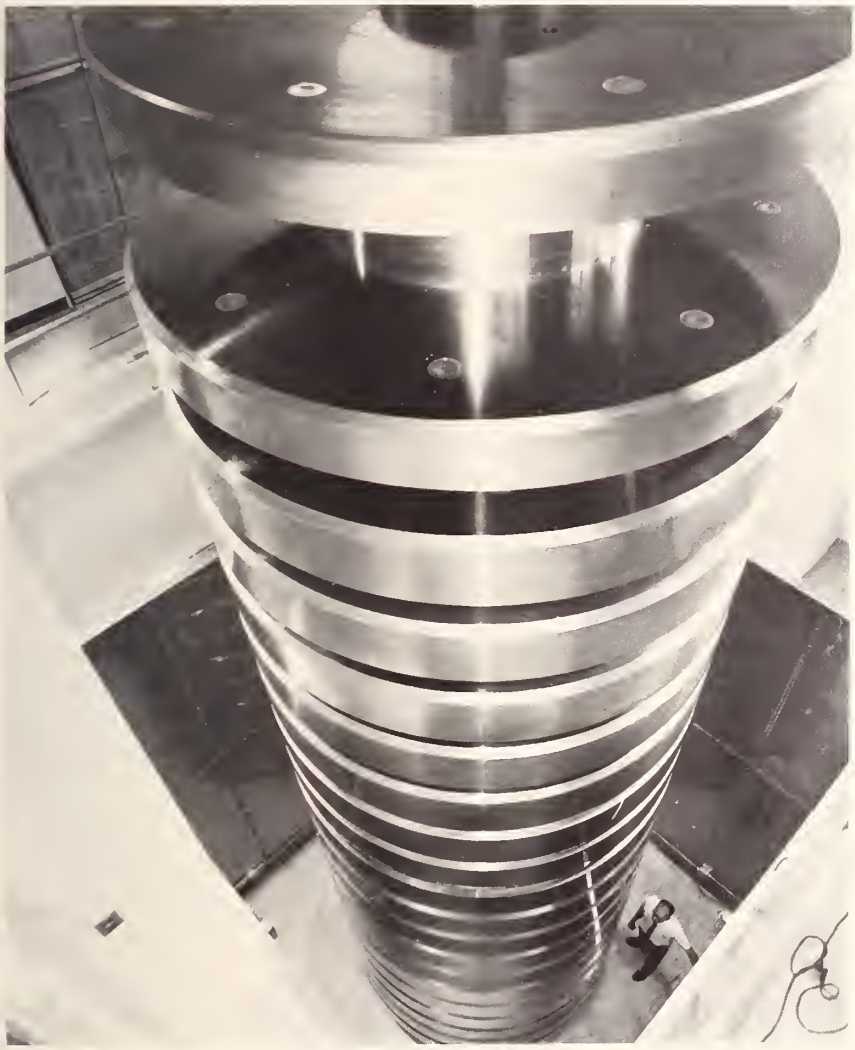
Deadweights prior to installation in three large-capacity deadweight machines at NBS. The 50,000-lb weights are 10 feet in diameter; the 1,000-lb weights are 3 feet in diameter.

gravity at the site of the dead weight machine and the standard value of 9.80665 meters per second. To provide the needed local value of acceleration due to gravity, an absolute determination, involving the measurement of the time required for quartz rods to fall known distances in a vacuum, has recently been completed. The results, which will be released shortly, provide the local value used in adjusting the masses to an accuracy of about one part in two million.

New Standards for Force Measurements.—Three new deadweight machines with 112,000- 300,000- and 1,000,000-pound force capacities have been manufactured, adjusted, and placed in operation. These machines provide approximately 9 times the deadweight capability previously available for calibrations of force measuring devices. Devices calibrated with these machines will be used as "transfer standards"; They will also be used directly in critical applications such as measuring rocket and jet engine thrusts, and weighing rockets and rocket components. Uses of the

transfer standards will include calibrations of testing machines for determining mechanical properties of materials. They can also be used as laboratory and plant standards for calibrating other force measuring devices.

Forces applied with these machines are derived from the acceleration due to gravity acting on the dead weight masses carefully adjusted to compensate for both gravity and air buoyancy such that the applied loads are in units of pound force. Errors in the applied forces do not exceed 0.002 percent, 10 times better than the older machines, and up to 50 times better than the previously used procedures and equipment for measuring 1,000,000 lb loads. Besides the increased accuracy, substantial savings



Deadweight stack of the new 1,000,000-lb deadweight machine. James I. Price, staff member, adjusts the temperature control.

in the time required to calibrate the larger devices has been realized. For example, time required to calibrate 300,000 lb-f and 1,000,000 lb-f capacity elastic force measuring devices in compression has been reduced about 30 and 50 percent, respectively.

Pressure

Work has continued on more precise determination of pressure scale reference points. This included preliminary measurements of the transition pressure for change in the crystalline form of bismuth (the Bi I-II transition near 400,000 psi). The work was done with a dead-weight-loaded free-piston gage, and is believed to be the highest pressure at which this type of instrument has been successfully used.

At lower pressure, work was initiated on an investigation of air-lubricated piston gages for possible use as standards of absolute pressure in the range near one atmosphere. If this work is successful, it may be feasible to supplant the mercury column as a reference device in many cases, thus providing a standard with substantially improved characteristics.

Vacuum

A Vacuum Measurement Section has been established in IBS as a separate entity to emphasize effort in a much needed area.

Absolute Instruments for Low Pressure Measurement.—In the range down to 10^{-5} torr, successful preliminary work has been completed on liquid column instruments of two types, with liquid surface displacement for the higher pressures being measured by micrometer driven point-contacts and for the lower pressures being measured by interferometric means. Work has been completed on a micrometer manometer which employs a silicone oil as the manometric fluid. The measurement uncertainty is 4×10^{-4} torr with a least count of about 1×10^{-4} torr.

Stable Pressure Generator.—The design of a balanced flow pressure facility to obtain stabilities of 1 part in a 1000 over the range 10^{-3} to 10^{-8} torr has been completed and construction has begun. The facility will give a stable environment with which a number of absolute procedures can be compared. Design aspects stem from previous molecular flow research.

Calibration Service.—A formal calibration service has been initiated for the range 1 to 1000 millitorr utilizing precision liquid columns, such as the NBS micrometer manometer, as reference standards. A console vacuum calibration facility is nearing completion; it will permit this work to be carried out with proper vacuum environments on a repetitive basis.

Vibration Measurements.—An improved secondary standard for comparison calibration of vibration pickups was built. Inaccuracy in earlier comparison calibrations usually arose because the two pickups being com-

pared did not experience the same motion at all frequencies and because the loading effect of the pickups and their mounting fixture caused unbalance.

Vibration Pickup Calibration.—The accuracy attainable in calibrating vibration pickup above 2000 Hz was increased by improvements in the design of piezoelectric vibration exciters. At frequencies below 2000 Hz the electrical measurements required for vibration pickup calibration consist of voltage ratio determinations. A new circuit for determining a-c voltage ratios was developed and found to be superior to earlier methods in senstivity, convenience, and speed. It uses a sensitive inductive voltage divider to reduce the larger of two signals to the level of the smaller. Thermocouples are used to convert the a-c signals to d-c so that they can be balanced.

Vibration Pickup Calibration by Interferometry.—The measurements required for vibration pickup calibration by photometric interferometry are voltage and frequency. New equipment was obtained to convert these quantities to digital signals and couple them to a tape punch. This arrangement ensures that the two quantities are determined simultaneously, minimizes errors in reading and recording data, and presents the data in a form suitable for use with a digital computer.

Microphone Calibration.—Using an anechoic—echo and reverberation free—chamber, measurements were begun on the ratio of the perpendicular to grazing-incidence response of standard microphones to plane sound waves. At frequencies above 10 kHz, it was found that the response of high-quality condenser microphones at grazing incidence is a function of the angular position of a microphone on its own axis of symmetry; it is felt that asymmetrical vibrations of the circular diaphragm occur and cause this effect. This was confirmed by observations of the sound pressure produced in a closed cavity by a condenser microphone used as a source of sound. It was concluded that for the utmost accuracy in calibrating a reference standard microphone, the propagation of sound waves during a calibration should be perpendicular to the plane of its diaphragm.

Humidity Calibration Service.—A service for the calibration of humidity-measuring instruments was initiated for both government agencies and the public. Instruments suitable for use as laboratory or plant standards are being accepted for calibration. The calibrations are normally performed by subjecting the instrument under test to atmospheres of known moisture content produced by the NBS two-pressure humidity generator which, in turn, has been calibrated against the NBS standard gravimetric hygrometer. Calibration results are reported in terms of dewpoint temperature (°C), mixing ratio (grams of water vapor/kilogram dry air), volume ratio (parts of water vapor/million parts of dry air), or relative humidity (percent).

Resistance Ratios

Mathematical analysis of a compensated series-parallel resistance box showed that it is feasible to construct a d-c resistance ratio standard (100:1) having an inaccuracy of only 1 part in 100 million.

Voltage

Zener Diode Studies.—Studies of zener diodes were conducted and show that some types in the 9-volt range exhibit voltage stability to 5 parts per million over a 4-year period.

Voltage Transformer Test Set.—A new type of voltage-transformer test set has been developed. It is compact and portable, has a large useful frequency range and surpasses present sets in accuracy by one to two orders of magnitude. The test set can compare voltage ratios to 2 parts per million, and phase angles to 15 microradians.

Current Ratio Standards

An international comparison of the new NBS a-c current transformers and the magnetic balance a-c current comparators of NRC in Canada has independently verified that the accuracy of each type is known to a few parts per million or better over a wide range of audio frequencies. These two very different types of ratio standards are very important devices for establishing the scale of alternating current. Their excellent performance should open up new possibilities for current-sensitive instruments and standards as well as to provide much more accurate calibration services for current transformers.

New Compensated Current Comparator

A "compensated current comparator" has been designed and constructed, using principles developed at NRC (Canada), with improvements in shielding and other details. It is intended as a standard for calibrating current transformers from 1 to 1000 amperes and low-audio frequencies (up to 1 kHz). Preliminary measurements where performance (according to NRC's experience) would be expected to be poorest show errors of less than 0.1 part per million up to 400 Hz, 0.4 parts per million at 1 kHz, and less than 3 parts per million at 5 kHz.

Absolute Electrical Measurements

New Standard Capacitors.—A bank of ten picofared standard capacitors has been completed and has undergone extensive testing. These capacitors contain fused silica dielectrics, and are improvements on an earlier NBS design. They appear to be unstable by less than 2 parts in 10 million per year, and have been successfully shipped via parcel post with no observable change in value. Some of these capacitors will be used in an international comparison of capacitance in the coming fiscal year.

New Voltage Dependence Measurement Technique.—A technique for measuring the dependence of capacitance upon voltage in three-terminal standards has been developed. Measurements on some standards were carried out to an uncertainty of about 1 part in a billion. This work is an essential part of the process for comparing transportable capacitors with a calculable standard, and will also be used in conjunction with a proposed absolute determination of the ohm.

Audio-Frequency Admittance Bridge Designed.—Design studies for a very wide range audio-frequency admittance bridge have been completed, and construction is under way. The bridge will be used to compare admittance from 1 to 10^{-8} mho with an uncertainty of a few parts in 10^9 from 160 Hz to 16000 Hz. The bridge makes use of multi-stage transformers and multiple null balances with weighing networks.

AC-DC Transfer Standards

All measurements of alternating current and voltage ultimately depend on a-c–d-c transfer standards which compare the a-c quantity with a d-c value derived from the basic standard cells and resistors. The Bureau has recently determined that the a-c–d-c difference of its new reference group of 5 and 10 milliampere thermoelements is less than 2 parts per million over the full range of audio frequencies—more than an order of magnitude better than any transfer standards heretofore available. This development will ultimately provide a firmer base for the construction and calibration of new types of commercial units, such as improved a-c voltage standards, which are now stable to better than 100 parts per million (0.01 percent).

Voltage Ratio Detector for Millivolt Signals

A ratio detector for measuring ratios of a-c or d-c signals 5 millivolts or larger was designed. Two ratio detectors have been put into operation, one in the calibration of transfer standards of vibration and the other in research on internal damping of solids. Ratios are determined with a precision divider which has an accuracy better than 0.001 percent and sufficient sensitivity and stability to indicate differences between two signals of 0.01 percent. Important characteristics of this design are that the measurement is independent of the wave shape and phase difference of the signals, and when two devices operate in series, the measured ratio is not affected by small changes in the amplitude of vibration.

ELECTRICAL QUANTITIES—RADIO

Low-Frequency Calibration

Voltage Standards.—The NBS voltage standards at the Boulder and Washington laboratories have continued to remain in agreement within a few parts in 10 million, determined by measurements on a traveling group of saturated standard cells.

Wire Winding Technique for Resistors.—A-c–d-c difference errors in mica-card wire-wound resistors have been successfully controlled by employing a special winding technique developed over a period of several years. These resistors are used as voltage multipliers in thermal voltage converters. A recently constructed set of thermal voltage converters has a-c–d-c difference errors less than 0.001 percent over the frequency range of 20 Hz to 50 kHz. The latest results indicate that at least some of the converters have very small errors up to 1 MHz.

Inductive Voltage Divider Calibrations.—Multi-section inductive voltage dividers having calculable relative errors were used as a basis for calibrations on inductive voltage dividers with limits of error of $\pm 0.2 \times 10^{-6}$ at 100 Hz and $\pm 2 \times 10^{-6}$ at 10,000 Hz.

Manganin Strip Temperature Determined.—It was determined experimentally that the temperature in the center of 2.5 mm thick manganin strip does not differ from the surface temperature by more than 0.05 °C while the manganin strip is carrying a current of approximately 10 amperes per centimeter of width. Hence, the precise determination of manganin temperature, which is required for the purpose of applying accurate corrections, may be made by affixing a thermocouple to the surface.

High-Frequency Electrical Standards

Coaxial Junction Intercomparison.—A coaxial "tee" junction developed during the year allows intercomparison of rf voltage measuring devices at frequencies up to 100 MHz with an uncertainty no greater than 1 percent regardless of the input impedances of the devices. Formerly, intercomparison uncertainties as large as 10 percent were common.

International Radio-Frequency Intercomparison.—Intercomparison of radio-frequency power standards was completed between the United States and Canada. This was done at two frequencies, 300 MHz and 1000 MHz, using a directional coupler-bolometer mount combination as a transfer standard. The transfer standard was first calibrated at the National Research Council, hand carried to NBS-Boulder Laboratories, and calibrated again, using the U. S. coaxial reference standard calorimeter. The difference between measurements in the two countries was 0.11 percent at 300 MHz and 0.24 percent at 1000 MHz.

Power Pulse Standard Frequency Range Extended.—The frequency range of the rf peak pulse power reference standard was extended to include the frequencies from 300 to 500 MHz. This new band augments the 900 to 1200 MHz band in which calibration service has already been established. The power range extends from 0.2mW to 2kW with an uncertainty of 3 percent. Work is in progress to further extend the measurement range to the 2000 to 2500 MHz band.

RF Power Standard Modified.—The dry-load coaxial rf power reference standard calorimeter was modified and evaluated for use at frequencies up

to 4000 MHz. Formerly the frequency range extended only to 1000 MHz. The calorimeter measures rf power in the range 0.02 to 5 watts with an estimated uncertainty no greater than 0.5 percent up to 4000 MHz. It serves as the basis for a new calibration service established at 3000 MHz.

Thermal Noise Generator.—A liquid-nitrogen-cooled thermal noise generator has been built to serve as an interim standard of noise power at 30 MHz. The generator source impedance is adjustable, drift is less than 150 ppm per hour, and temperature is constant to better than 0.05 °K over long periods of time. This generator is being used in the development of a calibration capability for random noise generators.

Hydraulic Method Produces Small Displacements.—A hydraulic method for producing small displacements is being investigated for use in the piston adjustment of a waveguide-below-cutoff attenuator. The system consists of a cylindrical cavity filled with hydraulic fiuid.

Field Strength Computation.—A highly efficient procedure was developed for computing the complex vector radiation pattern and the far field of large circular antennas from near field data.

High-Frequency Impedance Standards

Technique Determines Inductance.—A general numerical integration technique was developed for determining the self and mutual inductance as well as current distribution in systems of rectangular conductors. This technique is convergent to one part in 10^5.

Study of Ammeter Errors.—A comprehensive error analysis has been developed to optimize the operation of the electrodynamic ammeter. This instrument will provide a standard of radio-frequency current and consequently act as an independent check on high frequency power and voltage standards. The analysis include such things as the mutual inductance between a ring and a coaxial line as a function of position and orientation, errors due to mechanical imperfections, and effects of image current due to the ring on the walls of the system.

Resistor Ratio Instrument.—A new versatile ratio instrument has been developed which can compare resistors with ratios from 1 to 10,000 to 6-place accuracy. The use of tetrahedral junctions which eliminate transresistance errors makes the instrument possible. Not only can the instrument serve to measure high ratios more accurately, but it also serves as a universal ratio set, a direct reading ratio set, a set of 4-terminal resistance standards, and a 2- or 4-terminal 6-decade resistance box.

Coaxial Line Measurement.—Two significant developments were made in coaxial line measurement techniques. A floating tool technique now makes it possible to machine coaxial line standards to tolerances of 10 to 20 micro-inches over a 30 inch length. This is an order of magnitude improvement in the standards which serve as the basis for high frequency impedance measurements. Second, the NBS-designed critical mating con-

figurations have been accepted to standardize 7 mm precision coaxial connectors and are being used by major manufacturers in this country and abroad as the basis for their new precision connectors and instruments. Standardization of connectors used on precision electronic instruments makes possible assembly of high frequency circuits in a "tinkertoy" fashion with high precision and accuracy. This results in much improved performance with a considerable saving in time and money.

High Frequency Capacitor Standard.—A new set of capacitors has been put into operation to maintain the unit of high frequency capacity. They range from 100 to 100,000 picofarads. A computer program developed for intercomparing the capacitors gives initial stability and comparison precision sufficient to produce a standard deviation of around 30 parts per million without special temperature control.

High-Frequency Calibrations

During 1965, existing calibration services were expanded and extended, and new services, such as peak pulse power calibrations, were added. CW power bolometer calibrations, interrupted in 1963, were restored with a much lower calibration charge and with inaccuracy reduced by better than 50 percent. Every high frequency calibration service has been extended either in frequency, accuracy, or both.

Customer Liaison.—Emphasis has been placed on achieving closer liaison with the customers to better determine their needs and to acquaint them with services which are available. As a result there has been an increase in the number of calibrations requested, and it is felt that an even greater increase will be shown in the future.

High Frequency Coaxial Calibrations.—Because of the new precision coaxial connectors which the Bureau helped greatly to develop, most coaxial calibrations are now made at frequencies well above 1 GHz. The demand for higher frequency coaxial calibrations has been heavy. In many cases services have been ahead of the demand, and plans are to extend services to the extent made possible by the new components.

Immittance Calibrations Improved.—Increased accuracies of an order of magnitude or more are now being offered in immittance calibrations, partly as a result of the new precision connectors. This has resulted in a definite increase in immittance calibrations and should lead eventually to the recalibration of all such equipment in the country.

Microwave Standards

International Comparisons.—International comparisons were made during the year of impedance standards of Canada and the United States and of power standards of the United Kingdom and the United States.

X-Band Calibration Service.—Pending establishment of a permanent phase-shift calibration service in the Electronic Calibration Center, an

interim X-band service was provided by the Microwave Circuit Standards Section. Ten phase-shifters from the Army, Navy, Air Force, and several corporations were calibrated.

Transfer Technique Promotes Better Services.—The technique of transferring calibrations between power meters with different input waveguides has been refined to the point where it may now be employed with items having the type N connector. As a result, the announcement of a coaxial bolometer mount calibration service at a frequency of 9 GHz is imminent, and extension to other frequencies is envisioned.

High Power X-Band Source.—A high power X-band with an unprecedented combination of amplitude and frequency characteristics has been developed for use in a traveling-wave oscilloscope beam-deflection system. The source uses ultra-stable frequency control circuits modified to permit continuous frequency adjustment. Its output frequency is tunable between 9.8 GHz and 10 GHz with an accuracy and resolution of one hertz. The supply will deliver any output power in the range 1 to 750 watts with 0.1 percent per hour stability.

Quarter Wave Technique.—Analysis of a quarter-wave technique, i.e., a technique based on the use of a precision quarter-wave section as a "lossless" 180° phase-shifter, has pointed the way to experimentally simplified measurement of impedance and related quantities in limited areas. It was shown, both through theory and experiment, that in using an untuned reflectometer to measure reflection coefficients, the quarter-wave procedure eliminates the effect of the directivity factor and reduces to second order the effect of generator reflection. The new approach is well adapted to use in precision coaxial systems in the frequency range 100 to 1000 MHz.

Coaxial Waveguide Reflectometer.—Coaxial waveguide reflectometers covering the frequency range 8 to 18 GHz were constructed and used in the evaluation of precision connectors for 7 mm coaxial lines. This work is a part of a connector improvement and standardization program sponsored by the IEEE and involving national and foreign corporations.

Millimeter Wave Studies.—Millimeter wave progress has included the evaluation at 70 GHz of the two most popular commercial millimeter wave connectors and the phase-locking of a 155 GHz carcinotron to a National Working-Standard Frequency.

Microwave Calibrations

Two international comparisons in microwave attenuation measurements were made during the year. Fixed waveguide attenuators in WR 90 waveguide were used for insertion loss measurement comparisons at 10.0 GHz with Canada, and a variable waveguide attenuator in WR 284 waveguide was used for attenuation difference comparisons at 3.0 GHz with Sweden.

Microwave Power.—A microwave power calibration system was developed for the measurement of low-level, cw power in WR 112 waveguide

(7.05 to 10.0 GHz). In the interest of speeding up the calibration service, an existing waveguide microcalorimeter, designed for use in WR 90 (8.2 to 12.4 GHz) waveguide, is used to calibrate WR 90 working standards, which in turn are used to calibrate WR 112 inter-laboratory standards to an accuracy of ± 1 percent.

Microwave Impedance.—A microwave impedance calibration system (reflectometer) was developed for the measurement of reflection coefficient magnitude in WR 137 waveguide (5.85 to 8.2 GHz). This calibration system used improved frequency control methods to increase the system stability and improve measurement accuracy. The reflectometer uses a precision waveguide section with a modified gage-block design which approaches a dimensional accuracy of 70 micro-inches. Calibration services covering the waveguide frequency range were announced.

Microwave Noise.—A microwave noise calibration system (radiometer) was developed for the measurement of effective noise in the high-temperature range of WR 62 waveguide (12.4 to 18.0 GHz). Also, a hot-body noise reference standard was developed for operation at approximately 1000 °C in this waveguide size. Calibration services covering the waveguide frequency range were announced.

PHOTOMETRIC AND RADIOMETRIC QUANTITIES

Detector Spectral Response Recorder.—An instrument has been constructed to record quickly the spectral sensitivity of photodetectors in the visible spectrum. The output of a grating monochromator is split so that one portion is fed to the detector whose spectral sensitivity is under investigation while the other portion is fed to a vacuum thermocouple which also sees alternately a small incandescent reference source. This arrangement permits direct recording of the relative spectral sensitivity of a phototube and direct comparison of the spectral sensitivities of two or more tubes. The present wavelength limits are 0.36 to 0.80 micron. Recording time is about one minute.

Centroid Color Charts.—A new set of color charts has been produced by NBS in cooperation with the Inter-Society Color Council. It was published as a supplement to NBS Circular 553, Dictionary of Color Names, and is for sale by the NBS Office of Standard Reference Materials. The centroid colors illustrate typical colors of 251 of the 267 color designations in the ISCC-NBS method. Besides their use as a supplement to the Dictionary of Color Names, these centroid colors can be used for a number of purposes in science and industry including color standards for acquisition or inventory control, color-trend studies of consumer acceptance of manufactured goods, and color communication.

Infrared Spectral Reflectance Measurements.—Construction has been completed of an ellipsoidal mirror reflectometer capable of measuring bi-

directional reflectance, directional hemispherical reflectance, specular component reflectance, diffuse component of reflectance, and directional annular-cone reflectance. This instrument has been calibrated and tested and is capable of an accuracy of better than one percent from 0.4 to 10 micron for all engineering materials regardless of their level of reflectance or the manner in which they reflect (except retroreflectors). The instrument is presently undergoing extensive modifications to further improve its accuracy, versatility, and usability. It is intended that it will provide accurate data for future data-accumulation programs, theoretical property studies, heat-transfer studies, and the preparation of NBS reflectance standards.

Total Irradiance Standards.—The carbon-filament lamp standard of total irradiance set up in 1913 is handicapped by the high proportion of long-wave emitted energy whose absorption depends strongly on atmospheric humidity. Use of standards with higher filament temperatures (2,800 instead of 2,000 °K) would largely overcome this handicap, and considerable progress has been made toward establishment of three new standards in the form of 100-, 500-, and 1000-watt tungsten-filament lamps. The socket and the glass bulb, except a short section within the vicinity of the filament area, are shielded from the radiometer to reduce further the proportion of long-wave energy. The lamps are calibrated by radiometric comparisons with a blackbody supplemented by checks against the carbon-filament lamp standards.

Influence of Surround on Color Perception.—This influence has been long known qualitatively. A dark surround—or background—makes the target appear lighter; a red surround, greener; and a yellow, bluer. Quantitative studies indicate that lightness is particularly subject to this influence when the reflectance of the surround is slightly higher or lower than that of the target. A mathematical model has been formulated, and studies on the influence of chromatic surrounds have been carried out.

Reflectance Standards and Their Calibration.—Industrial laboratories have long desired a reproducible and easily prepared standard of spectral reflectance. Pressed-power specimens of magnesium oxide and barium sulfate have been under investigation by NBS for some time. This year, a test of reproducibility has been conducted under the auspices of the American Society for Testing and Materials (ASTM). When reagent-grade powder is used, pressed standards can be reproduced to a few tenths of a percent throughout the visible spectrum compared to a reproducibility of a few percent for freshly smoked MgO standards. As a result of the NBS investigation, ASTM is now publishing a Recommended Practice for Preparation of Reference White Reflectance Standards. NBS has also proposed adoption of an auxiliary-sphere technique for calibration of spectral-reflectance standards on an absolute basis and this material is being published by ASTM. The reproducibility of the calibration technique is now being investigated in cooperation with several industrial laboratories.

Theory of Chromatic Adaptation.—If chromatic adaptation is caused by changes in photopigment concentrations, the nonlinear character of Beer's law requires that the color-matching functions of the eye change with such adaptation. Experimental evidence, however, indicates no significant change in color-matching functions over a wide range of adaptations. A quantitative analysis of changes in the absorptance-curve shape with changes in pigment concentration has shown that if the initial maximum absorptance of a pigment is less than 7.5 percent, the change in the absorptance-curve shape cannot exceed 1 percent of maximum at any wavelength no matter how much the pigment concentration is reduced. This result shows that the photopigment-concentration theory of chromatic adaptation is tenable.

Thermopiles for Ultraviolet Measurements.—Quantitative measurements of solar energy in the vacuum ultraviolet region has been generally unreliable for lack of an adequate calibration technique. Research has been directed toward the application of thermocouples to this problem. Two effects which might limit the reliability of these devices have been studied. The first, the "blackness" of gold black was found to be adequate in the ultraviolet. The second effect studied, the cooling of the detector by electrons that had been ejected by high energy photons, was found to be significant. The problem can, however, be eliminated by applying a modest magnetic field to the detector.

Infrared Spectral Reflectance.—The past year has been utilized effectively in providing, for the first time, a fast and efficient method of making infrared spectral reflectance measurements independent of thermal energy emitted by a specimen. In response to demands by other laboratories for infrared reflectance data, the instrument is being utilized on a regular testing basis to provide these measurements when possible. Among the materials being examined are naturally occurring minerals. Approximately 150 samples have been examined, including such materials as limonite, hermatite, carbonates, quartz, bauxite, phosphates, lava, clay, and hoarfrost; also, ten rare-earth oxides have been measured in an effort to determine their infrared absorption bands.

IONIZING RADIATIONS

Radioactivity Standards and Calibrations.—Radioactivity standards sold and calibrations performed in FY 1965 totaled 438. One new radioactivity standard, niobium 94, in the form of a gamma-ray point source, has been developed. International comparisons of manganese 54 (the first electron capturer to be so compared) and of strontium 90 in flour, at environmental levels, have been undertaken. The sodium 22 and yttrium 88 standards have been recalibrated with greater accuracy. Standards of zinc 65 and cerium 141 have been reissued with about the same accuracies.

Automatic Sample Changer.—Tests on a recently constructed automatic sample changer for gamma-ray point sources have been completed and

Automatic changer for the calibration of twenty gamma-ray point sources.

have resulted in the very satisfactory attainment of a calibration precision of 0.1 percent.

Survey of Radioactivity in Steel and Aluminum.—A survey of radioactivity in commercial steel and aluminum alloys has been initiated on behalf of the U. S. Atomic Energy Commission. It is part of an extensive study of the low-level radioactive contamination of materials used in the construction of nuclear detectors and their shields. This study will also be concerned with such contamination in reagent chemicals.

Plutonium Assay in Biological Materials.—The methods for assaying plutonium in biological materials have been revised for the Atomic Energy Commission. The detection limits reached were of the order of 0.05 picocurie per liter.

Linac Beam Current Measurements.—Work was directed to producing a Faraday Cup having a design accuracy of 0.1 percent of measured charge, and capable of absorbing the entire electron beam power of the NBS linac (about 85 kW). Construction and purchase of all major components of the Faraday Cup system has been completed. The cooling system was assembled and is being tested, and a (relatively) low impedance electronic integrator was built and is being tested. Preliminary results indicated that the effective leakage currents of the system, with cooling water flowing, is in the 10^{-8} to 10^{-9} A range and stable to about 10^{-9} A, implying that 0.1 percent accurate current measurements may be feasible down to the

one microamp range (NBS linac maximum current will approach one milliampere).

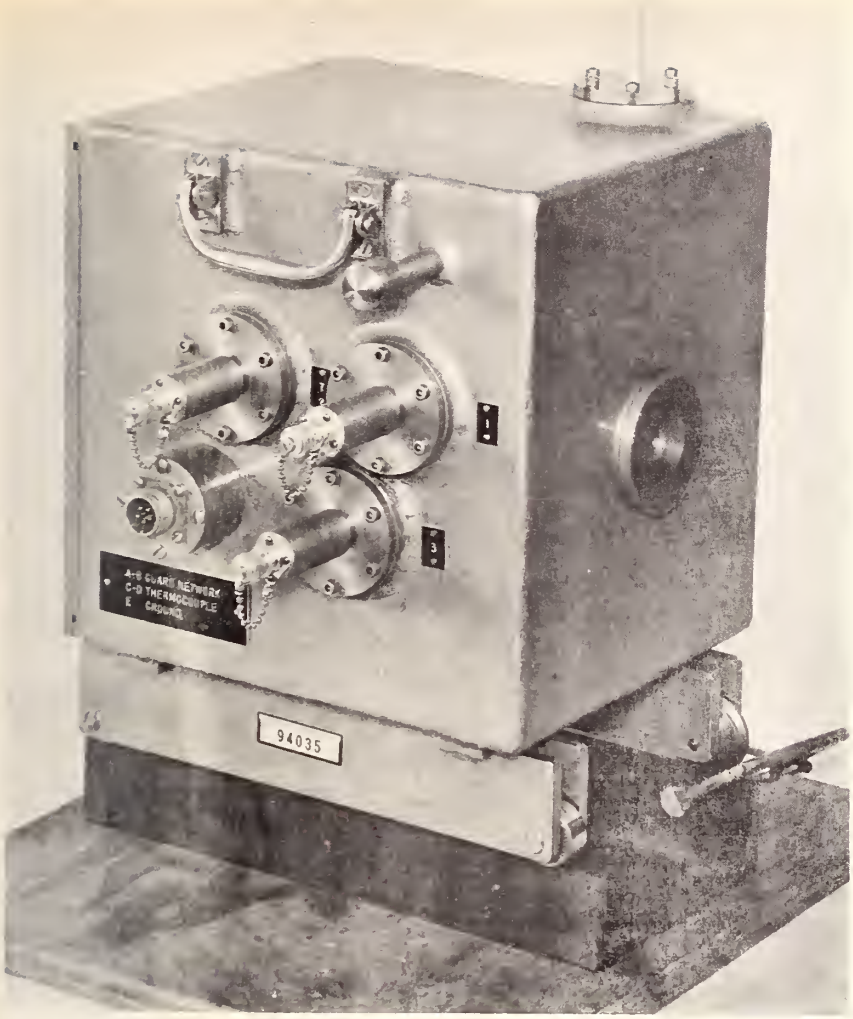
Charge Integrator.—The new high intensity electron accelerators at NBS have made necessary the development of precision current monitoring apparatus. This includes a low input impedance charge integrator. It has full scale ranges of 10^{-9} to 10^{-3} coulombs per second and its digital operation includes such advantages as a convenience, precision, visual readout, adaptability to present operation, and compatibility with on-line computers.

Calculation of Energy Required to Produce Ion Pair.—The absolute value of W, the average energy required to produce an ion pair in argon, nitrogen, and air, has been measured for alpha particles with initial energies between 1 and 5 MeV. The gases studied were chosen because they are commonly used in particle detectors. In previous investigations of this value for alpha particles with energies between 1 MeV and 5 MeV, independent determinations of the ionization and energy for the alpha sources employed were not made, and usually the energy of the sources was measured by a relative or indirect method. For the present measurements, the energies of sources, which were fabricated by placing various thicknesses of mylar film over a collimated Polonium 210 (5.3 MeV) alpha particle source, were determined by a time-of-flight method. Then the total ionization produced by a known number of alpha particles from each source in a parallel plate ionization chamber was recorded. By combining these results, W was calculated and was found not to change by more than 1 percent in the given energy range for any of the gases investigated. These results are different from reports of previous research in which an incrase of 5 percent or greater for W was observed to occur in nitrogen and air.

Cavity Chambers.—Instruments used as laboratory standards for x- and gamma-ray measurements by medical institutions, research laboratories, manufacturers, atomic energy installations, the military, and civil defense are calibrated, using the Bureau's x-ray and gamma-ray standards. The accuracy of the measurements used in these calibrations is presently better than 2 percent. During the past year, 70 such calibrations were performed.

Dye Systems.—Dye systems capable of detecting high level radiation in the 10^5 to 10^8 rad range have been studied. These dyes were previously developed for ultraviolet imaging; they are colorless until exposed to intense radiation, and their many advantages include low cost, low energy dependence, rate independence, stability, and high spatial resolution.

Advances in intense-beam radiation technology and the demand of many related applications have produced a need for better dosimetric techniques. In many high-level radiation applications—especially in food processing—the need for a uniform dose distribution is important. These new systems



The NBS national standard free-air ionization chamber for measurement of 30 to 100 kV x rays recently developed to calibrate instruments used by medical institutes and research laboratories.

are capable of high-resolution measurement of gradients—change of radiation dose over distances of the order of microns—in a heterogeneous radiation field of 10^5 to 10^8 rads.

Conventional dosimeters—such as ionization chambers, silver-halide emulsions, and certain liquid-chemical, glass, and solid-state devices—have been used for dose-distribution measurements, but these systems are generally unsuitable for the monitoring of radiation field gradients on a microscopic scale.

Intense colors are formed when the electron, x-, or gamma-ray irradiation reaches the megarad or megaroentgen level, the color depending on the type of dye used.

Source Calibration.—Calibration of radium and other small radioactive sources included 373 mg of radium consisting of 26 sources, and 465 mRhm (milliroentgens per hour at one meter) of cobalt-60 consisting of 7 sources. Five cesium 137 ranges were calibrated and 4 prototype calibration ranges were given evaluation tests. Evaluation tests of radiation instruments included 23 survey meters, 34 pocket dosimeters and 9 miscellaneous instruments.

Neutron Source Calibrations.—A Monte Carlo calculation of the correction factor for fast neutron reactions on sulfur and oxygen in the manganous sulfate bath calibration of neutron sources has greatly improved the accuracy of NBS calibration of neutron sources. This correction has been the largest source of uncertainty in most source calibrations.

Neutron Dosimetry.—A new theoretical description of the deposition of energy by neutrons in cavities has led to a better understanding of what has become a most powerful method in neutron dosimetry. Calculations based on this description have applications to fast neutron flux measurement and neutron radiobiology as well as to neutron dosimetry.

Radiation Expose Rate.—An air-filled cavity in a carbon-walled cavity chamber is often used as a standard for the measurement of exposure rate. One of the principal sources of inaccuracy of such a measurement is our lack of knowledge of the stopping power for electrons in carbon compared to the stopping power in air. The first of a series of experiments designed to improve the accuracy of this ratio has recently been completed.

ENGINEERING MEASUREMENT AND STANDARDS

Standards developed for basic and derived physical quantities find application to a great number of diverse measurement programs. All of these measurements have some connection with standards maintained by NBS, but the responsibility for utilizing the standards, developing and calibrating appropriate instruments, and interpreting the results is generally in the hands of other organizations. Occasionally, problems arise for which NBS has unique capabilities for helping to reach a solution, and in some cases NBS has an assigned responsibility to provide assistance or services, especially to other Federal agencies. Examples of such assistance are listed below.

Thermal Expansion of Materials.—Services in the length related area of thermal expansion of materials was continued this year. Samples of material with calibrated thermal expansion values and reference data on thermal expansion from the continuing compilation and evaluation of the literature were provided, on request. Expansion data for the elements have been collected and evaluated this year.

Temperature Studies.—To provide data not otherwise available, calibration equipment for the range 1100 to 1900 °K was completed. Development of other equipment for the range 0 to 300 °K is continuing, and

obsolete equipment covering the range 300 to 1100 °K was replaced. Automatic data processing programs were devised for more effective data reduction. Also, research on thermal expansion of anisotropic crystals was continued.

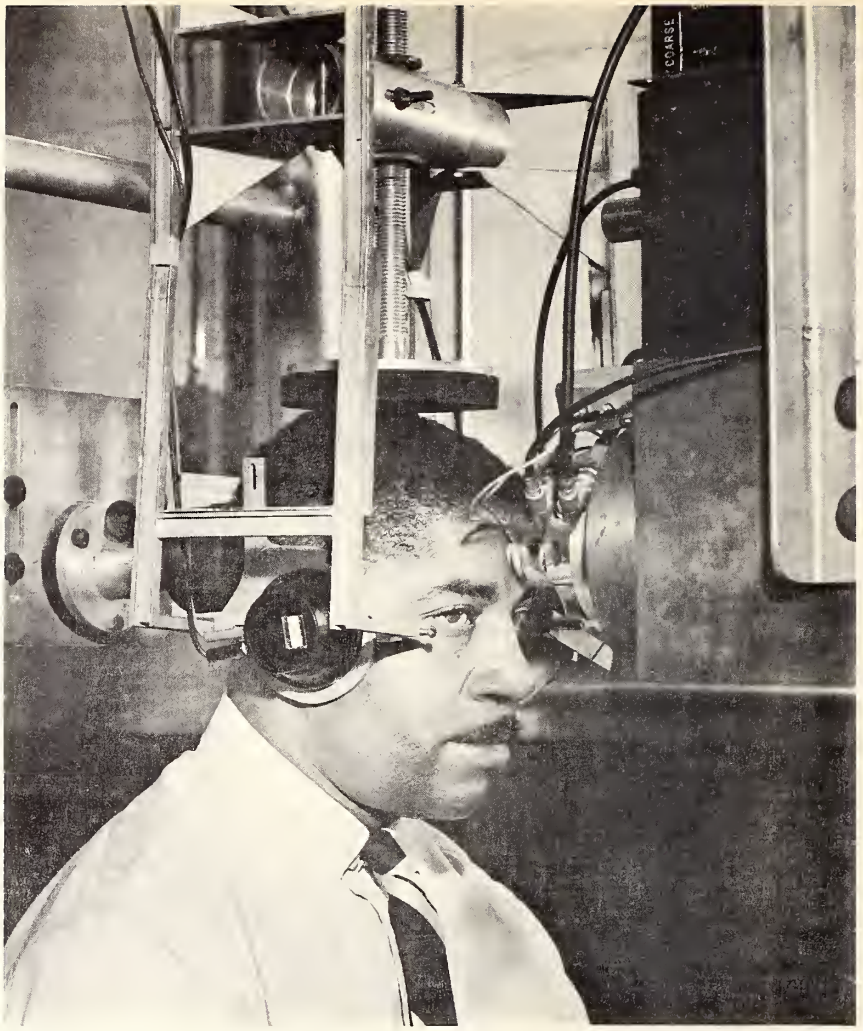
Surface Texture Simulator.—Tests using barium titanate crystal "shakers" have demonstrated the feasibility of using dynamic waveforms to test the operating characteristics of surface texture analyzers. Unlike existing surface texture specimens, the simulator provides a wide range of independently variable amplitudes and frequencies, thereby permitting response testing previously unavailable.

Stress Relaxation in Aeronautical Fasteners.—The rise in operating temperatures encountered by aircraft has increased the need for reliable and accurate design data on stress relaxation in bolts and other structural fasteners. Creep and stress relaxation studies are being carried out to establish usable correlations between the two properties; this will provide acceptable engineering estimates of fastener performance in service. Simultaneously, a standard test method is being developed for obtaining the elevated temperature stress relaxation properties of threaded fasteners.

Output of High-Power Lasers.—In response to requests for assistance from several organizations, NBS has initiated a program to develop methods of measuring the output of high-power lasers, including the "giant-pulse" or Q-switched laser, and of calibrating instruments in other laboratories which will be used for similar measurements. Two fundamental methods are being studied. In one method, the entire pulse of radiant energy from the laser is absorbed within a liquid-filled calorimeter, and the temperature rise of the liquid is measured by means of a thermocouple. In the second method, the entire laser pulse falls on a diffusing surface of known reflectance. A very small, but known, fraction of the reflected radiation falls on a thermoelectric or a photoelectric radiometer. The radiometer is calibrated by using a standard of spectral irradiance and suitable filters.

Calibration of Earphones and Bone Vibrators.—Bone-air cancellation has been investigated as a means of obtaining monaural bone-conduction thresholds of hearing by eliminating the contralateral ear and as a means of calibrating bone vibrators. For threshold measurements, the sound signal applied to the forehead bone, which stimulates both ears, was cancelled by an air sound signal in the non-test ear while a threshold determination was made in the test ear. Sensation levels (level above threshold) were measured for the bone vibrator and a calibrated earphone and compared as a means of calibrating the bone vibrator. This new technique supplements the loudness-balancing method of calibration.

Effect of Swirl on Flowmeters.—One of the parameters which can affect the performance of flowmeters is the presence of swirling flow at the meter entrance. One method of eliminating this problem is to use straightening



NBS physicist E. L. Smith shows how earphones are positioned on the subject and a vibration transducer pressed against his forehead in NBS studies of sound conduction by bone.

vanes or bundles of smaller diameter tubes immediately upstream. As part of the flowmeter calibration program, the flow of swirling incompressible fluids in straight round pipes is being investigated. Preliminary results show that for a given pipe, swirl decay depends on the flow rate, the fluid kinematic viscosity, and the swirl level present. Measurements of point velocities at several stations along a pipe now are being conducted to study a swirling flow field in more detail.

Calibration of Water-Current Meters.—NBS maintains and operates the only Federal facility expressly for the calibration of water-current meters. The U. S. Geological Survey depends on NBS for the calibration of its current meters; agencies in the States, other Federal agencies, and private

industry also use this service. It is a national service closely connected to the water resource problem. As many as 800 meters per year are calibrated for the U. S. Geological Survey alone. In the past year an additional 41 were calibrated for other Federal agencies, and 38 for private concerns. Over the range of velocity tested, the meters generally perform with an uncertainty less than about one percent.

The meters are mainly used for gauging of rivers and streams. This and other uses can be related to such problems as power generation, supply of potable water, erosion and flood control. irrigation, pollution abatement, harbor and ocean studies, and others.

Turbine Flowmeters.—In the aircraft industry and military services, turbine flowmeters are used extensively to measure the flow of liquid hydrocarbon fuels and of hydraulic and lubricating oils. In some applications pressure levels existing in these meters are in the range 1,000 to 3,000 psi.

NBS is conducting an investigation on the performance of turbine flowmeters at pressure levels of 1,000 to 3,000 psi. Preliminary results indicate that the more important factors influencing the performance of the meter are: (a) The effect of pressure on both the density and viscosity of the liquids metered, and (b) the effect of pressure pulsations (and accompanying flow pulsations), present in many high pressure circuits.

The investigation has shown that the effects of density changes may be predicted accurately through the use of suitable compressibility data. Effects of viscosity changes with pressure may be determined for particular meters by calibrating with liquids of different viscosities at ambient pressure.

Glassware Specifications.—Draft specifications have been prepared for precision glassware. In coordination with the General Services Administration, these specifications incorporate sampling plans and quality levels for acceptance testing. Work is in progress to assist the Food and Drug Administration in formulating inspection and test procedures suitable for their specific requirements.

PHYSICAL PROPERTIES

The scientific community has a growing need for readily accessible numerical information on the physical properties of substances. The interdependence of research laboratories, manufacturing facilities, distributors and users makes it essential that such information be expressed everywhere in compatible terms. In addition to its responsibility for the definition of physical quantities, IBS performs calibration services which provide others with the capability of making mutually intelligible property measurements. Augmenting this responsibility, IBS performs essential services for the public with regard to measurements of properties which need only be determined once. These are stored in generally accessible reference sources

and referred to by the user when he needs them. This mission is directed to economy of effort, reduction of duplication and increased use of a common bank of reliable information.

NBS conducts two general standard reference data activities: (1) experimental determination of needed values of the properties of matter and materials, and (2) management of the National Standard Reference Data System (NSRDS). Both activities are consistent with other NBS responsibilities. They focus on key measurements which improve the compatibility, consistency and reliability of the work of others. They coordinate and systematize the decentralized data compilation program of the NSRDS. Above all, they relate the selection of specific projects to the NBS mission of providing standards and measurement capabilities for the scientific community.

NATIONAL STANDARD REFERENCE DATA SYSTEM (NSRDS)

Recognizing the NBS responsibility for data dissemination activities, the Federal Council for Science and Technology in 1963 requested NBS to assume a direct responsibility in all government standard reference data compilation activities. This request took the form of a directive establishing NSRDS as a Federal policy. Under this directive NBS was requested to (1) coordinate existing data compilation and evaluation activities throughout all government agencies; (2) establish standards of quality for the products to be designated as Standard Reference Data; (3) establish standards of methodology including machine processing; (4) establish other functions as required to insure compatibility; and (5) operate a National Standard Reference Data Center.

NSRDS is, therefore, concerned with the production and dissemination of critically evaluated data compilations. The program includes the collection and evaluation of data from the literature, the preparation of critical reviews dealing with the state of quantitative knowledge in a particular technical field, and the computation of useful functions derived from Standard Reference Data or used in the interpretation of quantitative experiments.

In order to implement its responsibilities for the National Standard Reference Data program, NBS has established an Office of Standard Reference Data (OSRD) within the Institute for Basic Standards. For management purposes the technical area of concern to OSRD has been divided into seven broad categories: (1) nuclear data, (2) atomic and molecular data, (3) solid state data, (4) thermodynamic and transport data, (5) chemical kinetics, (6) colloid and surface properties, and (7) mechanical properties. In each of these areas, efforts are being made to develop a comprehensive, coordinated program of data compilation projects. Existing programs are taken into account and priorities are determined by consultation with groups of specialists from the academic world, from Government, and from industry.

During 1965 general activities followed the plan described in NBS publication NSRDS-NBS#1, "National Standard Reference Data System Plan of Operation" (obtainable from the Superintendent of Documents, Government Printing Office-15¢). Efforts were continued to establish and promote effective working relationships with program offices in other government agencies in order that the NSRDS program be most responsive to the needs of these agencies. Projects were undertaken in most of the seven technical areas within the mission of the NSRDS, and steps were taken to insure that persons working in closely related areas are fully aware of each other's activities.

The search for competent technical people willing to undertake data compilation and evaluation projects continues. Cooperation and participation by leaders of the U. S. technical community have been most gratifying. The establishment of NSRDS has been greeted with enthusiasm; its impact in some areas has already been substantial. Its potential for future contributions to the advance of science and technology is recognized to be great.

The status of developments in each of the primary areas of activity is described briefly below.

Nuclear Data

For many years the U. S. Atomic Energy Commission has been conducting a broad program of nuclear data compilation and evaluation. These compilations are indispensable tools of the nuclear physicist and reactor engineer. Through this effective program, AEC has met the most urgent needs of nuclear science and technology. However, recent consultations with nuclear specialists have indicated that the time is now appropriate for a re-evaluation of current activities. An informal round table discussion of a small group of nuclear physicists and chemists is now being planned jointly with the Atomic Energy Commission. The results will guide OSRD in making decisions on further activities in this field.

Within the NBS Radiation Physics Division a project is continuing for the compilation of data on photonuclear cross sections. A literature survey and classification of reaction types have been brought up to date, and evaluation of quantitative data is under way.

Atomic and Molecular Data

A panel of specialists under the leadership of Professor E. U. Condon of the University of Colorado has identified more than 60 properties in the Atomic and Molecular fields which are appropriate for data compilation activities. Of these, approximately 30 were designated to be of high priority for immediate action. Of these 30 high priority properties, only 11 are now being covered by existing projects, and none is considered to be of sufficient size to keep up with the magnitude of requirements.

A brief description of projects in this field under the full or partial cognizance of the Office of Standard Reference Data follows.

Atomic Energy Level Data Center (NBS).—This is a long-continuing compilation activity covering data on atomic energy levels and multiplets. A series of publications entitled "Selected Tables of Atomic Spectra: Atomic Energy Levels and Multiplet Tables" is being prepared and will bring up to date publications previously issued by NBS. During FY65 there appeared section 1 of NSRDS-NBS#3, containing data on silicon II, silicon III, and silicon IV.

Atomic Transition Probabilities Data Center (NBS).—A compilation of selected data is now in press and will appear shortly. (NSRDS-NBS#4).

Electromagnetic Cross Section Compilation.—New interpretations and correlations were developed leading to significant improvements in understanding of the data and in interpolating and extrapolating data in regions where experimental data are sparse. Some of the results of these evaluations will appear in 1966.

Atomic Collision Data Center (NBS-Boulder).—This long-continuing literature review activity has now matured to the stage of production of a series of critical reviews on selected topics in the field. The first of these will appear in 1966. Others are scheduled to appear at the rate of approximately one per year.

Mass Spectral Data Compilation.—This project serves as a literature review resource in the preparation of critical data compilations on selected topics.

Microwave Spectral Tables (NBS).—Two volumes of a projected five volume set have appeared. The remaining three are scheduled for FY66. Volumes will appear in future years when appropriate.

Atomic and Molecular Processes Information Center (Oak Ridge National Laboratory).—This is a cooperative project with AEC. This center recently issued a revised and updated set of data sheets.

X-Ray Wavelength Compilation (Johns Hopkins University).—A revision of tables of standard x-ray wavelengths has begun, taking into account recent explanations for long-standing discrepancies that have been a source of concern for years.

Fundamental Vibration Frequencies (University of Tokyo).—As an integral part of the developing program in molecular structure and thermodynamics, a program was sponsored at Tokyo University, employing the services of one of the world's leading groups in the field of spectral interpretation and molecular analysis. An increased level of activity in this field is planned in two or three other laboratories in the United States.

Infrared Spectral Data (ASTM).—Working in cooperation with ASTM, a program is under way to collect spectra from government and industrial laboratories, evaluate them, and publish those considered to meet set

standards. During FY65 the project has been in the spectra collection stage; evaluation will begin in FY66.

Quality Standards for Infrared Spectra (Coblentz Society).—The Coblentz Society, whose membership includes many of the leading academic and applied infrared spectroscopists in the United States, has agreed to assume responsibility for defining standards of quality for infrared spectra. This project is important not only for its specific function, but also it may serve to test the feasibility of specifying quality standards in many other fields.

Energy Level Transitions in Gas Lasers (Yale University).—This project is of particular interest because of the rapid growth of the laser field and its many applications. The literature survey is well under way and data tabulations are expected in FY66.

Solid State Data

The NBS-OSRD Advisory Panel on Solid State Data identified approximately eighty properties as important for eventual inclusion in a data compilation program. About one-third of these were designated as high priority. Coverage by existing projects includes only six of these properties.

The status of the projects under OSRD cognizance is described briefly below.

Crystal Data (Johns Hopkins).—During FY65, work continued on the revision of the compilation entitled "Crystal Data" under the general supervision of Professor Jose Donnay of Johns Hopkins University. This work is being used as a pilot project by OSRD to develop techniques of data processing for ultimate publication by the photocomposition equipment of the Government Printing Office. The project will give information on equipment needs, personnel skills, costs, etc.

Properties of Superconductors (General Electric Company).—This project will revise and update an existing compilation of the properties of superconductors (transition temperatures, crystal structure, critical fields, penetration depth, and coherence lengths).

Properties of Materials under High Pressure (Brigham Young University).—The high pressure research group at Brigham Young University (under the supervision of Professor H. T. Hall, the first man to make synthetic diamonds) has undertaken the task to develop a data center in this field. The program is in the literature survey stage at present and the first data compilations are expected to appear in FY66. The properties to be covered include phase relationships, crystal structures, densities, melting points, Curie points, Neel points, and others.

Thermodynamics and Transport Data

In March 1963, prior to the establishment of the NSRDS, a "Conference on Critical Tables of Thermodynamic Data" was held under the auspices of the National Academy of Sciences–National Research Council to survey

the present status of activities and to assess the need for additional work. It recommended that "support for the existing centers producing critical tables of thermodynamic data be doubled or tripled; that an approximately equal number of new centers be established, with adequate support . . ."

In May 1965 a similar conference with many of the same participants was again held under the auspices of NAS-NRC to give detailed advice to the NBS-OSRD on needs for increased compilation activities. The specific recommendations of this panel are too numerous to quote here. Because of the existing tradition of organized compilation projects in the field of thermodynamics, this area is better organized than many others. Hence, the thermodynamics advisory panel was better able than other panels to designate existing projects for expansion and assignment of new responsibilities and to name numerous specific individuals who are both competent and willing to undertake compilation projects.

The status of the projects with which OSRD has established a working relationship is described briefly below.

Selected Values of Chemical Thermodynamic Properties (NBS).—This project has been a continuing responsibility of NBS for more than 30 years. The data issued are regarded as definitive in their field and serve as the basis for innumerable computations in research and industrial technology. During FY65 a revised and updated selection of values for elements of atomic numbers 1 through 23 went to press. Other sections will appear during FY66 with a complete version, including descriptive and explanatory material, to be readied in FY67.

Low Temperature Heat Capacity Data (NBS).—This is a continuing project concentrating on heat capacities of inorganic compounds at low temperatures. During FY65 this project was in the literature survey stage with data evaluation scheduled to begin in FY66.

Thermal Behavior of Inorganic Carbonates (NBS).—This project concentrates on decomposition pressures and phase relationships in inorganic carbonate compounds. Data evaluation was brought up to date in FY65 and a data tabulation is being prepared for publication.

Standard Heats of Formation of Selected Organic Compounds (NBS).—The work of this project is similar to that of the first listed work in this category, but is, however, concerned with organic compounds exclusively. It operates on a much smaller scale, covering only a fraction of the data available in the literature. It is one component of a large program on thermodynamic properties of organic compounds that OSRD is endeavoring to coordinate and promote.

Thermodynamic and Physical Properties of Selected Organic Compounds (Texas A&M).—This is a joint project with the Manufacturing Chemists Association for the compilation and evaluation of data on a series of organic compounds. The program has been in existence for several years but is able to cover only a portion of the data available for evaluation. This

project is also one of the components of the overall program on organic compounds that OSRD is developing.

Cryogenic Data Center (NBS-Boulder).—This data center is a permanent activity of the cryogenic laboratory at NBS-Boulder. Its scope includes thermal functions, vapor pressures, PVT data, heat capacities, thermalconductivities, viscosities and related properties of all cryogenic fluids and other substances at cryogenic temperatures. The product consists of data sheets, charts, and topical reports. During FY65 the Cryogenic Data Center maintained its current literature survey and issued a variety of reports.

PVT Properties of Polar Gases (NBS).—The objective of this project is to prepare detailed and accurate data compilations on the PVT (Pressure, Volume, Temperature) relationships of gases comprised of polar molecules. During FY65 the properties of air over a wide temperature range were compiled. In FY66 the program will include ammonia and hydrogen fluoride.

Thermodynamic and Electrochemical Properties of Solutions (NBS).—The scope of this project includes standard emf's, activities, activity coefficients, heats of solution, and related properties, with primary emphasis on aqueous solutions of electrolytes.

Phase Diagrams of Binary Oxide Systems (NBS).—This project was established in FY65 to help speed the compilation of equilibrium data on phase relationships in binary oxide systems. In FY65 the project was in the literature survey stage; this survey has been brought nearly up to date. In FY66 data evaluation will begin.

Phase Diagrams of Ceramic Interest (NBS).—This project is conducted in cooperation with the American Ceramic Society which has published a series of volumes on the subject in the past. This group, however, found their resources unable to maintain currency with the accumulation of literature. By merging efforts, it is hoped that the output of evaluated phase information can be made current.

Equilibrium Phase Relationships between Metals and Metal Oxides (MIT).—This project was established in FY65 because of its great importance to the metallurgical industry. It is still in the early stages of development but it is anticipated that data evaluation will begin in FY66.

Thermophysical Properties Research Center (Purdue University).—The activities of this data center are concerned primarily with transport behavior, including thermal conductivity, thermal diffusivity, viscosity, diffusion, permeability, Prandtl number, and other related properties. Within its scope, this Center has covered the world's technical literature comprehensively and has begun the task of extracting and evaluating the quantitative data found therein. The TPRC is supported by several agencies in addiiton to the NBS-OSRD. During FY65 its task for OSRD consisted of a critical evaluation of thermal conductivity of a number of substances of potential

interest as thermal conductivity standards. A compilation has been prepared and will be published during FY66.

Diffusion Coefficients in Metals and Alloys (NBS).—This project is one of a group stimulated and coordinated by OSRD with the objective of providing comprehensive coverage of diffusion behavior in many types of substances. The other projects in this group are concerned with diffusion in semiconducting materials, in ionic crystals, in liquids and gases, and in oxides, sulfides, and carbides. Of the four projects in the group, only the NBS activity is funded through the Office of Standard Reference Data.

In addition to the projects listed above, there are several others in this technical area under the sponsorship of governmental and non-governmental agencies which should be considered as falling under the concept of the National Standard Reference Data System. They were mostly initiated by mission-oriented agencies (e.g., AEC, ARPA, NASA, Bureau of Mines) in response to an urgent need. They are not included in the present list because NBS played no role in their establishment.

Chemical Kinetics

The National Academy of Sciences-National Research Council Committee on Chemical Kinetics, which has served as the NSRDS Advisory Panel in this area, recommended that before any major systematic data compilation be started, a critical review of the state of quantitative knowledge in the area under consideration be carried out. The purpose of the review is to determine whether the data are really of lasting value and worthy of general dissemination. In accordance with this recommendation, the program of OSRD has consisted of two major activities: (1) the development of a literature survey resource that can be used to expedite the task of the critical reviewers, and (2) the commissioning of a series of critical reviews in selected fields. Some of the reviewers would use the central NBS literature resource while others would not. In the development of the program, NBS has worked extensively with ARPA and AEC, undertaking jointly supported projects with each.

The status of the various projects in this area is described briefly below.

Chemical Kinetics Information Center (NBS).—This Center is designed to serve as a major resource for reviewers and compilers. During FY65, literature review and acquisition has continued and an agreement was made with ARPA to incorporate the survey produced by Dr. Adolf Hochstim of Institute for Defense Analysis into the NBS holdings.

Unimolecular Decomposition and Association Reactions (Stanford Research Institute).—This project was began late in FY65 and a critical review is expected to be completed in FY66. Some of the data available in this field will probably have permanent value.

Isotope Effects in Chemical Reactions (Brookhaven National Laboratory).—This joint AEC-NBS project has as its objective a critical evalua-

tion of the literature data describing the effects of varying isotopic mass on chemical reactions. The literature review was well under way in FY65, and the final product is expected in FY66.

Solvent Effects in Solution Kinetics (G. C. Akerlof).—During FY65 the literature survey for this review showed that the number of papers to be evaluated was about four times greater than was originally estimated. When completed, this review will contain a complete summary of all the useful literature describing the influence of organic solvents on the rates and mechanisms of chemical reactions.

Radiation Chemistry Data Center (Notre Dame University).—This joint NBS-AEC project was established in FY65 as a permanent addition to the program of the radiation chemistry group at Notre Dame University. Plans call for this center to maintain complete documentary coverage in its field, and at intervals produce critical reviews and data compilations.

Colloid and Surface Properties

The National Academy of Sciences-National Research Council Committee on Colloid and Surface Chemistry had initiated planning of a systematic program of data compilations prior to the establishment of the NSRDS. Joining forces with this committee, the NBS-OSRD has supported the following projects which resulted from committee action.

1. Light Scattering Data Center (Clarkson College)
2. Data Center on Critical Micelle Concentrations (University of Southern California)
3. Surface Tensions of Solutions of Association Colloids (Naval Research Laboratory)
4. Surface Tensions of Fused Salts (Renssalear Polytechnic Institute)
5. Electrical Properties of Interfaces (Agricultural University, Wageningen, Netherlands)

Information Services

During FY65, as in FY64, the program of OSRD emphasized initiation and expansion of data evaluation and compilation projects, leaving to the future the development of specific information services utilizing the collections of compiled data. Nevertheless, groundwork for its services was laid. During FY65 therefore the following actions were taken:

Development of basic outline plan of service and methods of operation.—Possible services and methods of operation were examined and basic policy decisions were sketched. These decisions have been submitted to various specialists in scientific and information processing fields for their review. Comments and suggestions will be taken into consideration in formulating policy. Prior to such decisions, however, a number of user studies will be made to determine how to tailor the services to best fit user needs and preferences.

Establishment of data file group.—The initial task of this group has been to acquire known data compilations and to organize the collection systematically. At the same time general planning of ultimate methods of indexing, storage, and retrieval was begun.

Collection of Data Compilations.—One of the essential needs of the entire NSRDS is to discover what compilations already exist. Of course the large, well-known compilations present few problems, but unearthing the smaller, little-publicized products has presented extraordinary difficulties. Smaller compilations may be only a few pages in a review article or book, but their data may be comprehensive and the best available. In FY65 a contract was written with a commercial information science firm to survey existing sources. The first phase of this contract is to locate compilations of data on solid state properties; this task is expected to be accomplished by the end of calendar year 1965.

Use of Photocomposition Techniques.—Since the use of photocomposition equipment is well-established in the Government Printing Office, consideration has been given to its use for the products of NSRDS. Computer programs have been written for a number of editing and computation tasks.

MEASUREMENT

The IBS program for the measurement of physical properties is very broad in terms of its coverage of the physical sciences. However, it obviously can and does cover only a small portion of the whole field of physical property measurement. The experimental portion of this program parallels the data compilation activities described under the National Standard Reference Data System.

The Institute is also engaged in a substantial amount of theoretical investigation. Most of it is aimed at augmenting measurement capabilities by developing methods of calculating physical properties. This is done where the properties are not directly observable or where it is more efficient to establish functional relationships which make it possible to extrapolate measurements made under one or more sets of standard conditions to a wide range of environments.

Nuclear Properties

Much of the experimental work in the IBS program for determination of nuclear properties has been directed to developing specific lines of research made possible by the improved experimental facilities. New high-intensity sources, such as the 1.5- and 4-MeV direct accelerators, and the 100-MeV linear accelerator, will enable the Bureau to satisfy many of the increased requirements in the areas of radiation interactions with nuclei,

atoms, molecules, and bulk matter. This new equipment will also permit the development of improved techniques and instruments for the detection and measurement of radiation.

As a result of the increased capability, several programs have been re-evaluated. An era ended with the transfer of the 50-MeV betatron to Old Dominion College in Norfolk, Va., and the 1.4-MeV direct accelerator to the High Voltage Section of the Electricity Division. Although these accelerators are no longer adequate for the contemplated radiation research programs at NBS, they will continue to be of service elsewhere. During the 15 years that experiments were conducted with the betatron, a number of basic contributions were made toward understanding the structure of excited nuclei and the interaction of electromagnetic radiation with nuclei. The 1.4-MeV direct accelerator was used during the past 25 years for significant electron and x-ray research.

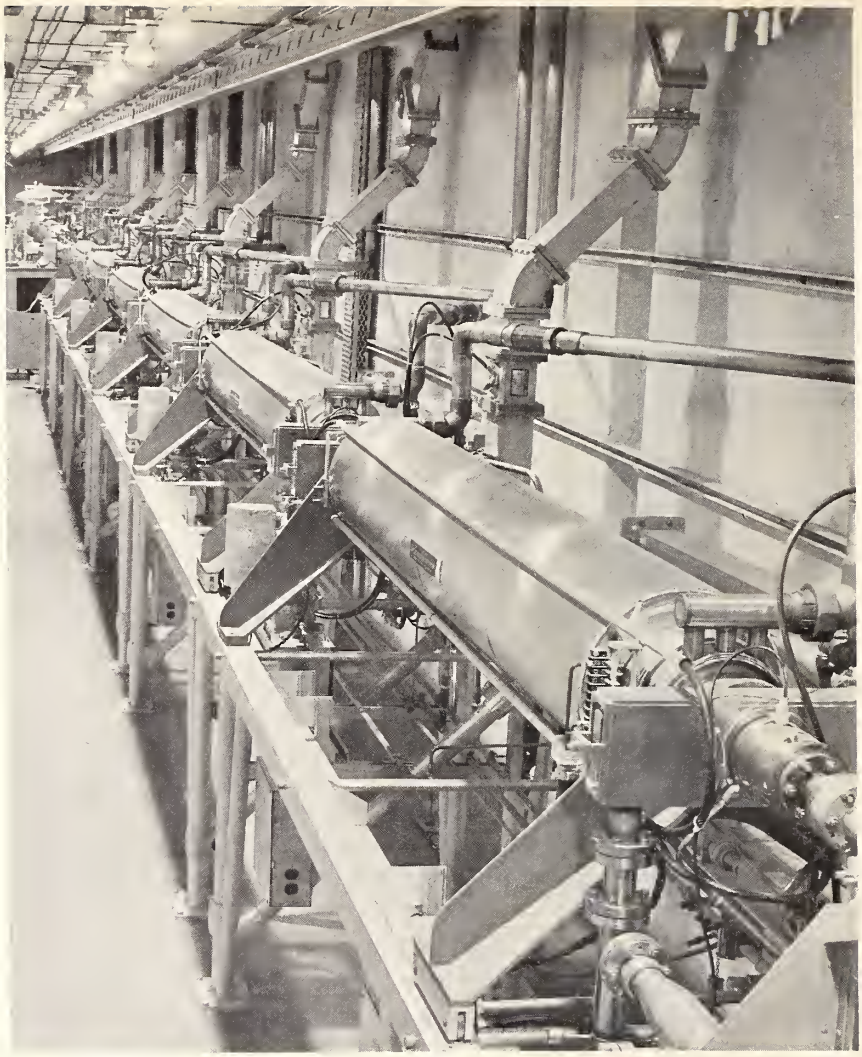
Inelastic Electron Scattering Measurements.—A series of measurements to determine the various inelastic scattering cross sections for electrons from nuclei of aluminum, copper, tin and gold has been undertaken. Preliminary results indicate that inelastic scattering cross sections may be larger than expected, particularly for large scattering angles.

500 keV Electron Accelerator.—The 500 keV electron accelerator has been almost completely revamped. New features include a pulsed electron gun with a variable pulse height, pulse width and repetition rate; a new beam handling system which features provisions for remotely positioning, focusing, and observing the electron beam; and a completely revamped vacuum system which incorporates a large number of interlocks to make it as foolproof as possible. These improvements will permit users to conduct a much larger variety of experiments with a speed and ease not heretofore possible.

Neutron Cross-Section Measurements.—Measurements of the total neutron cross section of holmium 165 at 14 MeV using an alined target have been completed. The effect of nuclear alinement on the total neutron cross section was found to be small (approximately 3% of the total cross section) and has been determined to an accuracy of 20 percent.

Adiabatic Demagnetization Cryostat.—In order to continue studies of beta-particle distribution from oriented nuclei, a self-contained adiabatic demagnetization cryostat which requires no large external pumps or magnets was designed and constructed. Its particularly interesting feature lies in the use of an externally-controlled drive to move the sample during demagnetization. Because of its unique operation, high magnetic field, and low initial temperature, the cryostat can be used with a wide variety of samples, including paramagnetic single crystals and contact-cooled ferromagnetic foils.

Linac.—A linear accelerator and associated equipment have been installed in the new Radiation Physics Building. The Linac wing of the



NBS linear accelerator. This instrument produces one of the world's most intense high-energy electron beams.

building was initially occupied on April 15, 1964. During the first year of occupancy the Linac was installed and brought to the point of producing an electron beam. Installation of the Linac beam handling equipment is nearing completion. Extensive personnel and experimental interlock systems, including radiation monitoring equipment, TV systems, experimental wiring, shielding, and high-quality water cooling systems for experiments have been installed. First electron beam on the Linac was observed in July 1965 with completion of the facility anticipated approximately January 1966.

Synchrotron.—Synchrotron operations have continued on a routine basis for a number of experiments. Among these are experiments on photo pro-

duction of protons, use of synchrotron light, production of radioactive samples, and operation of the synchrotron as a source of electrons for counter calibration work by NASA and NBS.

Photonuclear Research.—Photonuclear reactions have been studied using the betatron and synchrotron bremsstrahlung beams with end-point energies up to 166 MeV. The cross sections measured were in the reactions Al (γ,t) and copper 63 · copper 65 (γ,xn). The (γ,n) reactions with copper produced "tails" that, around 160 MeV, gave values of integral cross sections about 50 percent greater than those measured just above the giant-resonance region.

Also, a study of the photodisintegration of helium 3 was completed and a study of cross sections for producing photoneutrons from lithium 6, lithium 7, boron 10, and boron 11 was completed and published. Although more than 50 laboratories have been working in this field, no detailed measurements of these cross sections had been made. These data have supplied an important link in the systematics of the photonuclear effect for the *s*- and *p*-shell nuclei.

Electron Scattering.—A 30-inch radius, high resolution spectrometer system was installed and detailed measurements were made of its ion-optical properties. Although analysis of the results was not completed by the end of this year, indications are that the resolution of the spectrometer is exceptionally good. A sophisticated target holder providing for precise vertical, horizontal, and angular positioning of targets was built, together with a remote controller. Investigations of possible electron detector systems led to design work for a semiconductor detector "ladder-counter" system which is continuing.

New Facility Planning.—During the year, authorization was obtained for two major additions to the Linac facility: an above-ground neutron source for time-of-flight studies, and a beam-handling system for the third underground measurement room. Work to date consists of conceptual design of the ion-optical parts of the beam-handling system, and preliminary magnet designs.

S-Matrix Theory.—A method has been developed for the computation of the S-matrix for nuclear reactions. Of special interest is the finding that it is possible to compute directly by shell model methods the eigenstates and eigenvalues of the S-matrix, the so-called eigenchannels. Calculations for specific nuclei using this method have been started.

Nuclear Photo Effect.—The collective theory of the nuclear photo effect has been extended to spherical nuclei where the nuclear surface vibrations have very large amplitudes, and where they consequently have a marked influence on the photo-nuclear giant resonance. Comparison with available experimental data shows a qualitative agreement. The remaining discrepancies between calculations and experiment are very likely associated with nonlinearities of surface vibrations which, because of their large amplitudes,

should have an appreciable effect on the results. This effect is being investigated.

Elementary Particles.—The role of the groups SU(3) and SU(6) in elementary particle physics was explored in detail. Clebsch-Gordon coefficients for the group SU(6) were constructed.

The concept of W-spin was formulated and applied to both the nonrelativistic and relativistic descriptions of collinear processes. The classification of meson and baryon resonances was accomplished using the group $SU(6)_w$.

Charged Particles.—Work has continued on the calculation of charged-particle transport by a combination of analytical and random sampling techniques. Particular applications include the determination of the following quantities: (1) the radial and longitudinal distribution of absorbed dose in water phantoms that are irradiated with point-monodirectional beams of electrons with energies between 1 and 50 MeV; (2) the absorbed dose in air and tissue as a function of the distance from various beta ray sources, for point sources as well as spherical and disk-shaped sources; (3) the analysis of the safety hazard arising from fission-product beta-rays in reactor fuel elements; (4) the absorption of electron energy in thin targets as function of the target thickness and of the direction of the incident beam; (5) the angular and spectral distribution of electrons transmitted through aluminum foils.

Bremsstrahlung.—Systematic calculations have been made of thick-target bremsstrahlung production in aluminum and tungsten targets, for incident electrons with energies between 50 keV and 10 MeV. These data have been subjected to detailed comparisons with corresponding experimental data in order to point up deficiencies in the knowledge of bremsstrahlung production cross sections. The influence of higher stages of the electron-photon cascade on thick-target bremsstrahlung production has been studied. In particular, the energy dissipation by secondary electrons set in motion by bremsstrahlung has been computed for electrons (with energies up to 100 MeV) incident on a water phantom.

Atomic and Molecular Properties

NBS contributions to the measurement of atomic and molecular properties derive from a wide range of experimental projects, in a number of different laboratories in the Institute for Basic Standards. The work includes basic long range experimental programs such as atomic spectra and x-ray spectra, a variety of molecular spectroscopic specialties, theoretical chemistry and physics, and the development of photometric standards.

Rare Earth Elements.—The extreme complexity of rare earth spectra has, until recently, defied analysis, and a large measure of the recent success in this difficult field can be traced to pioneering work at NBS. During the past year, outstanding progress has been made on the spectra of doubly-ionized cerium, promethium, and lanthanum.

Energy levels have also been calculated for the only two remaining singly-ionized rare earths for which no levels were previously known. This was accomplished by combining data from other rare earth spectra with some relatively simple calculations. The elements for which data were thus obtained were terbium and holmium.

Intermediate Energy Range.—A program to obtain atomic data in the intermediate energy range was started several years ago and has continued to produce a wealth of new data in what was previously an inaccessible region. The rapid and successful progress in this NBS program is made possible by the combination of three resources: (1) the optical radiation from the NBS 180 MeV synchrotron which can be used as a continuum source for studies of absorption phenomena in the ultraviolet down to 50 A, (2) a very monochromatic low-energy electron monochromator developed at NBS and useful for measuring electron scattering in this same energy range and (3) a group of theorists at NBS who have contributed very significantly to the understanding of the new phenomena observed.

Resonance States in the Continuum.—NBS research has provided better understanding of the nature of the "resonance states" that lie in the continuum of the rare gases. All of the common rare gases—helium, neon, argon, krypton. and xenon—have been studied, both with electrons and in the synchrotron light; the structure of the first two is now quite well understood.

Optically Forbidden Transitions.—Studies with the electron monochromator have yielded important information on optically forbidden transitions. A variety of atoms and simple molecules, including Hg, SF_6, N_2, and H_2 have also been studied. Observations on electron scattering near threshold for a number of these species have yielded interesting and previously unconfirmed results. The influence of previously unknown negative ion states on scattering cross sections has also been detected.

The spectrum of a metallic element has now been studied for the first time in a wall-stabilized arc. Such arcs produce very stable high-temperature plasmas and are therefore useful in determining atomic transition probabilities. Their use has, in the past, been limited to studies of gaseous elements. In experiments performed this past year at NBS, the element nickel has been introduced into the arc in the form of nickel carbonyl. Results constitute the most precise measurements available to date on transition probabilities in neutral and singly-ionized nickel.

A program in atomic transition probabilities has been initiated in collaboration with the University of Colorado. Experimental measurements by the method of the Hanle Effect are being made for a number of atoms and ions of astrophysical importance. Successful results have been obtained for ionized calcium. Theoretical calculations by quantum mechanical methods have been completed for neutral argon and ionized silicon is now being studied.

Hyperfine Structure.—A theoretical study of the change in the hyperfine structure separation in cesium as a result of the confinement of the atom between two closely spaced conducting plates has been performed. Results show that the change in the electromagnetic mass of the electron resulting from this sort of confinement is significant and should be measureable. This suggests an additional effect that must be considered in specifying accuracy for atomic frequency standards.

Hydrogen Maser.—Multiple quantum transitions have been observed in the NBS hydrogen maser. A second hydrogen maser of improved design is in an advanced stage of construction and should be completed shortly. Also developed was an elementary theory to describe the behavior of the hydrogen maser when the source is switched on or off and when the Zeeman transitions are being driven.

Raman and Brillouin Scattering.—Stimulated Raman and Brillouin scattering have been observed from various liquids using a ruby laser. Techniques have been developed for observing spontaneous Brillouin scattering from liquids using helium-neon and argon continuous lasers. Brillouin scattering and Rayleigh scattering have been observed using the argon laser and a high precision scanning interferometer.

Laser Power.—A calorimetric method of measuring laser power with an accuracy of 1 percent has been developed for the purpose of providing a calibration service.

Electron Impact Excitation.—A new measurement of the relative cross section for the production, by electron impact, of Lyman-α photons from the $2p \rightarrow 1s$ transitions in atomic hydrogen has been made. This was done by studying the electron energy dependence of the Lyman-α flux emitted from an atomic hydrogen beam in a direction perpendicular to the plane containing the hydrogen beam and a transversely incident electron beam. Some results, for electron energies near threshold, have been published. The measurements have since been extended to an electron energy of 200 eV, using the same apparatus.

Electrons Colliding with H_2^+.—During the past year experimental apparatus for studying collisions of electrons with ions has been put into successful operation. Protons resulting from encounters of electrons with H_2^+ ions intersecting at right angles are separated from the primary ion beam by employing a 45° parallel plate electrostatic energy analyzer. Vacuum of 10^{-9} torr exist in the collision region where modulated beam techniques are employed. Agreement with theory is satisfactory to within the statistical spread of the data. Efforts are continuing to improve the quality of the results.

Two-Photon Photo-Detachment of I^-.—The June 21, 1965 issue of Physical Review Letters carries the report of experiments on the laser double quantum photo-detachment of I^-. This work is the first known reported result concerning a second order photoionization process involv-

ing free atoms in laser radiation. The results clearly show the expected quadratic dependence upon flux.

Electron Energy Loss in Liquid Metals.—Experiments were performed for the first time on the precise measurement of the energy loss of electrons scattered by liquid metals. Experiments on liquid and solid aluminum and gold have yielded the surprising result that the band structures are very similar in the liquid and solid for these elements. The technique used makes it possible, by alternately freezing and thawing the sample in a vacuum, to study electron scattering not only from liquid but also from very clean solid surfaces.

Low Energy Bremsstrahlung Production.—Work continued on the accumulation of x-ray spectral data. Efforts were focused on bremsstrahlung production by electrons having kinetic energies of about 0.1 and 0.2 m_0c^2. Complete spectral data were obtained for targets of different atomic number and ranging in thickness (t) from about $0.1 < \frac{t}{R_0} < 1$ where R_0 is the practical electron range. The spectral distributions were compared with Kramer's theory and show good general agreement with his predictions, especially at the lower atomic numbers. Comparisons were also made with the theory of Kirkpatrick and Wiedmann and with the Monte Carlo calculation of Berger and Seltzer of NBS.

Solar Eclipse Observations.—Scientists from NBS joined researchers from 70 nations along a narrow, 8,000 mile corridor of the South Pacific last May to view the 38th total eclipse of the sun this century. The eclipse provided an excellent opportunity to study solar activity, a subject of great scientific and practical interest. Solar activity affects the atmosphere through particle and x-ray bombardment, influences circumglobal radio communications and may provide the key to control of solar heat.

The Bureau scientists took with them a new photoelectric spectrometer specifically designed for this and similar occasions. The spectrometer measures variations of radiation intensity above the solar surface and automatically follows the intensity of different colors from the chromospheric layer as the moon passes over the sun's edge. The measurements proved to be more than ten times better than any previously obtained. The expedition was part of the continuing study designated as the International Year of the Quiet Sun, referring to the period which is a low point in the 11 year cycle of sunspot and solar flare activity.

Dielectric Constant.—During the year, work proceeded on the quantum theory of the dielectric constant from the standpoint of the adiabatic approximation and on the properties of exponential operators and parametric differentiation. A reflectometer for measuring linear and nonlinear properties of dielectrics at millimeter and optical wavelengths has been constructed.

Glasses for Wavelength and Photometric Scale Standards.—A study has been made of the spectral transmittance of silicate- and phosphate-base glasses containing one, two, or four of the oxides of the rare-earth elements (atomic numbers 58 to 71, excluding number 61). The narrow absorption bands of these glasses make them ideal wavelength working standards. This study has shown that two glasses, when used together, containing approximately 10 weight percent each of (1) Nd and Sm, and (2) Ho and Yb, have aborption bands suitable for wavelength calibration. A similar study has been made of the first transition elements (atomic numbers 22 to 30) in phosphate-base glasses for use as photometric scale standards.

Ferromagnetic Materials.—Nuclear magnetic resonance studies have been made of iron 57, gallium 69, and gallium 71 in gallium-substituted yttrium-iron garnet as a function of gallium substitution at several temperatures. Net magnetization studies have also been made at 77 °K up to gallium substitution of 53 percent. The site distribution of the iron ions and the sublattice magnetizations have been obtained. One of the most important results of these experiments was that a hyperfine field of approximately 2.3 teslas was found at the site of the non-magnetic gallium ions. The field is believed due to a superexchange mechanism.

Magnetism.—Nuclear magnetic resonances have been studied in ferromagnetic alloys. Results have yielded important data on the magnetic moment of various nuclei and internal magnetic fields. In addition, the first observation of the nuclear magnetic resonance of europium was made, using the europium nuclei in the ferromagnetic compound europium oxide at liquid helium and liquid hydrogen temperatures.

Band Spectrum of Fluorine.—The band emission spectrum of fluorine has been analyzed to yield more precise rotational and vibrational data, and a somewhat better understanding of the unusually complex perturbations present. Analysis of the spectrum present along with the previously recognized range bands of F_2 has shown the emitter to be F_2^+. The combined results for F_2 and F_2^+ have enabled the energy level scheme for F_2 to be clarified appreciably.

Infrared and Microwave Spectra.—NBS scientists have been among the world leaders in the measurement and analysis of high resolution infrared spectra of the simpler molecules. The combination of both infrared and microwave studies produces the potential for a deeper understanding of molecular structure than could otherwise be achieved by separate study. Through this combined research, new information has been obtained on vibration-rotation interactions in cyanogen chloride, cyanogen fluoride, hydrogen cyanide, and nitrous oxide.

Important studies have also been made on the microwave spectra of species stable only at high temperatures (500-1000 °C). The objective of this project is to detect and analyze the microwave and infrared spectra

of short-lived molecular species present in electrical discharges, flames, and other high temperature environments. The data will provide accurate structural information on important species present in such systems.

Microwave spectra of several other molecules have been analyzed. In particular, the study of the spectrum of methylsilylacetylene permitted the upper limit to be set on the barrier to internal rotation, thus providing a critical test of theories of internal potential barriers.

Infrared Spectroscopy Using Matrix Isolation Techniques.—Much of the recent work in low temperature chemistry has been concerned with the production and reactions of atomic species. Hydrogen atoms have been produced by the photolysis of HI and H_2S, and their reaction with CO to form the free radical HCO has been studied. An appreciable activation energy has been found to be required for the reaction of H atoms with CO. A much higher concentration of HCO has been obtained, using CO as the matrix at 14 °K, than was present in previous studies, permitting the direct observation of all three vibrational fundamentals of both HCO and DCO. Force constants and thermodynamic properties have been derived from these data.

The reaction of H atoms with the free radical CF_2 has also been studied. The photolysis of t-N_2F_2 has been found to provide a convenient source of F atoms for matrix isolation studies. Using this and other photolytic sources of F atoms. all of the vibrational fundamentals of the free radical FCO have been observed, as well as an ultraviolet transition associated with this species. Force constants and thermodynamic properties have been estimated for FCO. F atoms, unlike H atoms, are observed to react with CO with no activation energy. F atoms have also been found to react with CF_2 to produce the free radical CF_3.

Cl atoms, have been produced by the vacuum ultraviolet photolysis of HCl, as well as by a variety of other photolytic processes. The reaction of Cl with CO, like that of F with CO, occurs with no activation energy. All three vibrational fundamentals of ClCO have been observed, and the force constants and thermodynamic properties of this species have been estimated.

Studies of the photolysis of cyanogen azide at wavelengths longer than 2800 A have been shown to lead to the production of the free radical NCN in concentration sufficient for direct observation of the vibrational fundamentals of this species and of two ultraviolet transitions of NCN, one of them previously unobserved. The force constants and thermodynamic properties of NCN have been estimated. Also, the carbon-nitrogen bonds have been found to be weaker than those typical of doubly-bonded species.

When cyanogen azide and NCN are photolyzed with wavelengths shorter than 2800 A. carbon atoms are produced. These C atoms have been found to react with CO with no activation energy, forming the free radical CCO. Isotopic studies confirm a linear structure for this species and permit estimates of its force constants and thermodynamic properties. In addition to

the three vibrational fundamentals, a continuum near 5000 A has been observed for CCO. In the presence of another molecule of CO, CCO is observed to react with little or no activation energy to form C_3O_2. Preliminary studies have been made of the reaction of C atoms with a variety of other species, including C_2H_2, Cl_2, and HCl.

Infrared Matrix Spectra.—The infrared matrix spectra of a number of refractory substances have been investigated from the point of view of establishing all the vibrational frequencies and the geometry of the vapor species. To this end a furnace was constructed in which a Knudsen cell can be heated by electron bombardment to temperatures in excess of 2000 °C. The furnace is coupled to a special variable-temperature cryostat to facilitate the study of diffusion and polymerization in the matrix, and thus enable observations of spectra at frequencies as low as 30 cm^{-1}. The species examined in detail include MgF_2, CaF_2, SrF_2, BaF_2, and ZnF_2. In addition, observation of the bending vibrations of the Ca, Sr, and Ba compounds were made for the first time, and evidence of the bent configurations of CaF_2 as well as SrF_2 and BaF_2 obtained.

Ultraviolet Spectra of Unstable Species. Substantial progress has been made in the study of the ultraviolet spectra of transient and unstable molecular species, in both the gas phase and in rigid matrices. The combination of an evacuable scanning monochromator and a liquid helium cryostat has made possible the observation of the vacuum ultraviolet spectra of several new radical species. The radicals observed include CF_2, FCO, and NCN; they were produced by ultraviolet photolysis of larger stable compounds frozen in rigid inert solids. These studies, which are continuing, have made it possible to identify previously unknown electronic spectra of these species; to characterize, to some extent, the states of the molecules involved in these transitions; and to obtain some insight into the chemical reactions which may proceed under these conditions.

Photoionizaiton Mass Spectrometry. Construction of a photoionization mass spectrometer has been under way in the Mass Spectrometry Section for some time. This year, success was achieved in producing both argon and helium continuum sources of radiation, covering the whole range from 600 to 1200 A (12-21 eV). The following atoms and molecules were studied: Ar, Kr, Xe, H_2, HD, D_2, NO, CH_4, CD_4, C_2H_2, C_2D_2, C_2H_4, C_2D_4, CH_3Cl.

Franck-Condon Factors for Polyatomic Molecules. Following the experimental determination of vibrational structure in acetylene by photoionization, a method was developed for the calculation of Franck-Condon factors for polyatomic molecules. Initial calculations on C_2D_2 predicted a very small isotope effect on the vibrational transition probabilities, whereas the experiments indicated a much larger effect. Later experiments with improved instrumentation give good agreement with theory.

Molecular Quantum Mechanics.—The program of calculation of accurate electronic energies for polyatomic molecules was continued. Two important conclusions were reached during the year:

(1) Hartree-Fock (H.F.) calculations can be based upon Gaussian type orbitals with satisfactory results. Hartree-Fock results have been used to determine bounds to molecular correlation energy, the geometry of AH_n molecules, intermolecular potential of $He\text{-}H_2$, and the electronic properties of some Rydberg orbitals of H_2.

(2) The use of natural orbitals for pairs in a H.F. field has been found to be a very useful method of objectively improving a configuration interaction calculation with a minimal number of configurations. Results to date have been excellent and have resulted in the most accurate energies for the H_3 system yet published. The accuracy obtained is within less than 0.2 eV over the whole potential energy surface, and other small molecules have yielded equally accurate results. The technique should be applicable to a determination of correlation energy in a variety of molecular cases.

Dielectric Measurements.—A two-terminal dielectric-specimen holder has been constructed and used to make measurements on a single disk polymer specimen at room temperature over a frequency range from 10^{-2} to 6×10^8 Hz. A detailed analysis of the holder was completed and published as a guide to industrial laboratories interested in measuring dielectric properties. Also, a precision three-terminal cell was built for extremely accurate dielectric measurements using a two fluid technique. This cell will greatly aid the development of dielectric standards.

Refractive Index.—Measurements of the refractive index of transparent media throughout the range of the visible spectrum are made to satisfy the needs of those in industry and Government who are concerned with the manufacture and use of precise optical instruments. Improved optical media of either crystalline or isotropic nature are becoming available for which accurate value of refractive index are required. In addition, it has become necessary to extend the range of measurement beyond the visible spectrum into both the ultraviolet and the infrared region.

During the past year, refractive indices were measured for three specimens of optical quality infrared silica over the region 0.21 to 3.9 microns. In addition nine other specimens were measured over the limited range from 0.4 to 1.08 microns.

A program was initiated to investigate the effects of high energy radiation on the refractive index of glass. This study is being made to determine the magnitude of possible changes in index of optical media when exposed to an environment outside the atmosphere. Preliminary measurements show the occurrence of marked changes in the refractive index. They are sufficiently large that changes in the metrological characteristics of optical devices used in interplanetary space may be expected when the optical devices are exposed to that environment for an appreciable time.

Chromatic Aberration. A superachromatic prism was constructed to check the possibility of producing a lens system having negligible chromatic aberration over the visible region of the spectrum. The total variation in angular deviation was approximately 3 seconds over the spectrum region from 4800 to 6438A in a total angle of deviation of 30°, thus showing that the residual deviation is down to one part in 3600. This low value indicates that a lens system having negligble chromatic aberration is feasible.

Solid State Properties

The division of responsibilities among the NBS Institutes has led to the concentration of most of the solid state experimental and measurement research programs in the Institute for Materials Research. However, a small number of fundamental projects in the Institute for Basic Standards are concerned with solid state properties as they relate to other phases of the IBS mission.

In this area, and in the areas of chemical kinetics and colloid and surface properties, the IBS program is limited in scope to projects which will: (a) Increase compatibility of measurement capabilities by defining standards and measurement techniques; (b) relate directly to other IBS programs for standards; and (c) provide key measurements to serve as reference values for other workers.

Density of Single Crystals.—Measurements have been made on changes in density in single crystal rutile as a function of thermal reduction. In addition, several practical problems associated with classical hydrostatic weighing have been studied. Examples include devising methods for minimizing the imprecision associated with evaporation of water from the support wire and devising reproducible methods of fabricating hydrostatic support wires suitable for high precision work.

Energy Transfer in Organic Molecular Crystals.—Interest in this work has been focused on the problems associated with the transfer of triplet excitation from one chromophore to another and with the interactions of triplet excitations on different chromophores in weakly coupled, organic, molecular crystals. The transfer of triplet excitation energy is being studied by investigating the properties of molecules containing two chromophores isolated from each other by a saturated structure. This work is being extended to other molecules of more rigid structure, to study temperature effects, to make polarization measurements, and to study the charge transfer properties and such systems.

Semiconductor Radiation Detector Devolopment.—Sixty semiconductor counters for use in the focal plane of an electron scattering spectrometer were fabricated. The response of these counters was studied as a function of bias voltage and detector temperature. Electrons in the energy interval 10-40 MeV, obtained from pairs produced by the NBS synchrotron, were used in this study. For some of the counters, anomalous peaks were found

in pulse height distributions. Experiments are being designed to investigate the possibility that these peaks are related to the "channeling" effects that have been observed in silicon with protons and alpha particles having about the same momentum range.

Reference Table for Thermocouples.—A reference table has been developed for the platinum-rhodium 6 percent versus platinum-rhodium 30 percent thermocouple giving values of electromotive force as a function of temperature over an extended range. Manufacturers will voluntarily alloy their products to conform with this table, and the table can then serve as a basis for the establishment of tolerances to be agreed upon in purchasing specifications.

Crystal Resonances and Sound Velocities.—Ultrasonic determination of crystal resonances and sound velocities in crystals was accomplished by the use of nuclear magnetic resonance techniques. The work included development of a theory of the effect of finite lattice heat capacities upon lattice relaxation terms, and a general theory of nonlinear response in crystals.

Radio and Microwave Materials.—The radio standards materials program is designed to improve understanding of the dielectric, magnetic, and conductive behavior of materials as a function of frequency in terms of atomic constitution and structure of matter. The program covers a frequency range from about 30 kHz into the optical range.

Dielectrics.—An instrument was built for the determination of the linear dielectric properties of materials at millimeter and sub-millimeter wavelengths. This instrument is also designed to accommodate laser sources for the study of nonlinear effects.

Saturation Magnetism.—The precision and accuracy of saturation magnetization measurements on ferrites, using a vibrating sample magnetometer, was improved through the development of better temperature control, vibration isolation, and sample positioning and grinding techniques.

Spin Wave Theory.—The basic validity of the spin-wave theory of ferromagnetic resonance was verified and, in addition, the detailed effects of the parameters appearing in the theory have been examined. Theory and experiment suggest that porosity is a more significant relaxation mechanism than is crystalline anisotropy.

Paramagnetic and Antiferromagnetic Studies.—Paramagnetic and antiferromagnetic crystals were studied by resonance techniques to improve our knowledge of solids and how they interact with electromagnetic radiation, as well as to collect information for microwave and sub-microwave maser and other applications. Electron paramagnetic resonance studies on iron doped quartz established the location of the ferric ions and the nature of the crystalline field acting on them. A facility for antiferromagnetic resonance was developed for experimentation in the temperature range between 4 and 77 °K.

Nuclear Magnetic Resonance.—Several experiments in nuclear magnetic resonance were completed to investigate and to maximize the ability to add phonons to a crystal lattice in attempting to observe nuclear-Raman and nuclear-hexadecapole phonon interactions in solids. In this connection, the angular dependence of the direct quadrupole and the Raman process was calculated.

Phonon Avalanche.—Some effects of finite lattice heat capacity upon spin-lattice relaxation were studied. When the phonons created by spin-flips are not able to escape effectively from a paramagnetic substance, they will stimulate other spins to flip, thus creating other phonons. The rate of spin relaxation will therefore increase for a time as the relaxation progresses, giving rise to a possibly nonexponential relaxation and a sudden creation of phonons. This idea was developed mathematically and resulted in the prediction of a phonon avalanche which has since been observed.

Materials Synthesis.—Research on ultra-purification of materials and single crystal growth resulted in the preparation of large sodium chloride single crystals from aqueous solution. Electrical conductivity of these crystals indicates the presence of approximately 10^{15} current carriers per cubic centimeter. In addition, F-band coloration by x rays was found to be considerably lower than for the purest melt-grown crystals available.

Thermodynamics and Transport Properties

NBS has a long history of major contributions to thermodynamics. An increasing fraction of this effort is now being directed to the preparation of critically evaluated tables of self-consistent thermodynamic values, since such work requires a centralized, closely coordinated and well-organized attack, as well as the utilization of modern data-processing techniques.

Thermodynamic Contributions to Temperature Standards.—A program is under way to determine the thermodynamic temperatures of the physical transitions in pure materials used to define the fixed points on the International Practical Temperature Scale. Apparatus is being developed to exploit the method of gas thermometry for these determinations. A furnace has been completed and an interferometric technique perfected for measuring the temperature coefficient of expansion of the gas thermometer bulb material with the required high accuracy. Another aspect of the program is the effect of impurities in a material on the temperature of the particular transition being studied. Recent experiments have shown that the shapes of freezing curves for samples of pure gold will indicate comparative purities of samples beyond the capability of spectroscopic analysis.

High Speed Techniques for High Temperature Studies.—High speed electrical discharge techniques are being employed for generating high temperatures (above 2000 °K) in solid, liquid, and gaseous substances. Recent experiments with exploding wire and thin-walled tubular samples indicate that such dynamic methods provide excellent means for high-temperature spectroscopic and thermodynamic studies. High-speed photo-

graphic, photoelectric, spectroscopic, and other fast-measurement techniques are applied for time-resolved (millisecond and microsecond) measurements. Thus far, a high-speed (millisecond) method for measuring enthalpy, specific heat, and resistivity of electrical conductors up to their melting points has been developed. Exploding wire results have suggested a method for estimating temperature in a gaseous explosion mixture. A method for time-resolved (microsecond) measurements of electrical energy, power and sample resistance in high-current discharge circuits was also developed.

Thermal Quantities.—A new apparatus for studying the thermodynamic properties of solids and liquids at high temperatures has been developed and is now in operation at NBS. With this apparatus, accurate measurements of heat capacity, heat of fusion, and heat of transition can be made up to about 2800 °K (4500 °F). Previously, similar NBS measurements were limited to below 1200 °K (1600 °F). The apparatus has been used to measure accurately the heat capacity of pure graphite, a material which is under consideration as a heat capacity standard for high temperatures. A vital part of the new apparatus is the precise automatic pyrometer used to measure the high temperatures. This pyrometer uses a photomultiplier electron tube to eliminate the use of the human eye.

Electrochemistry.—Studies have shown that germanium tends to form an oxide layer in aqueous solutions at an electrical potential of 0.124 volts relative to the conventional hydrogen electrode.

Quantum Effects in Light Gases.—The general area of quantum mechanical effects in light gases has been of continuing concern. Of special interest has been the discovery that the core of repulsive forces present in the molecular potential of real gases plays a key role in determining the magnitude and temperature dependence of the spin-statistics effects such as those associated with the Bose character of helium.

Pyrolysis of Lead Oxides.—This study is important for the chemistry of lead-acid storage batteries. Thermogravimetric studies of lead dioxide, PbO_2, have shown that this oxide goes through the stages $5PbO_2 \cdot 4PbO$, $4PbO_2 \cdot 5PbO$, and Pb_3O_4 before reaching PbO. Heat and entropy changes for these transformations were determined.

Electromotive Force Series.—Electromotive force series for elements in solid and molten halides and oxide weres developed. In these series the elements are arranged in decreasing order of reducing power, i.e., each element has a positive electrical potential when placed in contact with the next below it in the series. Since these series give the relative stability of elements or metals in solid and molten salts, they have wide utility in interpreting industrial processes, such as electrochemical production of energy, electroplating, or electrorefining.

Dielectric Constant of Boric Oxide.—The dielectric constant of boric oxide, a molecular solvent, was measured over a frequency range of 1 to 50 kHz from 500 to 800 °C. These measurements showed that boric oxide

behaves like a nonpolar polymer with a static dielectric constant of approximately 3.

Transport Coefficients. An extensive review of time-correlation functions to obtain transport coefficients was explored in several papers dealing with Stoke's Law in fluids and with sound absorption in fluids with internal degrees of freedom.

New Approach to Absolute Viscosity.—As one portion of a major effort to improve and extend the range of methods for the measurement of the viscosity of Newtonian liquids, a viscometer consisting of a quartz rod oscillated in a torsional mode with a node at the center is under study. The resonant frequency and resistance at resonance are measured with the rod in a vacuum and in the liquid under study. The difference in these measured quantities, with appropriate constants calculated from the dimensions of the rod and known properties of quartz, can be used to calculate the viscosity of a Newtonian liquid. Results so far, after working with different rods and methods of mounting, show that the method is certainly valid as an absolute measurement to better than 1 percent, and indicate that for viscosities in the neighborhood of 5 centipoise, a few further refinements should bring precision of reproducibility to something like ± 0.2 percent.

Spectral Emissivity of Ceramics.—Design and development of a rotating cylinder appartus for measuring normal spectral emissivity of ceramic maetrials have been completed. Tests of the equipment show it is capable of providing reliable data for wavelengths of 1 to 15 microns and temperatures of 1200 and 1660 °K. Measurements on alumina, zirconia, and thoria have been completed.

Chemical Kinetics

NBS measurement projects in chemical kinetics are specialized activities, some of which originate in existing Bureau responsibilities in atomic and molecular spectroscopy and in the development of values for basic and derived standard quantities. These projects encompass both theoretical studies and laboratory programs.

Vibrational Energy Transfer.—An accurate potential energy surface for He-H_2 has been developed. This potential was then used as a basis for a precise "distorted wave approximation" calculation of collisional vibrational energy transfer probabilities. The calculated potential is appreciably softer than that obtained from measured Lennard-Jones potentials. The vibrational transfer probabilities predicted are orders of magnitude smaller than expected from the usual approximate theory. These probabilities, which describe inelastic scattering, are critically dependent upon details of the intermolecular potential, and depend strongly upon the elastic scattering moments (diagonal elements in the interaction matrix). The work also shows that non-colinear collisions are important and that the assumption

of a potential which is constructed from the pair-wise addition of atom interactions is a poor one. In brief, the work raises serious doubts concerning previous, apparently simpler approximations.

Unimolecular Decomposition Reactions.—The successful development of a comparative rate technique for use in a single pulse shock tube has permitted precision measurements on the rates of decomposition of organic molecules at high temperatures. The single pulse shock tube raises a gas sample to a high temperature by means of the compressions of incident and reflected shocks. The sample is then cooled by rarefaction waves resulting from the interaction of the reflected shock wave and the contact surface. The comparative rate technique consists of decomposing both an unknown and a standard substance in the same shock heated sample. If the two rates are not widely different, the standard's decomposition serves as an internal kinetic thermometer. The success of these studies depends most crucially upon the balance of cross reactions. This is facilitated by the short dwell time that is characteristic of shock tube experiments and the great sensitivity of modern gas chromatographic detectors. In the present experiments concentrations as low as 0.0005 percent reactants were used.

The results from the studies made to date show much higher precision in rate constants than for "absolute" rate measurements in the same shock tube. They are comparable in accuracy with the best results obtained from flow or static experiments and can be accepted with greater confidence since heterogeneous effects are no longer important. Three classes of compounds have been studied: alkyl halides, cyclohexenes and substituted ethanes.

Decomposition of Multiply-Charged Ions.—Studies continued on the decomposition of multiply-charged polyatomic ions by coincidence mass spectometry. The method involves detection of an ejected electron from an electron-impact ionization and simultaneous detection and mass analysis of both positive ion fragments. The hydrocarbon mass spectra showed a significantly greater abundance of high energy (up to 9-10 eV) protons than hitherto believed. Travel time correlations due to kinematic effects were experimentally demonstrated, and are of great potential utility. Approximate determinations of fragment ion kinetic energies were carried out, and it was established that a significant amount of some fragments, particularly protons and H_2^+, are formed by decomposition of multiply-charged ions. The possibility of studying the double ionization of molecular hydrogen is being investigated.

Vacuum Ultraviolet Photochemistry.—The development of rare-gas resonance lamps has been brought to a successful conclusion, and they were used in a variety of photolysis experiments. The technique for construction of the lamps involves fabrication of a high temperature graded silver-silver chloride seal between a lithuim fluoride window and Pyrex, and careful baking and gettering prior to filling with the rare gas. Spectral

purity is excellent, with, for the argon lamp, 95 percent of the radiation in the region 1000-2000 A consisting of the 1048 A resonance lines.

By choosing the filling gas to give the wavelengths required, photochemical studies can be made above and below the ionization potential of a molecule. As an example of the first type of investigation, the photolysis of ethane at 1067 A (previously carried out at 1470 A) has shown that the primary production of hydrogen atoms compared to molecular hydrogen elimination, increases with photon energy.

Interaction of Hydrogen with a Tungsten Surface.—During the year an instrument was completed which combines a molecular beam apparatus, which generates beams of molecular or atomic hydrogen, with a field electron emission microscope. The apparatus is completely bakeable and can be used to study the interaction of a beam of either atomic or molecular hydrogen with a clean tungsten surface, which acts as the emitter tip in the field emission tube.

The conclusions reached so far in this research can be summarized as follows:

(1) The sticking coefficient of H_2 and H on tungsten at 4 °K is a strong function of the thermal energy in the beam. As the temperature of the beam source increases, the sticking coefficient decreases.

(2) The onset of surface migration of hydrogen on tungsten depends upon the binding energy. The first layer is observed to spread across the emitter tip at 180 °K; the second layer spreads at about 50 °K; and the third layer exhibits spontaneous spreading at 4 °K.

Colloid and Surface Properties

Most of the IBS measurement activities in the area of Colloid and Surface Properties are specialized programs, and many of them derive from problems raised by long-term NBS missions in developing national standards. They are oriented in general toward providing a basis of standard values which will promote greater reliability in the work of scientists located elsewhere.

Determination of Work Functions by Surface Ionization.—The surface ionization of an alkali halide on an incandescent metal surface yields both alkali positive and halogen negative ions. For a constant flux of alkali halide molecules to the surface, the ratio of positive to negative ions desorbed is dependent only upon the surface temperature, surface work functions, ionization potential of the alkali atom, and the electron affinity of the halogen atom. Recent observations of the optical absorption spectra negative ions have provided reliable electron affinities for these species. Using this data together with the well known alkali atom ionization potentials, it is possible to determine the work function of a metal surface as a function if its temperature.

Mechanical Properties

Measurement programs in IBS for the determination of mechanical properties are focused on areas where particular scientific and engineering competence can be brought to bear on important problems. Such competence is a natural result of the long-term development of national standards for physical quantities directly applicable to mechanics.

Internal Waves in a Density-Stratified Liquid.—A study was undertaken of the internal waves created by the steady horizontal motion of a sphere through a liquid having a uniform rate of density increase from the surface downward. Such a fundamental study, involving the attainment of reliable laboratory measurements and their comparison with available or, if necessary, newly developed theory, is of considerable importance for oceanographic and meteorological applications.

The data obtained over a range of variables were found to correlate acceptably with reference to significant dimensionless parameters. As existing theories did not describe internal waves at distances near to the object (within ten sphere diameters), another theory was developed to make comparison with these experiments. Although this theory involves the numerical evaluation of an integral, it has been found to provide an adequate description of internal waves within the range of physical parameters of practical interest.

Single-Crystal Ice and Its Elastic Constants.—Single-crystal regular ice, like many other crystals, has 5 independent elastic constants. These have, in the past, received little attention at very low temperatures. They have now been deduced from measurements of the several speeds of sound, as a function of temperature, down to 65 °K. Thermodynamic theory shows that near 0 °K, the individual elastic constants should vary little with temperature; the new data conform very well to this requirement. The Debye temperature (an important characteristic of the crystal lattice) calculated from the elastic constants agrees well with that determined from specific heat measurements. It is hoped that a complete set of elastic constants down to liquid helium temperatures can be obtained with sufficient precision to resolve the questions of the lattice-vibrational properties of ice crystals.

Infrasonic Waves in the Atmosphere.—A new geo-acoustics (infrasonics) station was established with NBS help near Tel-Aviv, Israel; it is being operated by the Standards Institution of Israel. Data on infrasonic waves (periods of oscillation greater than one second) in the atmosphere at Tel-Aviv will supplement data already being obtained at our stations in Washington, D.C., and at Boulder, Colo. Each station consists essentially of four microphones, located several miles apart, and connected by telephone lines to a central laboratory.

A substantial amount of infrasonic waves was produced by the great Alaskan earthquake in March 1964. It was found that the waves from the earthquake traveling across the United States produced sound waves which traveled almost vertically upward to the ionosphere. The waves were amplified enough during the vertical propagation to cause large motions of the ionosphere, with oscillation speeds of more than 100 meters per second.

Groups of very long-period infrasonic waves sometimes occur in the Washington area. The time periods of such waves are approximately between 250 and 900 seconds. The speeds are in the range between 15 and 70 m/s. These waves seem to be connected with the jet stream in the upper atmosphere about Washington. It is believed that waves can form on the lower boundary surface of the jet stream when the atmosphere verges on having an unstable temperature gradient.

Radio Plasma

Basic research in plasma physics was pursued with emphasis on the study of plasma mechanisms and the development of necessary plasma diagnostics and plasma technology. During this year it was discovered that the negative glow in a d-c helium discharge constitutes a well behaved, noiseless and stable plasma ideally suited for precision measurements. This plasma has been built into experiments for the study of rate and transport mechanisms and wave mechanism.

This source was also used to intercompare different diagnostic tools and methods with sufficiently good agreement to indicate that it may in the future serve as a standard. As a preliminary for wave propagation measurements in a magnetized plasma, tubes have been developed for operation in magnetic fields. Measurements of electromagnetic noise emitted from the tubes indicates that they will serve well for precision measurements of wave propagation.

Plasma Boundaries.—A technique utilizing slow electromagnetic waves for the study of plasma boundary mechanisms has also been developed and put into use. Nonlinear diffusion in the presence and absence of a uniform steady state magnetic field has been solved theoretically and will serve as the basis for future experiments. Also the propagation of electromagnetic waves in an overdense, collision free and bounded magnetoplasma has been treated exhaustively and is expected to be helpful in the measurements of electromagnetic wave propagation in uniform plasmas.

Brush Cathode Plasma.—A brush cathode type of plasma was used to study a variety of effects, particularly pertaining to the diagnosis of plasmas. It was found that measurements with pulse probes gave very good agreement with spectroscopic measurements.

APPLIED MATHEMATICS

Mathematics lies at the foundation of measurement, offering guidance in the development of new measurement techniques and providing the central techniques for evaluation of the results of measurement. The Institute for Basic Standards conducts a program in applied mathematics and statistics to assure effective and productive performance in the measurement of physical quantities associated with the development and maintenance of standards and in the provision of calibration services. The mathematical needs of IBS require the employment of varied and advanced mathematical techniques, and in many cases existing techniques must be modified or new ones developed for the solution of particular problems. Therefore, in order to utilize mathematics effectively, the Institute must conduct fundamental mathematical research on a fairly broad scale.

Plasma Dynamics.—The research project in plasma dynamics was initiated in 1960 as a Bureau-wide program to investigate the dynamic behavior and transport properties of plasmas, and to provide theoretical cooperation in the various plasma activities.

The present research program consists of a selection of problems relevant to the fundamental behavior and properties of plasmas. It attempts to clarify the measurements and diagnostic techniques of primary physical quantities and properties, e.g., density, velocity, temperature, pressure, stresses, field intensity, viscosity, thermal and electrical conductivity in ionized gases under non-equilibrium dynamical conditions.

Statistical Mechanics of Nonequilibrium Ionized Gases.—Plasma turbulence has been observed in fusion experiments, stellar atmosphere, solar wind and in the transition region bounded by the solar wind shock wave and the terrestial magnetosphere. A magnetohydrodynamic theory has been developed and a kinetic theory has been proposed for a rarefied plasma. It is now possible to extend these theories to non-uniform conditions. Furthermore, the knowledge gained will facilitate the derivation of a kinetic equation for a turbulent plasma.

Magnetohydrodynamics.—The expansion of a plasma into a vacuum in the presence of a magnetic field was investigated. The numerical work was performed in cooperation with NASA with the use of the NBS computer and program.

Matroids.—During the past year, theoretical interest focused on the study of matroids. Efficient algorithms were found for several basic problems, e.g., for the case of a network to find as many connected subnetworks as possible, no two with an edge in common, and each meeting all the nodes. The first conference ever held on matroid theory was conducted; it gave a marked impetus to research in the field.

Graph Theory.—Significant progress in graph theory continued. Past work was extended to provide efficient algorithms for the "Chinese post-

man's problem" (to find a tour of minimum total length which traverses every link at least once), the "optimal interconnection problem" (to find a cost-minimizing set of interconnections, given the cost of each and the minimum number of other facilities to which each facility must be joined) and the "circuit packing problem" (to find, in a graph with values attached to its edges, a set of disjoint circuits whose edges have maximum sum of values).

Supersonic Transport.—Substantial assistance was rendered to the Commerce Department's Supersonic Transport Economic Analysis. Simulation and analytic models of air transport competition were developed. Models also were devised for cost-benefit comparisons and for balance-of-payments-effects analysis. The models were implemented as digital computer programs, and applied to a wide range of future possibilities and parametric values.

Postal Mechanization.—Investigations pertinent to postal mechanization continued to be performed for the Post Office Department. Some studies involved cost-benefit analyses of proposed mail-sorting subsystems and address-coding methods, while others dealt with stochastic aspects of certain mailhandling operations.

Textiles.—Collaboration in the industrial modeling efforts of the Bureau's textile technology continued.

Northeast Corridor Transportation.—Collaborative efforts were initiated under the Commerce Department's Northeast Corridor Transportation Project. The demand for consulting and advisory services in operations research and related mathematical fields continued to rise, especially from transportation-connected Federal activities.

Statistical Engineering.—NBS conducts a continuing program of research in mathematical statistics and probability. Continuing investigation of mathematical problems in the theory of experiment design led to new results on the classical tournament problem of combinatorial analysis, with applications to the construction of calibration designs for comparing groups of objects. These designs are useful in weighing and any other measurements where the objects to be measured can be combined into groups without loss of precision or accuracy in the comparisons.

Special attention has been given to the application of modern methods of mathematical statistics to the evaluation and clarification of statistical techniques used by physical scientists. Among those examined recently are Chauvenet's criterion for rejection of outlying observations, and propagation-of-error formula. It has been demonstrated that Chanvenet's criterion should usually be discarded in favor of more precise modern techniques. The correct method for constructing and applying propagation-of-error formulas has been explained in detail, with particular emphasis on the types of situations that arise in complex experimental programs

were several related measurements and the associated correction factors must be combined into a final result.

Phase Integral.—A successful investigation has been made of phase-integral methods used for problems of wave propagation and quantum mechanics. Asymptotic theory of differential equations developed earlier at the Bureau has been applied to put phase-integral methods on a firm mathematical foundation with a comprehensive error analysis.

Multiple Integrals.—The evaluation of multiple integrals by a combination of methods, such as the Monte Carlo method and the number-theoretic methods associated with uniformly distributed sequences, was studied and significant advances in error improvement were made. In certain instances integrals were evaluated by these methods which could not be previously efficiently evaluated.

Laboratory Data Reduction.—The reduction of laboratory data always represents a considerable chore and is often a serious bottleneck in the research process. It is, at first, surprising to note how much of this work is still being performed on desk calculators, even in organizations having large digital computers. One reason for this is that each application is seemingly so specialized that a programming effort is not justified—and, indeed, it often is not justified when the scientist is required to build his program from the ground up in the conventional manner.

At NBS this problem has been solved to a considerable degree by the development of OMNITAB—a general purpose computer program which gives the laboratory scientist the full power of the digital computer without requiring him to learn to program it. OMNITAB can be used for the calculation of tables of functions, for solutions of nonlinear equations, for curve fitting, and for statistical and numerical analysis of tabular data.

PERFORMANCE CHARACTERISTICS

The properties of well-defined simple substances can easily be measured, and results expressed in relation to basic physical quantities. But NBS is also concerned with the performance characteristics of devices—the lens and shutter assembly of a camera, a transistor, or an electric motor. The behavior of such devices is dependent on the properties of its components, and sometimes an exact and reliable connection between the two can be defined. More often, however, the most important question about the device is not its construction, but its performance as a whole, and the answer to the question must be based on testing related to the end use.

Lens and Lens Systems.—The successful use of many devices in metrological work depends upon precise knowledge of the performance characteristics of lenses or other optical elements used in the construction of the device. It is therefore necessary to develop methods of measurement that yield values of optical constants sufficiently accurate to meet current needs.

In addition, methods of analysis must be developed for use in pointing the way toward achieving still higher performance.

New Lens Measurement System.—A Moise fringe system of measurement has been adapted for use in the determination of lens constants. With this device, focal distances can now be measured to the nearest micron as contrasted to the precision of ± 20 microns achieved previously. This device is also used in the accurate determination of zone heights, resulting in increased accuracy of longitudinal spherical aberration values of lenses. Also, analytic methods have been developed for predicting the resolving power of a lens when measured or when design values of the longitudinal, spherical and chromatic aberration of the lens are known.

Photographie Information Coneentration.—Photographic emulsions can store more information per unit of area than any other device. A microphotograph of a printed page reduced 1,440,000 times in area was made recently, and the copy was legible through a high-powered microscope. Publishable reproductions were obtained by enlarging the copy nearly 4000 diameters. The information concentration on the copy was computed to be over 2 million bits per square millimeter, which more than doubles previous estimates of the emulsion capacity.

Cyelie Bending of Grounding Conductors.—At the request of the Rural Electrification Administration a machine with a reciprocating head, counter circuits and controls was constructed, and bending (fatigue) tests were made of conductors used in the grounding loop of pole-mounted power distribution transformers. Ungrounded transformers have led to substantial property loss and are hazardous to operating personnel. Test results of three widely used soft copper conductors showed 7 wire and 19 wire strands have about equal endurance times and that both types were about 5 times better than the solid wire when tested under similar laboratory conditions.

TECHNICAL ASSISTANCE TO OTHERS

The National Bureau of Standards is a national source of technical assistance and consultation in certain problem areas, and it inevitably assumes a leading role in cooperative efforts and scientific conferences directed at the solution of the problems.

All of the scientific specializations in the Institute for Basic Standards take some part in technical assistance, but the contribution in applied mathematics is especially significant. This emphasis is due primarily to the capability of the NBS staff to combine mathematical competence with thorough familiarity with the scientific fields to which mathematical analysis is applied.

The following are specific examples of technical assistance provided by IBS in the past year.

Conference on Critical Phenomena.—A Conference on Phenomena in the Neighborhood of Critical Points was held at NBS on April 5-9. The Conference was jointly sponsored by the National Bureau of Standards, the National Science Foundation, and the Office of Naval Research.

The Conference brought together experimentalists and theoreticians concerned with critical points and second order transitions in such diverse fields as thermodynamics and transport properties of liquids and liquid mixtures, superfluid helium, magnetism and antiferromagnetism, light and x-ray scattering, and ultrasonic propagation.

Calorimetry Conference.—In October 1964 the bureau was host to the 19th Calorimetry Conference, which attracted over 200 American and foreign scientists. The conference, which meets annually at various centers of calorimetry, provides an avenue for exchange of information and ideas by means of formal papers and informal discussions. Bureau scientists have been active in its affairs since its inception in 1946. This year's conference was sponsored jointly by the Bureau and the National Naval Medical Center. The joint sponsorship encouraged an interdisciplinary discussion of the rapidly developing application of calorimetric techniques to problems of biophysics and other life sciences.

Radio Standards Seminars.—The Radio Standards Laboratory maintains close contact with industry to better determine their needs and to keep them informed of the available services. In this connection the Laboratory offered three seminars during the year covering the latest developments in the measurement of microwave and high-frequency impedance, the measurement of microwave and high-frequency power, and the calibration of reference samples for magnetic and dielectric specimens. These seminars were attended by supervisors and engineers from industrial and government laboratories.

The Laboratory also contributed to two other seminars which were sponsored by the Bureau and arranged with the joint participation of the Electronics Industries Association and the National Electrical Manufacturers Association. These seminars were devoted to high pulse voltage measurements and microwave high power. They served to identify the areas in which future work by NBS would be most valuable to industry, and to recommend methods of measurement which should be proposed for adoption in military specifications.

Laser for Geodetic Measurements.—NBS, in cooperation with the Coast and Geodetic Survey, has demonstrated the superiority of a laser light source for measuring long distances across the earth. These measurements are normally made with a device known as a geodimeter. This instrument utilizes the known speed of light to measure distances of several miles. By substituting a laser light source for the conventional mercury lamp in

Scientists from NBS and the Coast and Geodetic Survey test a laser-geodimeter over an 8-mile path. The incorporation of a laser as the light source rather than the mercury lamps usually used promises to improve the accuracy and range of the geodimeter.

the geodimeter, considerable improvement in precision and convenience should be possible for long range surveys.

Sound Insulation.—Under FHA sponsorship, NBS prepared a guide dealing with the control of airborne, structure-borne, and impact noise in multistory buildings, with specific emphasis on apartment-type buildings. The guide should provide much-needed assistance to architects and builders, in the construction of adequately sound-conditioned buildings. It will also lay the groundwork for the development of noise control criteria.

Basic research on sound propagation in rooms and through structures, necessary for the engineering of sound control in buildings, was directed toward a study of the generation and analysis of diffuse or random sound fields. Instrumentation for measurement of correlation coefficients in such sound fields has been assembled and the preliminary design of an experimental rotating vane system for generation of diffuse sound fields has been completed.

Power Line Tests.—Tests were made for the Rural Electrification Administration to determine the relative resistance to burn down by lightning of a group of wire samples. The wires are of copper- or aluminum-clad steel intended for electrical transmission and distribution in rural areas. The wires contain high strength steel cores, permitting long spans and stringing under high mechanical tension. Thus, they result in considerable economy in building rural pole lines.

In the laboratory, each wire was strung under normal line pull, and an arc was struck to its midpoint from a surge-current generator. The amount of arc current was controlled by the series resistance and by the charging voltage of the capacitor bank. By successive tests on each kind and size of wire, its ability to withstand lightning burn down, relative to the others, was determined. About 20 kinds and sizes of wire were evaluated. Peak surge currents were as much as 75,000 amperes.

Formation Lights for Helicopters.—Until recently, flying helicopters in formation at night was extremely hazardous, as pilots could not see the rotors of adjacent craft. There have been many collisions and casualties resulting from this lack of visibility. NBS helped eliminate this hazard by incorporating lights within the tips of the rotors. The lighting system involves two major components. The first is a slip ring connector for carrying electric current up the rotating rotor shaft, and the second is the lighting fixture itself, flush mounted in the rotor blade. The direction from which the rotor light is visible can be limited at the time of installation. For example, a light placed on the top of the rotor cannot be seen from the ground, and only from certain angles from above. The lighting system will find wide military and commercial application.

Aging Blemishes on Microfilm.—Blemishes found on some microfilms, years after they were processed and placed in storage, have been intensively studied in a research program jointly sponsored by industry and Government. Extremely small amounts of information loss have been reported, and in some large collections of microfilm, no blemishes have been found. All evidence indicates that the blemishes are not caused by biological organisms; apparently, image silver is ionized, migrates, and is reduced to silver in a form other than that of the original silver grain. Gaseous products of degradation reactions in cardboard storage cartons also appear to be contributory.

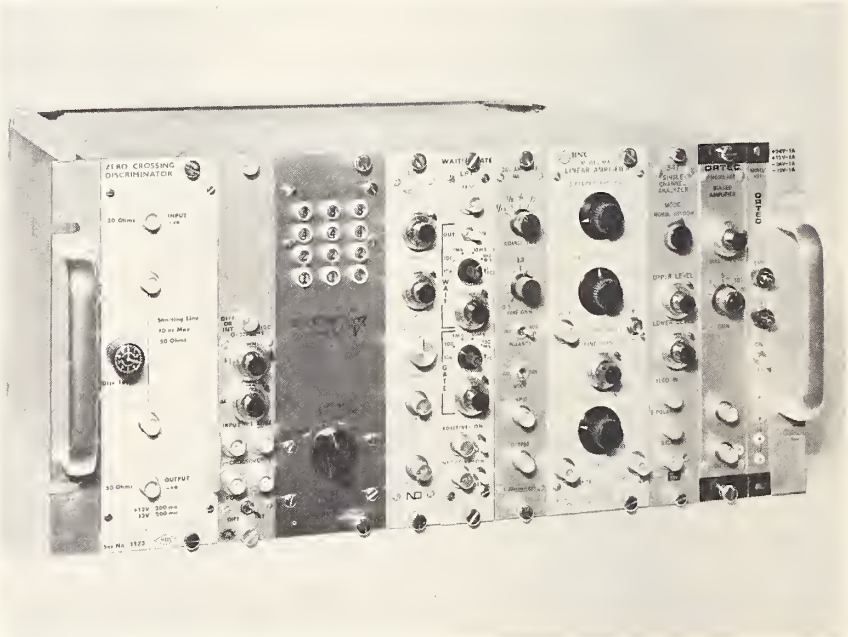
Neutron Studies.—A study of the penetration of neutrons from nuclear weapons has been made, and spectra and angular distributions of neutrons in air at various distances from a neutron point source have been calculated. Computer programs have been written to study the spatial variation and energy distribution of neutrons traversing ducts and voids in thick shields.

Gamma Ray Penetration.—A computer program has been written to calculate the penetration of gamma rays from a radioactive source uniformly distributed over a rectangular area. The program is designed as a first step in making more accurate calculations of fallout protection in urban areas.

Gamma Ray Reflection.—A technique for estimating the reflection of gamma rays or neutrons from a flat surface located near a point source and point detector has been devised. The accuracy of calibration of radioactive sources in 4 π geometry can be improved by using this technique to evaluate the backscattering effects of walls and floors.

Electron Beam for Counter Calibration.—At the request of the NASA Goodard Space Flight Center, a particle detector calibration facility was developed. The work consisted of the design, installation, and calibration of a magnetic analysis system to be used with the NBS synchrotron to provide beams of electrons and positrons. The energy, intensity, and intensity distribution of these beams were calibrated. Bremstrahlung and un-analyzed electron-positron pair beams were also provided. These beams were used by NASA personnel to calibrate their particle detectors.

Standard Nuclear Instrument Modules.—In conjunction with the National Laboratories of the U. S. Atomic Energy Commission, a standard nuclear instrument module system has been developed. This standard system,



An illustration of the compatibility of nuclear instruments constructed by six manufacturers and three laboratories in accordance with Nuclear Instrument Module System specifications. All the modules are plugged into the same bin, from which the proper operating voltages are obtained.

known as the Nuclear Instrument Module System, has been widely adopted by the National Laboratories, by numerous other laboratories and universities and by a number of manufacturers. This wide acceptance considerably alleviates the problem of incompatibility that arose with the transistorization of nuclear instruments. It provides interchangeability of different laboratories and manufacturers.

Data Handling System.—Computer controlled data-handling equipment for experiments using the NBS Linac was developed, and in addition, major executive type programming and about 150 separate data handling programs for specific experiments were developed. During the year a com-

panion system very similar to the NBS system was constructed for the Armed Forces Radiobiology Research Institute.

Radiation Guide.—NBS played an active role in assisting the Federal Radiation Council to develop protective action guides for strontium 89, strontium 90, and cesium 137. The report of the Federal Radiation Council, issued in May 1965, provides guides as to when protective action should be considered in the event of local high level contamination with any of these radionuclides.

Digital Computations.—NBS and the Harry Diamond Laboratories jointly purchased the IBM 7094 computer operated by the Bureau. The purchase permitted further reduction in computation charges. The Bureau continued to operate this computer and an IBM 1410 owned by HDL. An additional printer was attached to the 1410 to speed up turn-around time for the IBM-7094-1410 system.

In addition to performing computations on its own equipment the Bureau assisted other Government agencies in setting up problems for other computing machines. It also administered a Sharing Exchange, through which it helped other Government agencies and Government contractors obtain programming assistance and computing time among the Government computing facilities in the Washington metropolitan area. Serving as the Federal Computing Center, the NBS Computation Laboratory found itself in the position of offering technical assistance to a great many of the smaller agencies and contractors without computing system or staff of their own.

Important computations were performed on problems in polymers, plasma dynamics, radiation studies, nerve responses, interplanetary calculations, supersonic jet-transport economic analysis, fallout shelter computations, measurements of gage blocks, biological pattern data processing, and microfilm blemish analysis.

A computer program is being developed for automation of the analysis, reporting and record-keeping of measurements of refractive index. In addition to providing statistical procedures for the surveillance of factors affecting the accuracy and precision of the measurement process, it is planned that the computer output will constitute the laboratory notebook and will include the results of ancillary calculations used to check the data for consistency.

Measurement Seminars.—NBS staff in Washington and Boulder, Colo. collaborated to conduct a 4-day seminar on Precision and Accuracy in Measurements and Calibration for personnel of the calibration laboratories at Boulder. In Washington, in-hours courses on "Statistics of Measurement for Scientists and Engineers" and "Introduction to Mathematical and Statistical Analysis of Laboratory Data" were given.

III

INSTITUTE FOR MATERIALS RESEARCH

The Institute for Materials Research (IMR) is the principal focal point in the Federal Government for assuring maximum application of materials sciences to the advancement of technology in industry and commerce; it provides the main materials support to the other missions of the National Bureau of Standards. IMR assists and stimulates industry and commerce in the development of new and improved products and services by supplying an ever increasing understanding of the basic properties and improved characterizations of materials as well as by providing relevant measurement science and technology.

The objectives of IMR are to:

(1) develop techniques for the preparation and characterization of materials and for scientific studies on these materials,

(2) identify and measure meaningful physical and chemical properties of materials under carefully controlled conditions.

(3) supply on-site calibration services to science, industry, and commerce through a standard reference materials service,

(4) provide technical assistance to other government agencies on request for advisory and problem solving, and enhance the national materials science capability as a part of administration policy,

(5) identify critical materials problems preventing the attainment of major national goals and furnish unique relevant assistance,

(6) insure maximum interchange among IMR and industry, commerce, science, and other government agencies through various means of technical data dissemination.

Materials are the major problem and frequently the limiting factor in many major programs undertaken by both industry and Government to achieve national goals. High performance, utmost reliability, precise predictability and reproducibility of materials are necessary. Failure to meet or be able to measure these requirements in many instances, has led to widespread concern at the evident gaps in knowledge of production and

identification of materials that exhibit adequate reproducibility for engineering purposes.

PREPARATION AND CHARACTERIZATION OF MATERIALS

Preparation is the processing necessary to produce samples of materials with controlled chemical purity, composition, homogeneity, physical order, and required geometric shape. Characterization is the description of the composition and structure of a material that is significant for a particular operation and that suffices for reproduction of the material. Such descriptions have become indispensable in materials research, definition of standards, production of standard reference materials, and the acquisition of reference data.

Preparation

Pure Copper Prepared.—The purest copper ever made has been prepared by IMR scientists. The large single crystals contain no impurities that can be detected by emission spectroscopy. In the course of this study, extensive cryostat and instrumentation facilities were developed to study copper and its dilute alloys. In addition, results of the study gave the first significant information on the electronic mean free path in copper. This work is a contribution to the understanding of basic properties of materials and will permit advanced engineering hitherto impossible.

New Purification Technique.—A new purification technique has been developed which may permit the preparation of crystals approaching absolute purity. Experiment shows that the impurity content is reduced by a factor of as much as 10^4 in each half-hour stage of operation. A conjecture has been drawn that any number of stages can be employed with the same degree of purity improvement with no recontamination. This technique demonstrates a new idea and is a major advance in purification methods. It may lead to better processes in major crystal growth industries, spawn new industry and permit more sophisticated research in the universities and research institutes.

Characterization

Significant developments have been made in this important area of activity. Many new and improved analytical procedures were developed during the year. Some of the more important ones are described below.

Radiochemical Method Analyses Metal Chelates.—A new radiochemical method was developed for analyzing metal chelates. Chelates are widely used in analytical chemistry for separating metal compounds, and are useful as antidotes for poisoning by toxic metal compounds. For most uses, composition of the chelate must be accurately known. This method is more

Close-up view of the NBS apparatus used to obtain ultrapure materials. One impurity in the substance is a red dye which shows as gray in the picture. Two silver strips (left center) are in front and back of a crystallizing mound. Note that the color of material in the mound is lighter than the surrounding liquid because it is rejecting the dye impurity as it crystallizes.

direct and reliable than previously used optical methods and can be used in untidy environments—in oil sludge or blood, for example.

Spectroscopic Technique Analyses High Temperature Alloys.—IMR scientists desired an improved spectroscopic technique for chemically analyzing the high-temperature alloys being used in increasing quantities in

modern technology. The technique is readily adaptable to existing instrumentation and can save industry time and money because the number of primary standards needed to calibrate the analytical equipment is reduced.

Measurement of Tellurium in Metals.—A new method was developed for measuring small amounts of tellurium in metals. Small amounts of tellurium in metals provides advantages such as increased machinability of brass. The tellurium content of new standard reference brasses and cast irons is now certified, based on measurements using the new method.

Analysis of Noble Metal Alloys.—X-ray emission analysis was adapted for precise and rapid analysis of noble metal alloys. The time required for a complete analysis is only one-tenth that required for conventional wet chemical methods. The procedure is applicable to the manufacture of previous metal alloys in their production and quality control. Also, dental research will benefit. For example, the American public can expect to save many thousands of dollars per year in dental care costs as a result of the cooperative research program of the American Dental Association at NBS.

Solid NMR Studies.—The phenomenon of Nuclear Magnetic Resonance (NMR) was shown to be useful as an analytical technique in analyzing certain solid pieces of metal. In cases where the technique is useful, the costly procedure of first preparing a fine powder from the bulk material can be eliminated.

Soft X-ray Spectroscopy.—The usefulness of soft x-ray spectroscopy was increased by the removal of several inhibitors that had plagued the field for some time. Soft x-ray techniques provide information on the electronic structure of metals and alloys and, in general, open the way for obtaining better information on why materials behave as they do. Certain nickel alloys have already been studied and much useful data obtained.

X-ray Spectrometric Analysis of Metal Alloys.—An x-ray spectrometer which performs rapid chemical analysis of a wide range of metallic alloys was developed. Devices in this family, often used for on-line production control, can be switched from analysis of one metal to another only with considerable difficulty and loss of time. This instrument can be readily used to analyze virtually any of the hundreds of alloys now in commercial production.

MEASUREMENTS OF PROPERTIES OF MATERIALS

The Institute for Materials Research maintains an active measurements program. The principal aims are: (1) production of reference data; (2) development of new measurement methods; and (3) determination of the relationship of bulk properties to the characterization parameters of the material.

Basic Measurements on Basic Materials

The following items represent some of the progress in measuring the basic properties of basic materials:

New Atomic Weights.—IMR has a continuing program to redetermine values for chemical atomic weights. During the past year the determination for two more elements has been completed. The new atomic weight of bromine provides a more accurate value, 79.904 $\pm$0.001, which differs significantly from the currently accepted value, 79.909 $\pm$0.002. The high reliability of the new determination should assure rapid international acceptance. The chemical atomic weight of copper was also determined. Though the value of 63.546 $\pm$0.001 indicated that the presently accepted value, 63.54, is substantially correct, the recent determination establishes a new level of accuracy for this important chemical constant.

Properties of Parahydrogen.—Extensive data on parahydrogen, a fuel used in advanced chemical and nuclear powered rockets, have been published. Because of the important applications to space projects, the thermodynamic and transport properties of parahydrogen were determined with high accuracy over a wide range of temperature and pressure in both the liquid and gaseous states.

New Views of Metal Crystallization.—A field-ion emission study showed that, contrary to prior concepts, tungsten atoms deposited on a clean tungsten surface stick in the first lattice site they encounter rather than jumping or "migrating" to other positions. This new information is valuable in understanding crystal structure, and will influence future studies in surface and solid state physics.

High Pressure Single Crystal X-ray Diffraction.—A new method was developed for studying high pressure structural effects at the atomic level. For the first time, x-ray diffraction experiments at equilibrium conditions can be performed to at least 30,000 atmospheres and ambient temperatures up to 300 °C.

Atomic Arrangement in Crystals.—Single crystal x-ray diffraction studies have established the atomic arrangement in such diverse compounds as $Na_20.4B_2O_3$, and Bis-dodecacarborane ($C_4B_{20}H_{22}$).

Basic Properties of Engineering Materials

The Institute for Materials Research provides the basic properties of engineering materials to permit informed judgment on their engineering use.

Cryogenics Data Center.—One very important activity, particularly in this space age, is IMR's Cryogenics Data Center. In addition to in-house research and measurements, current literature is surveyed and a variety of reports are issued for use by industry, Government, and universities. The scope of the reports includes published data sheets, charts, and topical reports on the properties of cryogenic fluids and other substances at cryogenic temperature.

New Device Measures Dielectric Properties.—In seeking means of determining better ways of determining basic properties of materials, a new device was developed for measuring the dielectric properties of materials over a wide range of electrical frequencies. The device promises a saving in equipment and time as well as being capable of yielding more accurate and useful information. Dielectric measurements not only determine electrical properties but tell about the general mechanical behavior of the materials. The polymer industry, for example, uses such measurements to predict mechanical properties of new and improved plastics materials.

Engineering Properties of Engineering Materials

In order that meaningful performance criteria can be specified, the Institute for Materials Research engages in considerable work on the engineering properties of commercially available materials. Much of this work concerns the degradation of materials and methods for making meaningful measurements.

Effect of Slack-Quenched Structures in Steel.—Heat-treated steels with incompletely hardened (slack-quenched) areas pose a problem to the designer and to users because the mechanical properties of these areas have not been quantitatively established. The usual solution in case of doubt is to increase the safety factor or use steels with greater hardening ability. Both of these procedures are costly.

NBS evaluates the mechanical properties of such steels. Under certain limited conditions, the structures are found to be non-detrimental, but in most cases they degrade properties in varying degrees. Quantitative appraisal of the effects should give designers and users firm knowledge of when and where these steels can be used and thus reduce the need for overdesign and overalloying.

Polymer Deterioration.—Studies were conducted to determine the lifetime of polymers in outer space. Controlled measurements are being made on the rate of decomposition of polymers subjected to high energy radiation. Recent studies indicate that impurities in polymers may be causing some of the deterioration.

Fracture Characteristics of Polymers.—Studies of the fracture characteristics of brittle and amorphous plastics have produced data which will enable the engineer to trace the progress of failure in a plastic structure and also to determine events occurring at the molecular level during failure. Such information is essential to evaluating and improving the strength of structures.

Tensile Strength of Dental Amalgam.—A method for measuring the tensile strength of dental amalgam was developed in which specimens are stressed by high rotational speeds. The method is especially well suited for observing the strength of small specimens during hardening or setting—a prerequisite for developing an adhesive polymer filling.

Chemical Behavior of Sugars Revealed.—A simple method for measuring the rate of "enolization," the first step in the conversion of one sugar into another, was devised. Little is known concerning the fundamental chemistry of sugar reactions, yet this information is essential to an understanding of the biological processes on which life depends.

Fatigue Failures of Aluminum.—A study revealed that fatigue cracks in aluminum develop and grow more rapidly in a moist atmosphere than in a dry one. These findings will be valuable in designing aluminum structures, especially in extreme environments.

Heat of Vaporization of High-Temperature Metals.—A new method has been developed for measuring the heat of vaporization of refractory metals. Heat of vaporization is a major controlling factor in determining the high-temperature stability of metals and, in turn, plays an important role in the design of metal structures, such as space vehicles and launching equipment, which must survive in extremely high ambient temperatures. Several methods are now available for making these measurements; however, their results do not always agree. The new measurement method arises from a new theoretical base and provides an independent check on other measurements.

New Understanding of Fiber Behavior.—A new theory concerning strain travel through fibrous materials has been developed and checked experimentally. This theory makes it possible to understand better the behavior of such materials as tire cords and parachute lines when they encounter severe strains.

STANDARD REFERENCE MATERIALS

About 70,000 standard reference materials items were prepared and sold to more than 2,000 different companies. The materials are certified for one or more of their physical or chemical properties, such as purity, composition, viscosity, melting point, etc. They are used to calibrate measurement systems in science and industry in order to facilitate the exchange of goods, enhance yield in mass production, and provide quality control and performance criteria. Examples of types of industries which utilize this service are metal, petroleum, automotive, cement, chemicals, rubber, plastics, pharmaceutical, and transportation.

Cast Iron Standards.—Certification of the amount of 11 trace elements was added to the previous analysis supplied for white cast-iron standard materials. Because each trace element has an effect on the properties of the iron, the new information will permit simplified design and production of cast irons.

Improved Analysis of Cartridge Brass Standards.—Eight trace elements were determined in a series of five NBS cartridge brass standard materials. These trace elements—aluminum, antimony, arsenic, beryllium, bismuth,

cadmium, silver, and tellurium—were added to the certificates of analysis. This advance in certification capability enhances the value of the standards to the copper industry because each trace element uniquely influences the properties, and therefore the use, of the brass.

New Plutonium Isotopic Standard.—A new plutonium isotopic standard, containing predetermined ratios of 4 isotopes, was calibrated. Standard material will be made available on a provisional certificate of analysis. The Atomic Energy Commission requested the standard on an expedited basis to permit classification and accounting of plutonium isotopes, particularly in exchanges involving foreign governments.

Radioactivity Standards.—Seven new or renewed radioactivity standards for the calibration of radiation-measuring instruments were issued. One of these, americium 241, is for calibrating instruments used in civil defense. Two others, cesium 137-barium 137a and cerium 141, are the basis for measurement of important fallout products.

Glass Viscosity Standard Material.—A second glass viscosity standard was made available. To obtain glass products of uniform thickness, shape, and strength, particularly in high-speed mass production processes, viscosity must be held to close tolerances; therefore, improved viscosity measurements and standards lead to improved product quality control.

Glass Beads for Neutron Flux Measurement.—One of the real needs in the nuclear field is a simple, straightforward method for the absolute determination of slow neutron flux. Such a method has now been developed based on the use of glass beads, enriched in boron-10, to which one of several activators (potentially radioactive via neutron absorption) has been added. Three glasses—a dysprosium glass, an indium glass, and a cobalt glass—have proved successful. The first two are alternate absolute standards, while the latter is a transfer or secondary standard.

Graduated Glass Bead Sample.—A fine, powder-like standard particle-size-distribution sample containing glass beads, 2 millionths to 30 millionths of a centimeter in diameter, was prepared and made available to the public. These fantastically small beads were measured with a semiautomatic microscope and the data obtained were analyzed by a computer. The volume and weight of each particle was measured. The sample is intended for calibration of electronic counters which count particles either by weight or size.

TECHNICAL ASSISTANCE TO OTHERS

The IMR staff represents a national resource of great importance to the Government as a whole. Because of the unique competences among the staff, other government agencies frequently request advice and assistance. A few activities of this type are detailed below.

Properties of High Strength Glass.—At the request of the Air Force, IMR scientists measured the properties of a new high-strength glass devel-

oped by the glass industry for use in aircraft. Data from the study will aid aeronautical engineers and others in making best use of the glass.

Assist in Updating Paper Standards.—A new addition of the *Government Paper Specification Standards,* published by the Joint Congressional Committee on Printing, contains several improvements to which the Institute for Materials Research made significant contributions. New testing standards for bursting strength of heavy papers, visual comparison of color and

Slush hydrogen is formed at the bottom of a flask at the NBS cryogenics laboratory in Boulder, Colo. Solid hydrogen, formed on the surface of liquid hydrogen, sinks to the bottom and breaks into very fine particles.

a specification requirement excluding fluorescent brighteners are among the most important changes.

Assistance to the U. S. Mint.—The Bureau of Engraving and Printing requested assistance on a number of metallurgical problems associated with engraving and printing processes, and in the selection and treatment of materials for research and development equipment. In a particular case, a metal failure in two of four new currency machines resulted in their shutdown. NBS staff studied the failure, determined the causes and recommended corrective measures. Preventive measures were suggested to keep the other two machines in production until a permanent remedy could be incorporated.

Assistance to NASA on Cape Kennedy Corrosion Problems.—The technical problems involved in the launching of space vehicles and the operation of the Kennedy Space Flight Center are not confined to such things as booster rockets and guidance systems. Corrosion of gantries and other structures exposed to the marine atmosphere also presents a serious and challenging problem. At NASA's request, technical advice is provided on corrosion problems in order to minimize damage.

Thermophysical Characteristics of Liquid Hydrogen Slush.—The Cryogenic Engineering Division, in conjunction with National Aeronautics and Space Administration—Kennedy Space Center, has been investigating the thermophysical characteristics of liquid hydrogen slush to determine the feasibility of its use in the space program. The increased density and lower energy level of slush hydrogen provide a method of storing a larger quantity of the fuel for longer periods of time. Investigation to date has included particle size distribution, terminal velocity measurements, and aging characteristics.

Chemical Analysis Backs Medical Treatment.—At the request of Walter Reed Army Medical Center, a successful analysis was made of a fragment of metal taken from a soldier's eye. The analysis was needed so that toxic effects could be anticipated and counteracted. Although the piece of metal was less than a millimeter in diameter, the chemical analysis was performed using only one-hundredth of a square millimeter of the sample's surface.

TECHNICAL INFORMATION DISSEMINATION

Scientific information is of little value unless it comes to the attention of people who need it.

United States and Japan Cooperate on pH Standardization.—At the suggestion of NBS, the Technical Committee on the Determination of *p*H (acidity) of the Japanese Standards Association arranged a conference on *p*H standardization with an NBS representative. Both countries recognize the need for an international standard for *p*H, and plans were made for the formation of a group to draft a suitable document. In general, Japanese

practice in this important area of analytical measurement follows closely the lead of NBS.

Guidelines for Corrosion Protection of Underground Pipes.—NBS published engineering guidelines for the design of corrosion protection systems for underground pipes. The recommendations are based on corrosion data from 4500 metal specimens installed at 86 different soil test sites for periods up to 17 years.

Dental Research.—A 5-year study on complete dentures showed that gradual deterioration in stability and fit is caused by changes in the mouth tissues and not by dimensional changes in the dentures, a view widely held previously.

A review of the physical, chemical, histological, and clinical properties of a zinc oxide-eugenol dental cement originally developed at NBS was prepared. This review will aid manufacturers in developing improved formulations and will better acquaint the dental profession with the proper use of these cements.

Properties of Rare-Gas Solids.—A review of the basic solid-state properties of the rare gases—neon, argon, krypton, and xenon—was prepared. Because the solids formed by these gases are relatively simple, their properties are relatively simple to describe. Such a description gives insight into the properties of the more common and more technologically useful but more complicated solids—transistor materials, for instance.

National Standard Reference Data.—Work continues on the third edition of *Crystal Data.* This revision is a pilot project of the National Standard Reference Data System to develop techniques of data processing for ultimate publication by computer-controlled equipment at the Government Printing Office. This process should reduce to a few weeks the time between publication of the book and the inclusion of new data.

IV

INSTITUTE FOR APPLIED TECHNOLOGY

The mission of the Institute for Applied Technology (IAT) is to create opportunities for the application of technology in Government and in civilian industry. The Institute has a mediating role to play between the development and use of technology, and as a consequence, must scan and analyze the state of technology in order to identify appropriate opportunities for Government, at a given point in time, to facilitate its use. In this sense, the Institute's mission is part of the broad Department of Commerce mission of facilitating the commerce of the United States.

From among these opportunities the Institute must identify and understand those tasks appropriate in the National Bureau of Standards. These fall into the following broad areas: (1) engineering measurements and standards and (2) the dissemination of technical information to industry, government and the technical community at large, and (3) specific programs to foster invention and innovation.

ENGINEERING MEASUREMENT AND STANDARDS

This is the Institute's link to the national measurement system. IAT's function here is to provide a sound technical basis, in the form of test methods and performance criteria for standards, specifications and codes in a variety of fields, with special emphasis on building, information processing, and instrumentation. In addition, IAT provides links to standard, code and specification writing bodies so as to identify standards-related technical problems which need solving and to assure the maximum application of NBS knowledge and research results.

Electronic Devices.—During the past year work has continued in standardization, material and device characterization, and standard test method development. Work in areas such as Hall device standards, transistor

reliability studies, and silicon crystal resistivity measurement techniques have just about been completed.

One major direction of this effort has been the development of methods for measuring the characteristics of integrated electrical devices, establishing performance criteria for them, and developing definitions and terminology. Early experience has suggested that the reliability of these integrated circuits may greatly reduce the requirements for repair, overhaul, and maintenance operations.

Building Research

Many of the building research programs are addressed to the engineering properties of the materials used by the construction industry. These include materials like asphalt, concrete, and various metals. In this area it is important to recognize the cooperation of industry through financial support and through the provision of Research Associates who work alongside the NBS staff.

Weathering Data on Aluminum Enamel.—A Research Associate sponsored by the Porcelain Enamel Institute initiated an exposure test, at five locations throughout the United States, to obtain weathering data on architectural porcelain enamels for aluminum. Since enamels for aluminum are relatively new, reliable information is lacking on their weather resistance. This study will supply data on color stability, and so permit the preparation of improved specifications.

Engineering Properties of Asphalt.—Work related to the engineering properties of asphalts has revealed that ozone, a common constituent of smog, increases the rate of decomposition of asphalt roofing materials threefold. Understanding and control of this phenomenon is extremely important to the roofing industry in view of the fact that 80 percent of the roofing material used in this country today is asphalt.

X-Ray Investigation of Asphalt.—Asphalt roofing materials are usually so opaque that it is difficult to examine them by conventional optical methods. In a new method developed at NBS, x rays were used to produce images of the microstructure of asphalt-containing specimens. The distribution of reinforcing materials in asphalt films and mats, as well as the origin and development of failures in shingles and other structures were determined. This technique not only reveals many details of the mechanism of deterioration but is often able to show intrinsic weaknesses in design or formulation before they become apparent by other methods of analysis.

Concrete Testing Technique.—A recent investigation has resulted in a new analysis technique for testing concrete. A simple but relatively accurate method for determining the granular content of sulfur mortars was devised for use by cement testing laboratories. It will be especially useful to smaller laboratories which do not have the equipment necessary to perform the analysis by the ASTM method.

Commercial Sealants.—The properties and performance characteristics of commercial sealants used to seal building joints were studied. Watertight joints present one of the most difficult and troublesome problems in modern building research; essentially perfect joint seals are required to prevent leakage of wind-driven rain. Many new buildings have large curtain walls as exterior panels which are exposed to daily and seasonal temperature changes. Identification of significant performance characteristics and development of suitable test procedures enabled the General Services Administration to issue new Federal Specifications on joint sealants.

Exterior Columns for High Rise Structures.—The Federal Housing Authority asked NBS to develop engineering data on exterior columns of high rise buildings. The columns, exposed to changing temperatures on the outside face and relatively constant temperatures on the interior, change shape as the temperature differential changes. A mathematical analysis of this behavior has resulted in a computer program which will aid FHA in its future specifications decisions.

PERFORMANCE CRITERIA

Emphasis on the use of performance criteria, as contrasted with measurements based on narrowly drawn engineering specifications, has been receiving more and more attention within the Federal Government. A number of reports were prepared in the last year discussing the benefits to be gained from the shift to performance-based specifications. There has also been an increasing awareness that the Federal Government's own procurement programs, which represent large masses of purchasing power, might be used to encourage innovation as well as to promote economy of purchase, if procurement were based on performance criteria.

Data Processing

During this past year the Bureau of the Budget issued Budget Circular A-71 which made the Department of Commerce responsible for a number of functions in the data processing field:

> "The Department of Commerce is responsible for aiding in the achievement of increased cost effectiveness in the selection, acquisition and utilization of automatic data processing equipment."

A major emphasis in this Circular is one of developing performance requirements for the Government's procurement of computers and computer programs. The annual cost to the Federal Government of using electronic digital computers has been estimated at approximately $3 billion.

Computer Center.—A Center for Computer Science and Technology was formed by combining the former Information Technology Division and the Computation Laboratory of the Applied Mathematics Division. Among the principal efforts of the Center are the development of a technical basis for standards for data processing equipment, for information carriers such as

tapes, and for computer programming languages. The Center works jointly with industry groups, as well as government agencies, and will submit recommendations for standards pertaining to Federal purchases of computer hardware and software to the Office of the President.

Building Research

Military Construction Study.—The Department of Defense sponsored a feasibility study into using a portion of the military construction program to encourage private industry to develop new or improved building systems. The likely economic advantage to the Nation's building industry was considered as important as the economic benefits to be gained by the Department of Defense; new systems will provide a source of advanced technology for military and civilian programs alike.

The project as planned consists of five stages of development, of which the first feasibility stage has now been completed. Various military building programs were analyzed in order to find the building types which would lend themselves most successfully to a pilot program. This analysis included exploratory discussions with potential contractors to find the answers to such questions as:

— how large a commitment would be required to provide sufficient inducement to secure proposals?

— what companies now part of the building industry would be willing to participate in this project?

— what companies not now supplying building systems might be interested in bidding on this project?

Subsequent stages will include the development of performance criteria; submission of design proposals by industry; and final coordinated development of new building systems.

Plumbing Fixture Study.—Under the sponsorship of the Building Research Advisory Board of the National Academy of Sciences-National Research Council, IAT initiated an investigation of sanitary plumbing fixtures. The purpose of the investigation was to identify those characteristics that affect utility and sanitation and to develop tests to evaluate them.

In the initial step, a team of NBS investigators considered plastic bathtubs and glass fiber reinforced resined showerstalls for use in hotels, apartments and private homes.

Plumbing Pipe Sizes.—In another study, new criteria for selecting pipe sizes for horizontal drains were developed. Findings indicate that some drain sizes now specified in plumbing codes could be reduced without impairing efficiency—a reduction which would significantly decrease the cost of plumbing systems. Other projects, in a similar direction, investigated roofing performance in cold climates, and reasons for the failure of built-up roofs.

LINKING ENGINEERING MEASUREMENTS AND PERFORMANCE CRITERIA TO STANDARDS

Participation in Standardization Groups

NBS staff participates heavily in domestic and international standardizing bodies. Staff members jointly participate in the activities of about 1,584 such committees, of which 1,317 are domestic, 145 are governmental, and 122 are international. Technical advisory support furnished by NBS to 299 out of the 1,584 committees includes 95 committees of the American Society for Testing and Materials, 153 committees of the American Standards Association, 23 committees of the International Organization for Standardization, 19 committees of the International Electro-Technical Commission, and 9 committees of the Pan American Standards Commission.

Office of Engineering Standards

The Manager of Engineering Standards, (a position newly established in fiscal 1965) is responsible for the Office of Weights and Measures; for NBS activities in mandatory standards (assigned by the Congress to the Department of Commerce); for operation of the Office of Commodity Standards; and for the maintenance of a Standards Communication Center. All of these functions aim at linking technical work to standards needed in commerce, industry and Government.

Weights and Measures.—Among the significant accomplishments were: a revision of the weights and measures "bible," a major undertaking in which NBS Handbook 44, *Specifications, and Other Technical Requirements for Commercial Weighing and Measuring Devices*, was completely rewritten and subsequently adopted by the National Conference on Weights and Measures; the development of new test methods for quantities contained in aerosol packages, a project undertaken in cooperation with the Chemical Specialties Manufacturing Association; aid to South America in the development of weights and measures laboratories; the reclassification of package standards for plastic milk bottles; the development of detailed test procedures for vehicle odometers—a project which resulted in requirements for rental cars; the calibration of State "secondary standards"; and the study of aids to the oil industry for the development of more accurate slow-flow meters.

Product Standards.—Voluntary trade standards for manufactured products define quality levels and aid in holding variety to a minimum. All of these standards are subjected to technical review to insure that they provide effective requirements enabling customers to obtain products of recognized type, size, grade, and quality; they are subjected as well to review from the point of view of the representativeness of the committees of producers, distributors, and users which develop the standards.

In the past year, 12 new standards were produced, approved by NBS and issued by the Department of Commerce. These covered alumnium nails, aluminum alloy chain-link fencing, wood window units, steel medicine cabinets, plastic drain waste and vent-pipe, and a cattle hide trim pattern. Three additional standards were revised and five amendments to existing standards were approved. In addition, new procedures were designed and a considerable strengthening of the review procedures of the Office was undertaken.

Mandatory Standards.—NBS has responsibility for a number of mandatory standards, written into law by the Congress. These include standards for flammable fabrics, hydraulic brake fluids, refrigerator doors, and safety seat belts. In fiscal 1965, NBS succeeded in developing one flammability test comprehensive enough to satisfy the mandatory standards outlined by the Flammable Fabrics Act. Also, standards for automotive seat belts, one of the four mandatory safety standards required by public law, were developed in collaboration with the Society for Automotive Engineers and an ad hoc committee of representatives from Government agencies. The standards were published in the Federal Register on December 11, 1964, and became effective one year hence. They provide for three types of seat belt assemblies—a lap belt, a safety harness for adults, and a safety harness for children.

DISSEMINATION OF TECHNICAL INFORMATION

The Institute for Applied Technology maintains small specialized information centers in the fields of electronic components, instrumentation, and information retrieval technology. It also conducts technical information programs as part of the activity of the Textile and Apparel Technology Center, and maintains a standards information center. The principal program of information dissemination, however, lies in the operations of the Clearinghouse for Federal Scientific and Technical Information.

Federal Clearinghouse

The Clearinghouse completed its first full year of operation in fiscal 1965. In this period, the workload increased by 100 percent, and employment increased from 236 to 316. The Clearinghouse concept—endorsed by the Federal Council for Science and Technology in February 1964—is to make Government technical information more readily available to the scientific and industrial community by having a central agency for the collection, publicizing, and distribution of Government-financed research and development reports, translations, and information on research in progress. In addition, the Clearinghouse provides referral service to specialized information centers for data on specific technical problems.

Unclassified Defense Documents Processed.—A significant interagency agreement was reached between the Departments of Commerce and Defense

whereby the Clearinghouse would perform the documentation processing of DOD unclassified research and development reports and distribute them to DOD contractors, as well as sell them to the public. The processing and contractor distribution were formerly handled by the Defense Documentation Center. The Clearinghouse was able to begin this work at the start of the fiscal year, process over 15,000 documents, and distribute more than 750,000 copies to contractors.

Document Acquisition and Sales Activity.—The Clearinghouse expanded its document acquisition activities with AEC, NASA, and other agencies of the Federal Government. As a result, it collected over 60,000 documents

Receiving room of the NBS Clearinghouse for Federal Scientific and Technical Information. Here some 70,000 titles per year are entered into the Clearinghouse's filing, indexing, and distribution system. The walls aren't really bulging; the picture was taken with a very-wide-angle "fisheye" lens which tends to bend straight lines.

from all Government sources and sold (at the cost of reproduction and handling) approximately 1,500,000 copies to industrial firms, research organizations, academic institutions, and individual scientists and engineers.

Clearinghouse Centralization.—Appreciable savings to the Government resulted from the centralization of document distribution and bibliographic control, as well as improved internal efficiencies in the Clearinghouse. A very significant achievement was the consolidation from three separate locations in the Washington area into one building at Springfield, Va.

Government-Wide Index.—The Government-Wide Index to Federal Research and Development Reports (GWI) resulted from a major coordina-

tion effort with DOD, AEC, and NASA. The GWI is a monthly index to reports announced in the journals of the four agencies. The purpose of the GWI is to provide a single source of access for scientists, engineers, and other researchers, to new technical report literature. Computer prepared, the INDEX is arranged by report number, accession number, corporate author, personal author, and subject. Over 2,000 subscribers were receiving this combined listing at the end of June 1965 with the number of subscribers increasing at the rate of 400 per month.

U. S. Government Research and Development Reports.—The *U. S. Government Research Reports* announcement journal became the *U. S. Government Research and Development Reports* (USGRDR) to reflect the wide variety of documents being acquired by the Clearinghouse. A "Research Highlights" section of the USGRDR draws special attention to significant new reports. Personal author, contract number and corporate source indexes were added to the journal for reader convenience. Electronic photocomposiiton of USGRDR is planned for the fall to provide better readibility, fewer pages, and better indexes.

Technical Translations.—Major improvements in the *Technical Translations* (TT) announcement journal included the addition of the contents of journals translated cover-to-cover, improved announcement time and the utilization of computer prepared indexes.

Special emphasis was placed on a program to expand coverage of translation of foreign technical information from Russia, Eastern Europe, and Communist China.

Fast Announcement Service.—A new Fast Announcement Service (FAS) was created to provide direct and rapid announcement of selected new reports with significant industrial and/or scientific information to scientists, engineers, and research managers. Nearly 2,000 technical reports categorized into 49 industrial interest areas were described in the 449 Announcements issued by the Clearinghouse in Fiscal 1965. By the end of June 1965, 12,000 individuals and firms were receiving the FAS.

Regional Information Packaging.—The Clearinghouse began an intensive program of "information packaging" in response to the demands of local, state, university, and trade groups. Government R&D literature is searched for information on specialized recommended subjects. A five-page summary is published which includes bibliographies and price lists. Over 30,000 package summaries were distributed in fiscal year 1965. This Regional Dissemination Program will be fully operational in late Fiscal 1966.

Current Research Information.—The Science Information Exchange of the Smithsonian Institution agreed to furnish the Clearinghouse with magnetic tapes of current research projects in the physical sciences, engineering and related technology. This data will make up a new section, "Current Research in Progress," of the Clearinghouse journal *U. S. Government Research and Development Reports.* The section will provide a single

point of contact for information in specialized areas and avoid costly duplication of research.

Industrial Referral Service.—The Clearinghouse created an industrial referral service on specific technology problems designed to provide referral to sources of technical expertise from a single point of contact in the Federal Government. The Clearinghouse and the National Referral Center of the Library of Congress are cooperating in extending these services.

Defense Documents Located by Computer.—With the cooperation of the Defense Documentation Center the Clearinghouse is now able to search by computer the unclassified Department of Defense portion of its collection.

Clearinghouse is "Bookdealer".—Negotiations with the Superintendent of Documents resulted in the designation of the Clearinghouse as a bookdealer for scientific and technical documents sold by GPO. The Clearinghouse will distribute microfiche of current documents and supply all such technical documents listed by GPO as "out of print."

Cataloging Standards.—Clearinghouse staff members have taken an active role in interagency subcommittees working for the Committee on Scientific and Technical Information (COSATI) on rules for microfiche standards, corporate author headings, subject fields and groups, national document handling systems, exchange of foreign reports, social science translations, and vocabulary compatibility. The Clearinghouse participated with other agencies in developing microfiche standards for the Federal Government and has adopted, in accordance with COSATI recommendations, subject fields and groups used for categorization in document announcement journals, and new descriptive cataloging standards designed to promote uniformity throughout the Government.

Increased Efficiency.—Improvements in efficiency and systems design led to reduced order handling time. Documents maintained in quantity on the shelf can be distributed to customers within two days (exclusive of mailing time) while those needing reproduction require only five days.

Inventory Control.—A detailed manual system of inventory control was replaced by a combination of computer inventory and small parts systems. A document identification directory arranged by accession was developed to replace the catalog card files in the verification of customer orders.

Statistical Control.—During the year a comprehensive statistical control system for all operational aspects was implemented. A time and labor reporting system was established to be used in production reporting, and work standards were set up in accordance with the Commerce Department's Production Measurement Program. These statistics permit production reporting for daily monitoring by management production figures to determine the proper workload-manpower balance, information for cost accounting, employee effectiveness and productivity, and effectiveness of special programs.

Clearinghouse Accounting System.—A Clearinghouse Deposit Account

system was implemented to decrease the processing time for customer requests and to provide management with better financial information. By the close of the year, data processing programs for automated billing and posting of cash transactions were complete and ready for implementation in Fiscal 1966.

Price Schedule.—A new standard pricing schedule reduced overall document prices 30 percent while photocopy prices (blowback) were cut 66 percent.

Demand Prediction Models.—Statistical document demand prediction models were developed which enable the Clearinghouse to print a document in quantity prior to any requests being received. Cost and time savings are realized by printing a report instead of using single copy reproduction methods. Automatic wrapping equipment speeded up distribution and reduced costs. Most documents are now individually machine wrapped in polyethylene packages.

Intern Program.—Recent science and engineering graduates, documentalists and science librarians will have an opportunity to enter a one-year Internship Program at the Clearinghouse during Fiscal 1966. The program is designed to acquaint the intern with modern methods of handling large volumes of Federal scientific and technical information and to provide broadly based work experience upon which he may build a career in science documentation and information handling.

INVENTION AND INNOVATION

Technical Innovation.—At the request of the Office of Science and Technology, of the Office of the President, IAT has undertaken a project to analyze the effects on technical innovation in industry of various Federal policies. These include taxation, antitrust, and regulatory policy. Work in this area has proceeded with the cooperation of the Departments of Treasury, and Justice, the Small Business Administration and the Council of Economic Advisors. A panel on taxation, antitrust and regulatory policy was recently appointed by the Secretary of Commerce.

Inventor's Congress.—IAT actively encourages States in the development of inventors' expositions and congresses. Through these congresses, inventors and representatives of industry meet to explore the value of specific inventions, many of them developed by independents. As a result, new inventions are brought to light and into commercial production, at a rate which exceeds the usual ratios of success for invention-screening operations. IAT operates a Government Referral Center which handles considerable correspondence from individual inventors regarding their ideas. During fiscal year 1965, state inventors' congresses were held in 12 states, including Nebraska, Arizona, North Dakota, Arkansas, Missouri, Texas, and North Carolina.

TEXTILE AND APPAREL TECHNOLOGY

The Textile and Apparel Technology Center functions with funds provided by the Congress under the Civilian Industrial Technology (CIT) appropriation in fiscal year 1963 and subsequently. The money was made available to encourage the textile and apparel industries' efforts to develop ways of coping with the pressures of economic cycles, foreign competition, displacement by other materials, changing consumer demands, and the impact of new materials. Projects have been chosen with the aim of helping to begin institutional activities which the industry itself will continue to support. Projects to date have included the development at the Massachusetts Institute of Technology, of a thesaurus of standard technical terms for the dry-processing of textiles, the beginning of a program for monitoring foreign textile developments and making them available to U. S. industry, and the offering of a number of short courses and seminars for textile management personnel (courses at Auburn University in 1964 and 1965 were financed fully by the Department of Commerce; similar courses will be 50 percent funded by industry during this coming year; after that industry will support them fully. Similar courses are being offered at the Lowell Technological Institute in Massachusetts).

Apparel Research Foundation.—The Department of Commerce has encouraged the American apparel industry to form a cooperative research and development association, comparable to similar associations in Europe and Japan. This group, The Apparel Research Foundation (ARF), is directing its first projects to research on automation of the garment-making process and on technological intelligence concerning foreign apparel technology. Support of its efforts is currently provided both by the NBS Textile and Apparel Technology Center and the industry itself. Rapid growth of ARF should lead to self-sufficiency in the near future. The Textile Research Institute, affiliated with Princeton University, is engaged in a fundamental research program with Department of Commerce support.

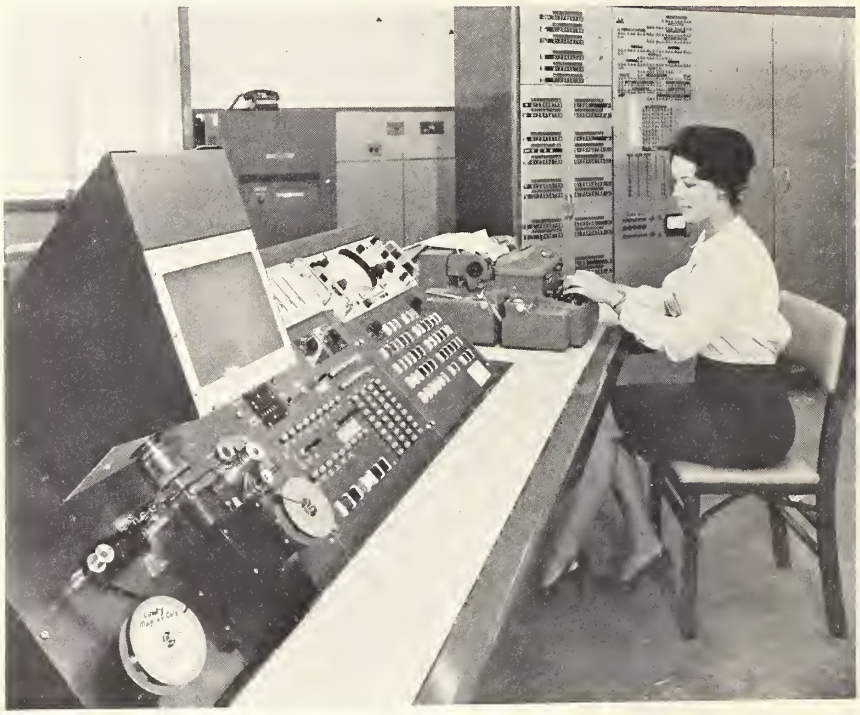
North Carolina University Textile Study.—Support has been provided North Carolina State University for research aimed at developing more competent technical professionals for the textile industry. In addition, the Center has explored the use of new management techniques, especially those made practical by computer technology, for analysis of the technical economic problems of the textile and apparel industries. Several studies have been completed which analyze trends in foreign competition, introduction of paper and plastics to the traditional textile and apparel market, and variations in the size of companies—all of which affect the textile and apparel industries' economic performance. A system analysis using simulation and modeling techniques has been developed which would allow computer comparison of various management strategies for problems such as the volume of production runs, the best level of inventory, and the maximum efficiency of labor.

ASSISTANCE TO OTHER AGENCIES

NBS has continued in its traditional statutory mission of providing technical assistance to other government agencies. Within the last year, however, the character of this service has tended to move away from the development of hardware and toward systems analysis.

Chemical Information Processing (HAYSTAQ).—NBS has been engaged for the past eight years in a cooperative venture with the U. S. Patent Office to investigate the feasibility of mechanizing some of the patent literature searching activities. Chemical information searching is of particular interest because it is the area of greatest activity in the U. S. Patent Office at the present time; 25 percent of the patents issued are in the area of chemistry.

Chemical structures lend themselves to precise definition and are therefore more amenable to machine manipulation than more ambiguous information such as natural language text. A large part of the work per-



The ACCESS computer system, developed by NBS for the Office of Emergency Planning, accepts pictorial data and presents them in a manner meaningful to man. Left to right: the FOSDIC microfilm scanner, its control, the data processor control, keyboard and punched tape inputs (in front of operator), and, in the background, logic and memory components. ACCESS can identify sections of map on 16-mm microfilm and assemble the map sections in correct relative positions to produce a magnetic tape instructing a plotter in reproducing the entire map.

taining to the development of search systems for chemical information has been continued in Project Haystaq, a report on which has been made public this year.

Emergency Communications Computer (ACCESS).—The ACCESS System (Automatic Computer Controlled Electronics Scanning System), designed and developed at NBS, was completed and delivered to the Office of Emergency Planning. ACCESS is intended to serve as a communications center in a national emergency. It would handle large amounts of data for damage assessment and resource status evaluation. ACCESS is designed to meet a wide range of requirements through rapid manipulation of data with the results disseminated to central, regional, and local or field Civil Defense offices. This distribution would facilitate decisions by key personnel in all locations.

Vigilometer Tests Human Alertness.—Work sponsored by the U. S. Army Personnel Office resulted in the development of the Vigilometer, a computer type research instrument for testing and recording the alertness of human subjects. The machine was designed to determine how the instrument monitoring performance of Army personnel is affected by such factors as time on duty, common distractions and characteristics, or displays to be monitored. The Vigilometer should also be useful in industry for the development of information on work methods and conditions.

Computer Simulation of Transportation Network.—The newly established Technical Analysis Division has undertaken for the Office of Transportation of the Department of Commerce a series of analytic and simulation tasks pertaining to the transportation system of the Northeast Corridor. A variety of new transportation technologies—high-speed rail, automated highways, vertical takeoff aircraft and the like—have been proposed and partially developed for transportation corridors such as the Boston to Washington corridor. In order to permit evaluation of these and similar technologies, TAD has developed a computer simulation of the transportation network of the corridor.

This simulation is capable of describing all transportation links between major urban areas, for a wide variety of modes; it can then "run" estimated mixes of passengers and freight in order to determine the flow characteristics of the transportation system.

In addition, TAD is developing a benefit-cost model, also computerized, which will serve as an aid to decisions concerning relative benefit and cost of transportation technologies for the corridor, in terms of transportation flow within the system and return on investment.

Mathematical Model of Patent Activities.—NBS is currently undertaking for the Patent Office a mathematical model of patent examining activities. This model will predict the backlogs, examiner workload, and output by the month, for several years into the future. It is designed to

help the Patent Office with its problem of backlog—currently about 200,000 applications, with an average waiting time of about 3½ years.

Measure of Benefit Programs.—NBS has been asked, by a number of Department of Commerce agencies, to develop measures of benefit of various programs, in order to permit benefit-cost analysis of these efforts.

The Weather Bureau has requested the development of these techniques with reference to weather services. The economic consequences of good weather forecasting systems in highly weather-dependent industries like construction and agriculture have been calculated for certain specific occasions. Much more difficult, however, is the problem of determining exactly how to measure the benefits of weather forecasts for the American public. If one could measure these benefits and relate them to the level of effort invested by the Weather Bureau, then further progress could be made toward determination of the kind and character of optimum Weather Bureau services.

Engineering Seismology Program.—NBS has been asked by the U. S. Coast and Geodetic Survey to measure the economic implications of the Engineering Seismology Programs. This pilot project will analyze data from earthquakes in order to determine optimum construction standards to guide the building industry and others concerned with safe construction.

Pressure Transducer Performance Evaluation.—The Electronic Instrumentation Division is working for the Department of Defense to develop techniques for evaluating the performance of transducers and sensors. These devices are used to measure pressures on a rocket surface under the extreme conditions of space flight. Work is under way to develop dynamic temperature tests for pressure transducers, and to develop methods of precise calibration of accelerometers in the earth's gravitational field.

V

CENTRAL RADIO PROPAGATION LABORATORY

The NBS Central Radio Propagation Laboratory is an assigned central responsibility which the Bureau performs for the Federal Government because of its unique technical competence.

CRPL is responsible for collecting, analyzing, and disseminating information on the propagation of radio waves along the surface of the earth, in the atmosphere, and in space. Complete understanding of these problems requires research on the physics of electromagnetic waves and of the media in which they travel. In recent years, interest in this field has expanded along the electromagnetic spectrum to include frequencies, such as infrared and visible light, which are not included in the "radio" classification, but which are becoming more and more useful in communications.

The Central Radio Propagation Laboratory is responsible for assisting administrative and operating activities of both Government and industry in the field of radio propagation. It does this at the international level by active participation in the work of the International Scientific Radio Union (URSI), and the International Radio Consultative Committee (CCIR), the engineering organization of the International Telecommunications Union.

Members of the CRPL staff direct the CCIR standards and international allocation work in the United States in the fields of radio systems, tropospheric and ionospheric propagation. The work is coordinated in this country by the Department of State. Eight members of the CRPL staff were selected to be delegates to the CCIR meetings held in Geneva, Switzerland, in 1965.

The twentieth century is an age of telecommunication—involving a telecommunications industry grossing $20 billion annually. Radio, television, and microwave relay of telephone calls are part of our daily life, and essential to our well being. As our population grows and new market areas

are created, as the number of aircraft flights increases, as our space program develops, as our defense needs evolve, the demand for dependable interference-free communications increases continually.

Through its work, CRPL makes possible more reliable telecommunications and more efficient use of the electromagnetic spectrum. This second factor is extremely important since the electromagnetic spectrum, like other natural resources, is limited—only a certain range of frequencies is available for communication use. We cannot enlarge the spectrum beyond its present limits, but we can expand its usefulness by careful allocation of its frequencies.

During the year, CRPL instituted organizational changes to meet more effectively its new space age responsibilities. Special emphasis is being placed on research and services in monitoring and practicing disturbances in the earth's space environment. These predictions are mainly concerned with the effect of solar events on the upper atmosphere and near space. In addition to their effect on communications, such solar events are dangerous to space travelers, and the CRPL work is important in protecting space missions from radiation and matter given off by the sun.

IMMEDIATE OBJECTIVES

The reorganization which moves the Central Radio Propagation Laboratory from the Bureau into the Environmental Science Services Administration (ESSA) will improve the scientists' ability to look at man's physical environment as a whole and permit a fuller understanding of the interactions among air, sea, and earth, and the upper and lower atmosphere. It will enhance the capability to identify and solve important long-range scientific and technological problems associated with the physical environment.

As the immediate objectives are to further the development of the newly created Environmental Science Services Administration they are somewhat broad in scope, but include:

—A common environmental warning service using a common communications network and one central office to disseminate warnings of potential disasters.

—A single source of environmental information to the many industries effected. The communications industry, now served by the many CRPL activities, will gain better information on atmospheric, ionospheric, and oceanographic conditions.

—Better service to Federal agencies concerned with environment, and a central source within the Federal Government to provide this information.

—Research programs to stimulate interdisciplinary approaches.

Ionosphere Research

The reflection of radio waves by the ionosphere plays a crucial role in long-distance communication, serving important needs which land-line, submarine cable, and satellite cannot meet. At present, the nature of ionospheric radio propagation is well understood; the main problem is to understand the processes responsible for the complexity of the ionosphere and to learn to predict the ionosphere's effect on radio waves.

New Division Formed.—A new division, Ionospheric Telecommunications was formed to conduct research and provide services to the Nation's radio telecommunications media operating at frequencies below about 50 MHz. A very substantial part of the nation's defense and economy is linked to this visible, time tested method of communication. Much of the foreign commerce of the United States, transocean air traffic control, and transmission of U. S. information through international broadcasting, depends on ionospheric transmission.

Southeast Asia Defense Communications.—NBS studied the possibility of establishing short-term, localized forecasting of radio propagation conditions in southeast Asia on behalf of the Defense Communications Agency.

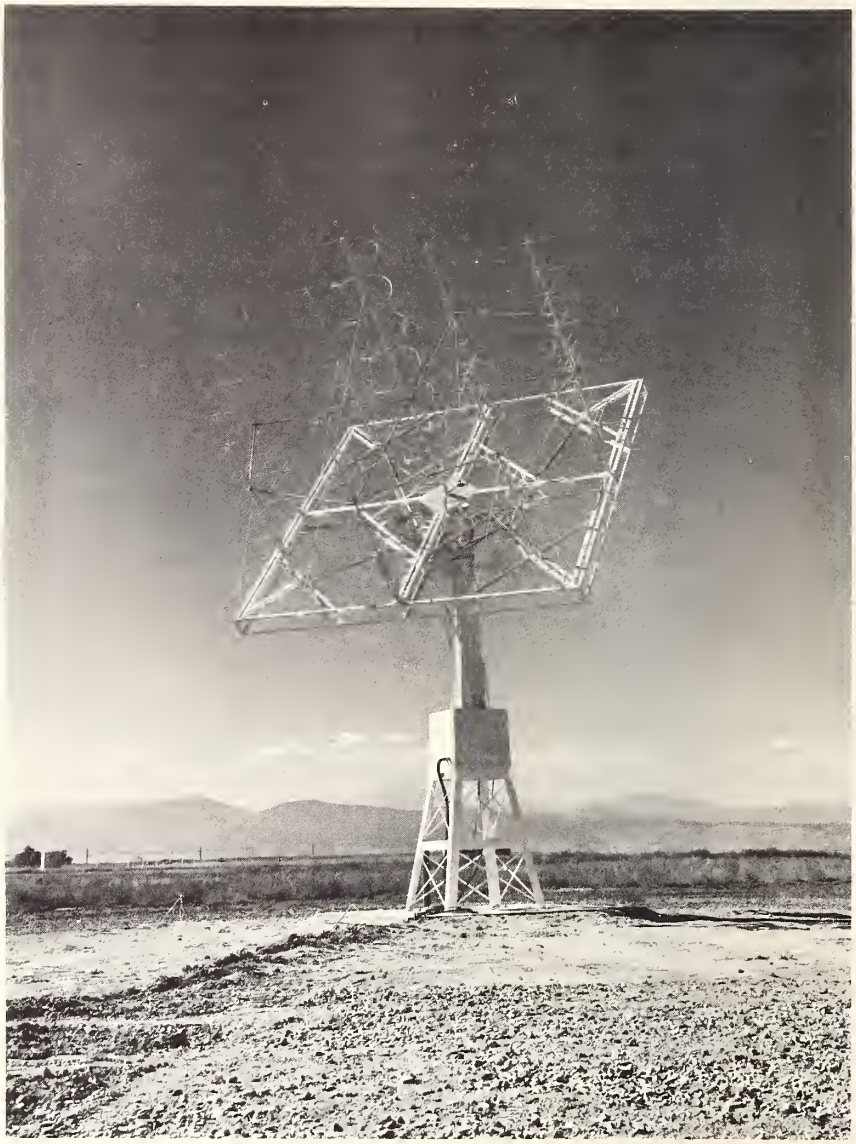
Modern warfare, especially a diffuse operation in difficult terrain such as is going on in Viet Nam, is heavily dependent on radio communications. But the reliability of radio communications is at the mercy of natural forces—especially the behavior of the ionosphere.

For many years, NBS has published worldwide predictions of the behavior of the ionosphere so that radio users can choose the proper radio frequencies to obtain the most reliable results. But these global predictions cannot be used to predict short-term variability of local radio conditions in limited geographical areas.

For this reason, it is thought that a special prediction service for southeast Asia would make possible more efficient control and utilization of the radio frequencies used in defense communications and improve the reliability of the operations.

Frequency Utilization Improved.—Research on more accurate methods of predicting the performance of ionospheric radio systems provided improved statistics describing the temporal and geographic variation of upper frequency limitations and transmission loss. Computer methods now facilitate efficient application of the predicted data to specific radio paths. These methods optimize frequency usage in simple simulation air-ground communication systems and assist in the scheduling of Voice of America high frequency broadcast facilities, improve ground communication services in support of NASA Manned Space Missions, assist in the design of antennas for long range U. S. Air Force circuits, and improve Naval high frequency communication.

Ionosphere Satellite Successfully Launched.—On August 25, 1964, the Ionosphere Explorer "A" satellite (fixed frequency topside sounder) was put into a polar orbit approximately 550 miles above the earth from the Western Range in California. The primary ionosphere sounding experi-



This antenna array at the NBS Gunbarrel Hill (Colo.) field station will be used to communicate with TOPSI, a topside sounder satellite launched by NASA.

ment was conceived by CRPL scientists as a means of studying many important properties of the high ionosphere that are unobservable from earth. The information is expected to allow more efficient use of the ionosphere for communications purposes.

As principal experimenter, CRPL is responsible for controlling the worldwide program of data acquisition from the satellite and will analyze the resulting data.

Early observations indicated that the satellite is in a very satisfactory orbit and that all instrumentation is working properly.

Troposphere Research

Radio wave propagation, noise, and interference in the atmosphere are the concern of tropospheric research. Efforts are aimed at the development of theoretical and semiempirical prediction methods and their statistical comparison with samples of radio wave propagation and radio noise data.

New Section to Study Millimeter Waves.—A Millimeter Wave Propagation Section was established to study the propagation of extremely high frequency waves through the atmosphere and to examine the usefulness of this portion of the electromagnetic spectrum. One of the potential uses of these waves is in telecommunications used to probe planetary atmospheres.

Study of Over-Water Microwave Propagation.—NBS scientists studied variations in radio signals traversing over-water paths at the Atlantic Missile Range. The findings will aid in appraising the stability of over-water microwave links.

The microwave system studied at Eleuthera Island in the Bahamas is an essential part of the Mistram precision missile trajectory measurement system. The accuracy of this system depends on the stability of the microwave transmission.

Instrument Landing System Analyzed.—A study of the service restrictions imposed on the Instrument Landing System (ILS) by cochannel and adjacent-channel interference was published. Results of this study will aid the Federal Aviation Agency in making more effective frequency assignments for the Instrument Landing System.

Computer Reduces Worldwide Noise Data.—The automatic reduction and tabulation of all data from the NBS worldwide network of atmospheric noise recording stations is now accomplished by computer techniques. These data, which include some short-term statistics in the form of amplitude probability distributions, are applied by theoretical means and computer programs to the analysis of several types of binary-coded communication systems. Atmospheric noise and error rates were recorded simultaneously in a test of the Minuteman Radio Launch Control System. They proved to be in good agreement with predictions of system performance. The noise on these recordings is being analyzed to determine other important statistics of the noise affecting system performance, such as the autocorrelation function, pulsewidth distributions, and bandwidth effects.

New Instrument for Interference Studies.—The primary objective of NBS electromagnetic interference studies is to provide information on the level and characteristics of radio interference and the influence of this interference on the performance of various types of radio telecommunication. To help carry out this objective, the Energy Spectrum Recorder was completed and field tested. This instrument scans a predetermined pattern of frequencies between 20 Hz and 600 kHz, recording noise and signal levels for these frequencies at a given location.

Communication by Light Beams.—An Optical Propagation and Laser Communications Section was established to study atmospheric limitations on optical communication. Laser beams, in particular, are finding increasing application in high-precision surveying, wide-band information channels, and optical-radar measurements of orbiting satellites. To aid in the research, a new laser transmitter site on Table Mountain, near Boulder, will act as a mobile receiving van to measure the atmospheric effects on the laser beam over distances of one to 150 km.

Optical Distance Measurement Improved.—Commercial optical devices presently being used for distance measurements in geodetic surveys are limited in accuracy to a few parts per million. Improvement of this accuracy has so far been prevented by the difficulty in estimating the variable effect of the atmosphere upon the velocity of light. A new way of correcting for this effect has been devised. It involves comparing the distances as measured with red and blue light. The small difference in the two measured distances promises to provide a means for stimulating the correction with at least ten times the accuracy now available.

Space Environments

Study of the sun, planets, stars and interplanetary space is blossoming into several new fields because of the dictates of the space program and modern astronomy. Space environment research, solar-planetary interrelationships, and lunar studies, are of vital importance to the furtherance of national and international programs. In addition, understanding and predicting disturbances such as solar flares and storms is essential not only in communications, but in protecting travelers in outer space.

Forecasting Space Environments.—The Space Environment Forecasting Division was created on February 1, 1965 for the purpose of studying and ultimately predicting disturbances in the upper atmosphere, in space, and on the sun. Studies are proceeding on three major aspects of solar disturbances: the solar flares, i.e., electromagnetic radiation, the polar-cap absorption (PCA) caused by solar protons, and the auroral phenomena due to the enhancement of solar plasma streams. In the work on the occurrence of solar flares, corrected data were published for the period July 1955-June 1957. Methods for the early recognition of solar flares were surveyed, comparing x-ray bursts detected on satellites and in optical and radio emissions from the sun with the resulting ionospheric effects.

Protection of Space Travelers.—The results of some NBS research will be invaluable in protecting space travelers from hazards in the space environment. NBS works on ways of predicting space hazards—such as radiation bursts from the sun—so that space travelers can avoid them or prepare to meet them.

NBS scientists described how bursts of cosmic rays come from special locations on the rotating sun, and how those areas can be identified and watched. Other work explained how electrically charged particles from the sun sometimes travel rapidly to the earth and at other times are delayed for many hours. An understanding of this effect could be extremely important in protecting space travelers from being showered by solar particles.

Assistance in Mariner IV Mars Probe.—NBS assisted the Jet Propulsion Laboratory in preparation for a study of the ionosphere of Mars conducted by the Mariner IV space probe during its flyby of Mars, on July 15, 1965. Measurements on radio signals transmitted by Mariner IV as it went into eclipse behind Mars were used to estimate the extent of the Martian ionosphere. But adequate corrections had to be made for the effects of the earth's own atmosphere on these observations. These corrections were made using data gathered on NBS ground-based ionospheric measurement programs during the Mariner flight.

Spaceglow Program Aided by Gemini Flights.—As the manned space program becomes more sophisticated, astronauts are having greater opportunities to make visual astronomical observations. Such phenomena as the zodiacal light, a faint hazy cone of light visible in the western sky after sunset or in the east before sunrise, is a good example. The zodiacal light, caused by the scattering of sunlight by dust particles in interplanetary space, is quite bright for elongations a few degrees from the sun, but tapers off in brightness until it is barely visible. Many discussions have been held between NBS scientists and the astronauts about the possibilities of observing the zodiacal light.

Satellite Data Aids Atmospheric Studies.—NBS is using satellite data in a detailed study of Faraday fading in the ionosphere. This fading is the periodic disappearance of a radio signal caused by the combined action of the earth's magnetic field and electrons in the ionosphere. Study of data from three different satellite sources, including Sputnik III, will enable scientists to obtain a more complete, overall picture of the electron density in the ionosphere.

Detecting High Altitude Detonations.—Supported by the Advanced Research Projects Agency, the Bureau is developing techniques to detect high altitude nuclear detonations. Such detonations produce some geophysical effects believed distinctive and some similar to the effects produced by natural disturbances. Recognizing man-made events against the natural background requires setting up representative geophysical experiments to acquire data on the natural background. Considerable progress was made

on the problem of collecting data through the use of on-line digital computer and high-speed analog devices.

Lunar Communications Analyzed.—A recent NBS Monograph and consultative work provide a reference for future studies of the power requirements of lunar surface communication systems using groundwave propagation. The effects of external noise and antenna ground proximity losses are included with calculations of groundwave propagation and recommendations for further studies expected to be useful in NASA's extended Apollo program for lunar exploration.

Milky Way Used as Standard Reference Light Source.—NBS scientists developed a method of using the Milky Way as a standard reference light source in photometry. The light of the closely packed stars in the Milky Way remains essentially constant over centuries. As a standard reference light source, the Milky Way is available to experimenters, no matter how remote they may be from laboratory standards. The method will increase the reliability of results obtained at widely separated observatories, thus assuring that similarities or differences between readings at different locations are true, and not due to reference variations or calibration inaccuracies.

Atmospheric Processes

Atmospheric processes, both chemical and physical in nature, are an important key to an understanding of the structure of the atmosphere. New knowledge relates directly to radio propagation and prediction capability.

Thunderstorm Information Aids NASA.—Measurements of Colorado thunderstorm radio forward scatter characteristics were analyzed to determine statistical factors for interference prediction puposes. Meteorological data are being studied to establish more general inteference prediction techniques for other geographical areas. Specific interference predictions were made for NASA tracking sites.

Laboratory Measurements of Ionospheric Processes.—NBS made the first laboratory measurement of the reaction between molecular nitrogen ions and atomic oxygen atoms, a process important in the operation of the ionosphere. This knowledge contributes to our basic understanding of atmospheric and ionospheric processes, facilitates our utilization of the ionosphere for telecommunications, and increases our ability to predict the effects of large scale man-made disturbances (nuclear explosions) on military communication systems.

Re-examination of Theories of Earth's Development Suggested.—NBS scientists, by reproducing upper atmospheric processes in the laboratory, showed that a mechanism previously believed to keep the concentration of helium in the earth's atmosphere constant does not, in fact, do so.

Decay of radioactive material in the earth's crust produces enough helium

to reach present concentrations in just a few million years. Over the long history of the earth, the concentration would have risen far above current levels unless there was some mechanism by which helium "leaks" away into space.

Now that the NBS research has shown that the mechanism (neutralization of helium ions by reaction with oxygen) thought to cause this leakage cannot accomplish it, geophysicists will have to reconsider many beliefs about the history and development of our planet. The findings even suggest that some catastrophic event occurred in the past few million years which boiled off part of the earth's atmosphere.

Plasma Theory Aids Ionosphere Study.—A general theory of plasma fluctuations, developed in the plasma physics program, provides a broad and rigorous basis for interpreting measurements of the ionosphere by scattering and radiation emission techniques. The plasma physics program is one of the few in the nation that ties in directly with environmental and telecommunications sciences and consequently contributes to understanding the properties and behavior of the ionosphere and interplanetary media.

Infrared Properties of the Atmosphere.—Analyzing infrared properties of the atmosphere has provided a more thorough and exact understanding of its absorption characteristics. Theoretical studies of the absorption characteristics of water vapor and carbon dioxide in the infrared spectrum were conducted in great detail and were found to be in excellent agreement with controlled laboratory experiments. Continuing efforts in this area are enlarging the knowledge available on other infrared spectral regions of the major atmospheric absorption components.

APPENDIXES

ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS *

The Bureau is headed by a Director who is appointed with the advice and consent of the Senate. The Director is assisted in the ovarall management of the Bureau by a Deputy Director. In addition, there are three Associate Directors and a Manager of the Boulder Laboratories who are responsible for the planning and operation of various technical and administrative management services in support of the Bureau's technical programs.

Technical program activities are conducted in four major organizational units known generally as Institutes. Each is headed by an Institute 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 13 divisions (4 in Boulder, Colo.), each serving a classical subject matter area of science and engineering;

(2) The Institute for Materials Research, which consists of 7 divisions (1 in Boulder, Colo.), organized primarily by technical field;

(3) The Institute for Applied Technology, which includes 12 industry-oriented divisions; and

(4) The Central Radio Propagation Laboratory, which comprises a series of four divisions located at Boulder, Colo.

DIRECTOR
ALLEN V. ASTIN

DEPUTY DIRECTOR
I. C. SCHOONOVER

Assistant to the Deputy Director
P. H. KRATZ

OFFICE OF THE DIRECTOR
Assistants to the Director
G. E. AUMAN
C. N. COATES
W. H. GAMMON

*As of June 30, 1965

Senior Research Fellows
C. Eisenhart
U. Fano
K. Shuler
J. R. Wait

Associate Director for Resources Planning
S. Silverman

Office of Public Information
A. V. Gentilini, *Chief*

Office of Radio Frequency Management
A. Barnabei

Office of Industrial Services
R. L. Stern

ASSOCIATE DIRECTOR FOR ADMINISTRATION

R. S. Walleigh

Accounting	J. Seidenberg
Administrative Services	H. P. Dalzell
Budget and Management	J. E. Skillington
Internal Audit	H. F. Whittington
Patent Advisor	D. Robbins
Personnel	G. R. Porter
Plant	M. B. Goetz, *Acting*
Supply	G. B. Kefover

ASSOCIATE DIRECTOR FOR TECHNICAL SUPPORT

Vacant

Coordinator of Special International Programs	L. L. Marton
Instrument Shops	F. P. Brown
Technical Information and Publications	W. R. Tilley
Radiation Safety	Vacant
Research Information	Vacant
Library	S. A. Jones
Measurement Engineering	G. F. Montgomery

MANAGER, BOULDER LABORATORIES

R. B. Scott

Consultant, Statistics	E. L. Crow
Communications Liaison Officer	A. Barnabei
Assistant and Manager for Planning Facilities	S. W. J. Welch
Technical Information Officer	J. R. Craddock
Library	L. E. Leonard
Administrative Services, Chief	H. D. Stansell
Shops, Chief	F. P. Brown
Plant, Chief	E. A. Yuzwiak

Institute for Basic Standards

The Institute for Basic Standards provides the central basis within the United States for a complete and consistent system of physical measurement and coordinates that system with the measurement systems of other nations.

The Institute is also responsible for measuring the physical constants and properties of matter. In doing so, it is able to provide more accurate determinations of the basic and derived standards, to provide new and improved calibration services and reference data, and to monitor and check the measurement system.

IBS disseminates measurement capability by calibrating master standards for other standards laboratories, by aiding and advising measurement centers and by providing means for self-calibration.

An additional important responsibility of the Institute is the operation of the Office of Standard Reference Data which coordinates the National Standard Reference Data Program and provides a national file of critically evaluated data in the physical sciences.

INSTITUTE FOR BASIC STANDARDS
Director
R. D. HUNTOON

OFFICE OF STANDARD REFERENCE DATA
- Thermodynamics & Transport Data
- Chemical Kinetics
- Information Systems

ELECTRICITY
- Resistance and Reactance
- Electrochemistry
- Electrical Instruments
- Magnetic Measurements
- Dielectrics
- High Voltage
- Absolute Electrical Measurements

APPLIED MATHEMATICS
- Numerical Analysis
- Computation
- Statistical Engineering
- Mathematical Physics
- Operations Research

HEAT
- Temperature Physics
- Heat Measurements
- Cryogenic Physics
- Equation of State
- Statistical Physics

METROLOGY
- Photometry and Colorimetry
- Refractometry
- Photographic Research
- Length
- Engineering Metrology
- Mass and Volume

MECHANICS
- Mechanical Measurements
  - Pressure Measurements
  - Vacuum Measurements
  - Vibration Measurements
  - Humidity Measurements
- Fluid Mechanics
  - Fluid Meters
  - Hydraulics
  - Aerodynamics

ATOMIC PHYSICS
- Spectroscopy
- Infrared and Microwave Spectroscopy
- Far Ultraviolet Physics
- Electron Physics
- Atomic Physics
- Plasma Spectroscopy

PHYSICAL CHEMISTRY
- Thermochemistry
- Surface Chemistry
- Elementary Processes
- Mass Spectrometry
- Photo Chemistry and Radiation Chemistry

LABORATORY ASTROPHYSICS *

RADIATION PHYSICS
- Radiological Physics
  - X-ray Physics
  - Dosimetry
  - X-ray Standards
- Nuclear Physics
  - Radioactivity

Neutron Physics
Photonuclear Physics
Nuclear Spectroscopy
Accelerator
Accelerator Engineering
Radiation Physics
Instrumentation
Accelerator Physics

RADIO STANDARDS LABORATORY *

RADIO STANDARDS PHYSICS *
Frequency-Time Dissemination
Research
Frequency-Time Broadcast Services
Radio and Microwave Materials
Atomic Frequency and Time
Interval Standards
Radio Plasma
Microwave Physics

RADIO STANDARDS ENGINEERING *
Low Frequency Calibration Services
High Frequency Calibration Services
High Frequency Electrical Standards
High Frequency Impedance Standards
Microwave Calibration Services
Microwave Circuit Standards

* Located at Boulder, Colo.

Institute for Materials Research

The work of the Institute for Materials Research is basic both to the Bureau's measurement missions, and to the operations of science and industry in general. Precisely defined materials properties serve both as measurement standards and as a means for conveying measurement capability to the users. Also, more functional, resourceful, and precise application of materials in science, technology, and industry, requires refinements in measurement capability and better understanding of material behavior. To further these objectives, IMR conducts research on the fundamental properties of matter and materials; develops techniques for preparing materials and measuring their properties; develops criteria for evaluating the behavior or performance of basic materials; and develops, produces, and distributes standard reference materials.

Standard reference materials are a product of the Institute's unique capacity to carefully measure and certify the physical and chemical properties of a particular material. NBS reference materials are used in industry for the evaluation and control of both raw materials and finished products and for the calibration of measuring instruments.

Fundamental materials research in support of the Standard Reference Materials program involves improvements in methods of preparation, purification, and characterization of materials and production of new research materials with special characteristics, i.e., high purity, well-defined structure or other specific properties. One of the most valuable results of this research is more accurate and complete data on the properties and performance of materials and a better understanding of the behavior of materials in specific environments.

INSTITUTE FOR MATERIALS RESEARCH

Director
G. K. Teal

OFFICE OF STANDARD REFERENCE MATERIALS

METALLURGY
- Engineering Metallurgy
- Alloy Physics
- Lattice Defects and Microstructures
- Corrosion
- Metal Physics
- Electrolysis and Metal Deposition
- Crystallization of Metals

ANALYTICAL CHEMISTRY
- Radiochemical Analysis
- Spectrochemical Analysis
- Electrochemical Analysis
- Quantitative Separations
- Analysis and Purification
- Analytical Mass Spectrometry
- Organic Chemistry

INORGANIC MATERIALS
- Inorganic Chemistry
- Glass
- High Temperature Chemistry
- Crystal Chemistry
- Physical Properties
- Crystallography
- Solid State Physics

CRYOGENICS *
- Cryogenic Technical Services
- Cryogenic Data Center
- Cryogenic Properties of Solids
- Properties of Cryogenic Fluids
- Cryogenic Systems
- Cryogenic Metrology
- Cyogenic Fluid Transport Processes

POLYMERS
- Polymer Solutions
- Polymer Chemistry
- Polymer Physics
- Molecular Properties
- Dental Research
- Polymer Characterization
- Materials Evaluation
  - Laboratory
  - Materials Evaluation and Testing
  - Procurement Systems
  - Evaluation Criteria
  - Performance Research

REACTOR RADIATIONS
- Reactor Operations
- Engineering Services
- Neutron Nuclear Physics
- Neutron Solid State Physics

* Located at Boulder, Colo.

Institute for Applied Technology

The Institute for Applied Technology creates opportunities for the application of new technology in government and private industry. In government this activity contributes to the solution of national problems; in industry, it stimulates the smooth introduction of new technology into research and production. Three interrelated programs are designed to carry out this mission—technical information dissemination, engineering measurements and standards, and consulting services.

The Institute's technical information program is built around its Clearinghouse for Federal Scientific and Technical Information. The Clearinghouse makes available to industry, commerce, and the general public, results of government-sponsored research and development. Also, technical information on innovation, computer application, building research, electronic instrumentation, and textiles is developed and disseminated by other parts of the Institute.

The engineering measurements and standards program is a major underpinning of our mass production economy. It makes possible the inter-

changeability of parts, improves communication between producer and consumer, and facilitates the introduction of new technology. IAT provides technical support to trade associations, professional societies, and private standards bodies for the development of performance criteria in the fields of building, textiles and information processing. In addition, it develops the instruments and test methods which are used in evaluating industrial products.

Consulting services, largely for other Government agencies, include:

—computer services, in the form of information processing and automatic data processing

—operations research studies, such as the Northeast Corridor Project

—electronic research, e.g., laser applications

—building research, which is introducing a more integrated approach to construction

INSTITUTE FOR APPLIED TECHNOLOGY

Director
D. A. Schon

OFFICE OF MANAGER OF ENGINEERING STANDARDS
- Commodity Standards
- Mandatory Law Standards
- Technical Standards Information

COORDINATOR OF ENGINEERING STANDARDS

CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION
- Document Management
- Document Analysis and Reference
- Automated Systems and Services
- Customer Relations
- Plans and Development
- Administrative Services
- Joint Publications Research Service

INFORMATION TECHNOLOGY

PILOT
- Research Information Center
- Components and Techniques
- Computer Technology
- Measurements Automation
- Engineering Applications
- Systems Analysis

OFFICE OF WEIGHTS AND MEASURES

OFFICE OF INVENTION AND INNOVATION

TEXTILE AND APPAREL TECHNOLOGY CENTER

OFFICE OF TECHNICAL RESOURCES
- Domestic Technology Information
- AID Technology Information

BUILDING RESEARCH
Structures
Fire Research
Environmental Engineering
Materials and Composites
Codes and Standards

TECHNICAL ANALYSIS
Transport Systems
Northeast Corridor
Industrial Technology
Building Industry
Simulations

Central Radio Propagation Laboratory

The Central Radio Propagation Laboratory (CRPL), located at Boulder, Colo., has the primary responsibility for providing information on electromagnetic wave propagation along the surface of the earth, in the atmosphere and in space. It conducts basic and applied research on techniques for the efficient use of the radio spectrum. Such studies were, in the recent past, expanded to include virtually the entire electromagnetic spectrum. In particular, infrared and visible light, not part of the "radio" sector, are proving more and more valuable in communications. CRPL work is the basis for efficient use and conservation of the limited resources of the electromagnetic spectrum which is becoming seriously overcrowded at precisely the time when communications needs are explosively expanding.

CRPL is also responsible for investigating, monitoring, and forecasting disturbances in the earth's space environment. The effects of solar events on space and the atmosphere require intensive study both for effective communications and for safe travel in space. When CRPL is incorporated into the new Environmental Science Services Administration, it will join in the effort to look at the whole of man's physical environment and analyze the interactions among space, atmosphere, sea, and earth.

CENTRAL RADIO PROPAGATION LABORATORY
Director
C. G. Little

IONOSPHERIC TELECOMMUNICATIONS
ELF to MF Propagation Branch
VLF/LF Research Section
Radiodetermination Section
Electromagnetic Theory Section
HF Propagation Group
HF and VHF Propagation Branch
Ionospheric Radar Section
HF Propagation Theory Group
Radar Facility Group
Ionospheric Predictions Branch
Prediction Services Section
Field Engineering and Operations Sect.
Prediction Research Group

Communications Technology Branch
  Frequency Utilization Section
  Information Transmission Section
  Antenna Section
  Systems Group

AERONOMY

Geomagnetism Group
Equatorial Airglow Studies
Instrumentation Group
  Laboratory Plasma Physics
  Atmospheric Collision Processes
  Rocket and Satellite Experiments
  Ionosphere and Exposphere Physics
  Ionospheric Structure
  Optical Aeronomy

TROPOSPHERIC TELECOMMUNICATIONS

Data Reduction and Instrumentation
Atmospheric Spectroscopy
Optical Propagation and Laser
  Communications
Electromagnetic Interference Environment
Millimeter Wave Propagation
Tropospheric Propagation Predictions
Spectrum Utilization Research
Radio Meteorology
Tropospheric Physics

SPACE ENVIRONMENT FORECASTING

Space Disturbance Research Programs
  High Altitude Nuclear Detection Studies
  Solar Flare Detection Techniques
  Radio Phase Studies
  High Latitude Ionosphere Physics
  Magnetoionic Storm Theory
  Numerical Forecasting Techniques
  Solar Proton Event Detection
  Infrasonics
  Ionosphere Responses
  Solar Radio Astronomy
  Solar Activity
  Radiation Environment
Space Environment Forecasting Services
  Boulder Magnetic Observatory
  Space Environment Data Services
  Forecasting Services
  High Latitude Space Disturbances Monitoring

FIELD ESTABLISHMENTS

Institute for Applied Technology

Office of Weights and Measures Field Stations:
  Master Railway Track Scale Depot — Clearing, Ill.

Building Research Field Stations:
  Materials Testing Laboratories — Denver, Colo.; Seattle, Wash.

Institute for Basic Standards

Metrology Division Field Station:
  Visual Landing Aids Field Laboratory — Arcata, Calif.

Radio Standards Laboratory Field Stations:	
Standard Frequency Station WWV	Greenbelt, Md.
Standard Frequency Station WWVL-WWVB	Fort Collins, Colo.
Standard Frequency Station WWVH	Maui, Hawaii
Laboratory Astrophysics Division Field Station:	
Poor Man's Relief Mine, Four-Mile Canyon	Boulder, Colo.

Central Radio Propagation Laboratory Field Stations

ALASKA
Adak **
Barrow
College **

ANTARCTICA
Byrd Station **
Eights Station **
Pole Station **

ARIZONA
Kitt Peak Observatory

AUSTRALIA
Cook **
Sydney **

BOLIVIA
La Paz **

BRAZIL
Natal **
Sao Jose Dos Campos **

CALIFORNIA
Lompoc Pacific Missile Range
Los Angeles **

CAMEROON
Douala **

CANADA
Baie St. Paul
Cape Jones **
Frobisher Bay **
Great Whale River **

CHAD
Fort Lamy **

CHILE
Concepcion **
Santiago **

COLOMBIA
Bogota **

COLORADO
Akorn
Beulah
Cheyenne Mountain
Erie
Fritz Peak
Green Mountain Mesa
Gunbarrel Hill
Haswell
Karval
Kendrick
Kolb
Lafayette
Rocky Flats
Sunset
Table Mountain

ECUADOR
Quito **

FLORIDA
Eglin Air Force Base **

FORMOSA
Taipei **

GHANA
Accra **

GREENLAND
Godhavn **
Narssarssuaq **

HAWAII
Kauai (Kekaha)
Maui, Haleakala **
Maui (Puunene Airport)

ILLINOIS
Long Branch

INDIA
New Delhi **

ISRAEL
Tel-Aviv **

ITALY
Anacapri **

JAPAN
Ohira **

MALAGASAY (MADAGASCAR)
Tananarive **

MALAYA
Singapore **

MICHIGAN
Pontiac **

MINNESOTA
Cedar Creek **

MOROCCO
Rabat **

NEBRASKA
Shickley

NEW JERSEY
Fort Monmouth **

NEW MEXICO
White Sands **

NIGERIA
Kano **
Zaria **

OKINAWA
Okuma **
Onna **

OKLAHOMA
Mangum

** Contract or mutual cooperation.

SUMMARY OF NBS STAFF AS OF JUNE 30, 1965

	Washington	*Boulder*	*Total*
Total permanent staff	2784	1218	4002
Other Staff *	347	245	592
Total on rolls	3131	1463	4595
Research Associates and Guest Workers	160	39	199
Total on rolls at NBS	3291	1502	4793
Professional Staff **			
Physicists	442	237	679
Chemists	293	10	303
Engineers	183	204	387
Mathematicians	51	56	107
Other	111	20	131
Total professional staff	1080	527	1607

* Part time, intermittent, consultants, students, teachers, post-doctoral fellows and temporary limited employees.

** Full-time permanent, excludes any under *.

FINANCIAL DATA FOR FISCAL 1965

Program and Source of Financing	*Obligations Incurred (Rounded)*		
Supported by NBS Appropriations:			
Operating Programs:			
Research & Technical Services	$31,760,000		
Civilian Industrial Technology	347,000		
Special Foreign Currency Program	687,000		
Subtotal		$32,794,000	
Construction and Facilities Program:			
Plant and Facilities	1,827,000		
Construction of Facilities	1,509,000		
Subtotal		3,336,000	
Total NBS Appropriation			$36,130,000

Supported by Other Funds:			
Other Federal Agencies	25,526,000		
Nongovernment Sources	1,082,000		
Subtotal		26,608,000	
Calibrations, Testing, Standard Samples and Other Technical Services		6,271,000	
Total Supported by Other Funds			32,879,000
Total Program			$69,009,000

ADVISORY COMMITTEES

STATUTORY VISITING COMMITTEE

Reports annually to Secretary of Commerce on NBS activities. Dates indicate expiration of appointment.

Dr. E. R. Piore, Vice President, Research & Engineering, International Business Machines Corporation (1967), Chairman

Dr. Frederick Seitz, President, National Academy of Sciences (1966)

Professor Charles H. Townes, Provost, Massachusetts Institute of Technology (1965)

Dr. Elmer W. Engstrom, President, Radio Corporation of America (1968)

Dr. Paul C. Cross, President, Mellon Institute (1969)

TECHNICAL ADVISORY PANELS

During the past year a number of changes were made in the Bureau's program in order to obtain increased advisory input from the Nation's scientific and technical community. A new agreement was reached with the National Academy of Sciences-National Research Council whereby the functions of the former NBS Advisory Committee on Calibration and Measurement Services and the Advisory Committee on Textile and Apparel Research were included in its continuing evaluation and review of technical programs of NBS. The NBS Weights and Measures Advisory Committee was replaced by a Committee on Liaison with the National Government under the National Conference on Weights and Measures. The Advisory Committee on Engineering and Related Standards was discontinued because its functions were essentially duplicated by normal working contacts between NBS and the organizations represented on the Committee.

Twenty NAS-NRC advisory panels and committees were constituted during 1965. Of these, all panels except those for the Analytical Chemistry,

Metallurgy, and Cryogenics Divisions met at least once, and the Advisory Committee on Textile and Apparel Research met on five occasions. Comments and recommendations from the panels have been very helpful to NBS officials in formulating and adjusting the Bureau's technical program. The composition and operation of the advisory groups are still in the process of modification to adapt to the reorganization of the NBS into Institutes.

Institute for Basic Standards

Dr. R. D. Huntoon, Director

Advisory Panel to Applied Mathematics Division

Dr. Alston S. Householder, Oak Ridge National Laboratory, Chairman
Prof. T. W. Anderson, Columbia University
Prof. Francis J. Anscombe, Yale University
Prof. Charles R. DePrima, California Institute of Technology
Prof. Joaquin B. Diaz, University of Maryland
Dr. Ralph E. Gomory, International Business Machines Corp.
Dr. Alan J. Hoffman, International Business Machines Corp.
Dr. Bernard O. Koopman, Institute for Defense Analyses
Dr. J. P. LaSalle, Research Institute for Advanced Studies
Prof. Peter D. Lax, New York University
Dr. Elliott W. Montroll, Institute for Defense Analyses
Dr. J. Barkley Rosser, University of Wisconsin
Prof. John Todd, California Institute of Technology

Advisory Panel to Electricity Division

Dr. William G. Amey, Leeds & Northrup Company, Chairman
Dr. Richard M. Bozorth, Short Hills, N. J.
Mr. Ivan G. Easton, General Radio Company
Prof. Raymond M. Fuoss, Yale University
Dean R. B. Lindsay, Brown University
Mr. E. C. Starr, U. S. Department of the Interior
Prof. M. B. Stout, University of Michigan
Prof. John G. Trump, Massachusetts Institute of Technology

Advisory Panel to Metrology Division

Dr. J. H. Webb, Eastman Kodak Company, Chairman
Prof. Isay A. Balinkin, University of Cincinnati
Dr. Alsoph H. Corwin, The Johns Hopkins University
Mr. C. L. Crouch, Illuminating Engineering Society
Mr. A. M. Dexter, Bausch & Lomb Incorporated
Dr. Robert E. Hopkins, University of Rochester
Mr. Floyd W. Hough, American Geophysical Union
Dr. Elmer Hutchisson, Portola Valley, California
Mr. Louis Polk, Dayton, Ohio
Prof. John Strong, The Johns Hopkins University

Advisory Panel to Mechanics Division

Prof. S. R. Beitler, American Society of Mechanical Engineering, Chairman
Prof. Lynn S. Beedle, Lehigh University
Prof. Arthur T. Ippen, Massachusetts Institute of Technology
Dr. Harry F. Olson, Radio Corporation of America
Prof. Jesse Ormondroyd, University of Michigan
Dr. M. E. Shank, Pratt & Whitney Aircraft
Prof. R. S. Rivlin, Brown University

Advisory Panel to Heat Division

Dr. Charles F. Squire, Texas A&M University, Chairman
Prof. Henry A. Fairbank, Duke University
Prof. H. R. Griem, University of Maryland
Prof. Burgess H. Jennings, Northwestern University
Prof. Joseph Kestin, Brown University
Dr. Paul G. Klemens, Westinghouse Research Laboratories
Prof. Robert S. Mulliken, University of Chicago
Prof. John Ross, Brown University
Prof. Clayton A. Swenson, Iowa State University
Prof. Edgar F. Westrum, Jr., University of Michigan

Advisory Panel to Atomic Physics Division

Prof. Peter Franken, University of Michigan, Chairman
Prof. R. Grant Athay, University of Colorado
Prof. W. R. Bennett, Jr., Yale University
Dr. Bruce H. Billings, Aerospace Corporation
Dr. Wade L. Fite, University of Pittsburgh
Dr. Leo Goldberg, Harvard College Observatory
Dr. R. L. Sproull, Advanced Research Projects Agency
Prof. Gabriel Weinreich, University of Michigan
Prof. E. Bright Wilson, Jr., Harvard University

Advisory Panel to Physical Chemistry Division

Dr. Henry Eyring, University of Utah, Chairman
Dr. Paul Cross, Mellon Institute
Dr. Benjamin P. Dailey, Columbia University
Prof. Hans H. Jaffe, University of Cincinnati
Dr. Joseph O. Hirschfelder, University of Wisconsin
Dr. Max S. Matheson, Argonne National Laboratory
Dr. Daniel R. Stull, The Dow Chemical Company
Prof. Harold S. Johnston, University of California

Advisory Panel to Laboratory Astrophysics

Dr. Wade L. Fite, University of Pittsburgh, Chairman
Prof. W. R. Bennett, Jr., Yale University
Dr. Bruce H. Billings, Aerospace Corporation
Prof. Peter Franken, University of Michigan
Dr. Leo Goldberg, Harvard College Observatory

Dr. Arthur Kantrowitz, Everett Research Laboratory
Dr. A. Keith Pierce, Kitt Peak National Observatory
Dr. O. C. Wilson, California Institute of Technology

Advisory Panel to Radiation Physics Division

Dr. Robley D. Evans, Massachusetts Institute of Technology, Chairman
Dr. John S. Blair, University of Washington
Mr. Casimer J. Borkowski, Oak Ridge National Laboratory
Dr. Harold A. Lamonds, Edgerton, Germeshausen & Grier, Inc.
Dr. John S. Laughlin, Sloan-Kettering Institute for Cancer Research
Prof. Harold H. Rossi, Columbia University
Dr. Vance L. Sailor, Brookhaven National Laboratory
Dr. Warren K. Sinclair, Argonne National Laboratory

Advisory Panel to Radio Standards Laboratory

Dr. E. W. Houghton, Bell Telephone Laboratories
Dr. George Birnbaum, North American Aviation
Dr. Cullen M. Crain, The Rand Corporation
Prof. E. U. Condon, University of Colorado
Prof. Walter Gordy, Duke University
Prof. H. A. Haus, Massachusetts Institute of Technology
Dr. C. Lester Hogan, Motorola, Inc.
Mr. Frank McGinnis, Sperry Gyroscope Company
Prof. Arthur A. Oliner, Polytechnic Institute of Brooklyn
Dr. Bernard M. Oliver, Hewlett-Packard Company
Dr. John C. Simons, Jr., Weston, Massachusetts
Prof. M. W. P. Strandberg, Massachusetts Institute of Technology

Advisory Committee on Calibration and Measurement Services

Dr. C. E. White, AVCO Corporation, Chairman
Dr. William G. Amey, Leeds and Northrup Company
Mr. Marvin Friedland, Eau Gallie, Florida
Mr. S. C. Richardson, General Electric Company
Mr. Bruno O. Weinschel, Weinschel Engineering
Mr. A. J. Woodington, General Dynamics/Astronautics

Institute for Materials Research

Dr. Gordon K. Teal, Director

Advisory Panel to Analytical Chemistry

Dr. Charles E. White, University of Maryland, Chairman
Prof. George T. Austin, State College of Washington
Prof. Clark E. Bricker, University of Kansas
Prof. W. D. Cooke, Cornell University
Prof. George Morrison, Cornell University
Prof. Charles N. Reilley, University of North Carolina
Prof. L. B. Rogers, Purdue University
Dr. James White, Oak Ridge National Laboratory

Advisory Panel to Polymers Division

Dr. Raymond F. Boyer, Dow Chemical Company, Chairman
Dr. C. M. Blair, Union Carbide Corporation
Dr. J. H. Dillon, Textile Research Institute
Dr. Charles C. Price, University of Pennsylvania
Dr. C. G. Overberger, Polytechnic Institute of Brooklyn
Dr. J. F. Downie Smith, Carrier Research and Development Company

Advisory Panel to Metallurgy Division

Dr. Robert H. Aborn, Millington, New Jersey
Dr. W. A. Dean, Aluminum Company of America
Dr. D. J. Dienes, Brookhaven National Laboratory
Mr. A. R. Lytle, National Academy of Sciences-National Research Council
Prof. E. F. Osborn, Pennsylvania State University
Dr. Albert J. Phillips, American Smelting and Refining Company
Prof. Robb M. Thomson, University of Illinois

Advisory Panel to Inorganic Materials Division

Dr. Joseph E. Burke, General Electric Research Laboratory, Chairman
Dr. C. L. Babcock, Owens-Illinois Technical Center
Dr. Morris Berg, AC Spark Plug
Dr. James R. Johnson, Minnesota Mining and Manufacturing Company
Dr. Ralston Russell, Jr., The Ohio State University
Prof. Henry Taube, Stanford University

Advisory Panel to Cryogenics Division

Dr. Clyde McKinley, Air Products and Chemicals, Inc., Chairman
Dr. E. F. Hammel, University of California
Prof. A. L. Hesselschwerdt, Massachusetts Institute of Technology
Prof. Edward Lady, University of Michigan

Institute for Applied Technology

Dr. D. A. Schon, Director

Advisory Panel to Building Research Division

Mr. James H. Binns, Armstrong Cork Company
Dr. J. V. Fitzgerald, Tile Council of America, Inc.
Mr. Thomas H. Harkins, Carl M. Freeman Associates
Dr. Robert A. Hechtman, Planning Analysis and Design Corp.
Prof. Hoyt C. Hottel, Massachusetts Institute of Technology
Prof. James T. Lendrum, University of Florida
Dean Warren L. McCabe, Chapel Hill, North Carolina
Mr. Joseph H. Newman, Tishman Research Corporation
Mr. Alwin B. Newton, Borg-Warner Corporation
Mr. Raymond C. Reese, Toledo, Ohio
Mr. Herbert H. Swinburne, Nolan, Swinburne and Associates

Mr. C. H. Topping, E. I. DuPont De Nemours and Co.
Mr. T. E. Werkema, Dow Chemical Company

Advisory Panel to Information Technology Division

Mr. William N. Papian, Washington University, Chairman
Mr. Vico E. Henriques, Business Equipment Manufacturers Association
Dr. Alan J. Hoffman, International Business Machines Corp.
Prof. Charles L. Miller, Massachusetts Institute of Technology
Dr. Elliott Montroll, Institute of Defense Analyses
Prof. Morris Rubinoff, University of Pennsylvania
Dr. Abraham Sinkov, Arizona State University
Dr. Arthur Tyler, Vestar, Inc.
Dr. Willis H. Ware, Rand Corporation
Mr. Carl W. Clewlow, Arthur Young and Company
Mr. Frank White, Air Transport Association

Advisory Committee on Textile and Apparel Research

Mr. Richard T. Kropf, Belding Heminway Co., Inc., Chairman
Mr. William A. Newell, Whitin Machine Works
Mr. William J. Bank, Blue Ridge Manufacturers, Inc.
Dr. Malcolm E. Campbell, University of North Carolina
Dr. David W. Chaney, Chemstrand Research Center, Inc.
Mr. J. B. Goldberg, Textile and Allied Industries
Mr. George Perkel, Textile Workers Union of America
Mr. Kurt Salmon, Kurt Salmon Associates, Inc.
Mr. Horace A. Secrist, The Kendall Company
Dr. Paul B. Stam, J. P. Stevens & Co., Inc.
Mr. Levon M. Yacubian, Barre Wool Combing Co., Ltd.

Central Radio Propagation Laboratory

C. Gordon Little, Director

Advisory Panel to: Ionosphere Research and Propagation Division, Troposphere and Space Telecommunications Division, Radio Systems Division, Upper Atmosphere and Space Physics Division

Mr. Stuart L. Bailey, Alexandria, Virginia, Chairman
Dr. Elie J. Baghdady, ADCOM, Inc.
Dr. C. M. Crain, The Rand Corporation
Dr. W. H. Culver, Institute for Defense Analyses
Mr. R. P. Gifford, General Electric Company
Mr. Milton Greenberg, Geophysics Corporation of America
Dr. S. W. Herward, Westinghouse Electric Corporation
Dr. D. C. Hogg, Bell Telephone Laboratories
Dr. F. S. Johnson, Southwest Center for Advanced Studies
Dr. John M. Kelso, ACF Industries, Inc.
Prof. W. J. Ross, The Pennsylvania State University
Dr. O. G. Villard, Stanford University

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 1965:

Recipient	*Award*
Astin, Allen V.	Award to Executives from American Society for Testing and Materials
Bennett, John A.	Award to Executives from American Society for Testing and Materials
Brenner, Abner	William Blum Award of the Electrochemical Society
Fullmer, Irvin H. and McPherson, Archibald T.	Edward B. Rosa Award National Bureau of Standards
Kline, Gordon M.	Standards Engineers Society—American Society for Testing and Materials Award
Group Award:	
Ambler, Ernest	
Hayward, Raymond	Samuel Wesley Stratton Award
Hoppes, Dale	National Bureau of Standards
Hudson, Ralph	

Department of Commerce Exceptional Service Awards

(Gold Medal)

Recipient	*Technical Area*
Armsby, Ruth B.	Employee Development and Relations
Green, Melville S.	Statistical Physics
Hamer, Walter J.	Electrochemistry
Hoffman, John D.	Polymer Research
Scott, Russell B.	Cryogenic Engineering
Stegun, Irene A.	Digital Computation
Joint Award:	
Gallet, Roger M.	Computer Programs
Jones, William B.	
Group Award:	
Knecht, Robert W.	
Shapley, Alan H.	
VanZandt, Thomas E.	
Watts, James M.	Upper Atmosphere Physics and
Lawrence, Robert S.	Plasma Physics

Calvert, Wynne
Ferguson, Earl E.
Goe, Georganna B.
Green, Richard G.
LaBaume, Leray

Department of Commerce Meritorious Service Awards

(Silver Medal)

Recipient	*Technical Area*
Andrews, David H.	Frequency and Time Broadcasts
Barnes, James A.	Atomic Frequency and Time Interval Standards
Berger, Martin J.	Radiation Theory
Berkley, Jessie B.	Management Analysis
Brenner, George E.	Scientific Instruments
Brown, Daniel W.	Polymer Chemistry
Florin, Roland E.	Polymer Chemistry
Hauler, Arthur R.	Administration
Hopper, Natalie J.	Library Research
Krauss, Morris	Physical Chemistry
Lide, David R., Jr.	Infrared and Microwave Spectroscopy
Lopez, Alfred S.	Accelerator Engineering
Peiser, H. Steffen	Crystal Chemistry
Sugar, George R.	Digitization of Field Data
Zwanzig, Robert W.	Statistical Physics

EDUCATION, TRAINING, AND UNIVERSITY LIAISON

A broad employee program, implemented primarily through the NBS Graduate School and non-government educational and training facilities, is available to all staff members. The program covers education through postdoctoral research and is offered at both the Boulder and Washington Laboratories. The primary objectives—to increase employee efficiency in assigned duties and to prepare systematically for increased responsibilities—are to an increasing extent encompassing the management and supervisory areas as well as the traditional areas of science and technology.

The NBS Graduate School

The NBS Graduate School curriculum includes graduate and undergraduate courses in the physical sciences, mathematics, and certain branches of engineering. A series of scientific colloquia and seminars are led by research leaders from the Bureau and from other research centers and, in addition, general staff development courses, such as scientific German, practical metallurgy, and mathematical symbolism and terminology are

offered. Educational counseling is available, and employees may receive thesis accreditation for research done at the Bureau. In addition, a Technician Career Program, for subprofessional laboratory personnel, offers a series of in-hours courses on the fundamentals of science and mathematics. Surveys periodically redetermine course offerings and keep the program in step with the changes and variations in educational requirements.

An interesting variation of the basic theme finds the Graduate Program at Boulder associated with the University of Colorado in a Joint-Course program and Adjunct Professor Plan. Various graduate departments of the NBS Graduate School and the University offer courses which mutually benefit the Government and the University.

Since the establishment of the educational program in 1908, 42 universities have awarded 317 graduate degrees based partly on credits obtained or thesis work carried on under the NBS Graduate School Program.

Non-Government Education

Non-government education, authorized by the Government Employees Training Act of 1958, falls into three categories—full-time (3 to 12 months) postdoctoral 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 local educational institutions.

Four hundred and thirty-six staff members at Washington and Boulder were trained through non-government facilities last year; 13 career scientists were selected for full-time 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.

Short concentrated courses and training programs at universities and in industry were attended by 132 staff members. Two hundred and ninety-one employees, mostly from technical divisions, attended job-related courses at local educational facilities.

Interagency Courses

The interagency series of courses is another important area of government-sponsored programs. Two hundred and one Bureau employees participated in a wide range of special courses with a sizeable number in the supervisory-management fields. In addition, the Commerce Department offers an intra-department Science and Technology Fellowship Program. Last year eight NBS employees went to other Bureaus in the Department while six were assigned to NBS.

Student Trainee Program

Each year a student trainee summer program is held for college and graduate students majoring in the physical sciences, mathematics, and certain branches of engineering. At this time an integrated work-study plan including lectures, tours, demonstrations, supervised laboratory assignments, and professional counseling is conducted. The program acquaints young

people interested in career scientific research opportunities with the work of NBS. Other summer programs include the assignment of high school teachers to the Bureau under National Science Foundation sponsorship and American University administration. Last year eighteen physics and chemistry teachers worked in NBS laboratories. Sixty-three students, primarily at the high school level, had summer assignments at Washington and Boulder under the Youth Opportunity Program for young people qualifying on the basis of economic need.

Postdoctoral Programs

In collaboration with the National Research Council, the National Bureau of Standards offers postdoctoral resident research associateships. Selection covers young scientists promising to become creative leaders in the various branches of the physical and mathematical sciences. While improving themselves professionally, opportunities are open to increase scientific knowledge by developing new approaches and laboratory skills. Last year the following were selected: Ludwig Balling, John Deutch, Richard Duffy, Harvey Gould, Werner Hartl, Lester Lipsky, Kenneth Miller, Archie McAlister, James Root, Jewel Shapiro, Allan Smith, Rosemarie Stemmler, Peter Sullivan, Eugene Tschuikow-Roux, Claude Veillon, Herbert Wood.

Sabbatical Opportunities

Distinguished scientists are encouraged to spend their sabbatical years, summer vacations, or other extended periods at the Bureau. These visiting scientists increase the Bureau's ties with the academic community and provide a continuing influx of new ideas into the Washington and Boulder programs. The Bureau is seeking legislation to increase the availability of the visiting scientists program. The changes would make it possible to reimburse visiting scientists for the necessary travel and transportation of household effects.

PUBLICATIONS*

PUBLICATIONS IN THE BUREAU'S SERIES

During the year NBS publications totaled 1258 published papers and documents.

Of the formal publications, 275 appeared in the Journal of Research, and 715 in the journals of professional and scientific societies. Also, 161 summary articles were presented in the Bureau's monthly Technical News Bulletin. A third periodical, the monthly Central Radio Propagation Laboratory Ionospheric Predictions, presented radio propagation data needed for determining the best radio frequencies for use in long-range radio communications.

---

* 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). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

In the nonperiodical series, 107 documents were published: 17 in the Monograph series, 4 in the Handbook series, 14 in the Miscellaneous Publication series, 53 in the Technical Notes series, 16 Commercial Standards, and 3 National Standard Reference Data Series.

Journal of Research. Contains full research papers, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Advances in measurement standards and techniques . . . physical constants . . . properties of materials . . . instrumentation . . . radio propagation.

The Journal is published in four separate sections . . .

A. Physics and Chemistry, issued six times a year. Annual subscription: Domestic, $5; foreign, $6.75; single copy, 75 cents.

B. Mathematics and Mathematical Physics, issued quarterly. Annual subscription; Domestic, $2.25; foreign, $2.75; single copy, 75 cents.

C. Engineering and Instrumentation, issued quarterly. Annual subscription: Domestic $2.75; foreign, $3.00; single copy, 75 cents.

D. Radio Science (formerly Radio Propagation), issued monthly. Annual subscription: Domestic, $9; foreign, $11.50; single copy, $1.00

Volume 68A (Phys. and Chem.), No. 4 (July-August 1964)

Metallographic characterization of an NBS spectrometric low-alloy steel standard. R. E. Michaelis, H. Yakowitz, and G. A. Moore.

X-ray investigation of strain in cold-worked silver iodide. G. Burley.

Light scattering measurements on solutions of some quarternary ammonium salts. S. P. Wasik and W. D. Hubbard.

Thermodynamic properties of some methylphosphonyl dihalides from 15 to 335 °K. G. T. Furukawa, M. L. Reilly, J. H. Piccirelli, and M. Tenenbaum.

Calorimetric properties of some alkali pentaborate hydrates from 15 to 370 °K. G. T. Furukawa, M. L. Reilly, and J. H. Piccirelli.

Rates of adsorption and desorption of polystyrene on chrome surface. R. R. Stromberg, W. H. Grant, and E. Passaglia.

An iterative unfolding procedure. R. P. Uhlig.

Mass spectrometric study of photoionization. I. Apparatus and initial observations on acetylene, acetylene-d_2, benzene, and benzene-d_6. V. H. Dibeler and R. M. Reese.

Volume 68A (Phys. and Chem.), No. 5 (Sept.-Oct. 1964)

Relaxation modes of trapped crystal point defects: the three-neighbor shells model in NaCl. A. D. Franklin, A. Shorb, and J. B. Watchman, Jr.

Viscosity of a standard soda-lime-silica glass. A. Napolitano and E. G. Hawkins.

Hydrothermal preparation of a gehlenite hydrate. E. T. Carlson.

Action of water on calcium aluminoferrities. E. T. Carlson.

Infrared spectra of the crystalline inorganic borates. C. E. Weir and R. A. Schroeder.

Effect of pressure and temperature upon the optical dispersion of benzene, carbon tetrachloride, and water. R. M. Waxler, C. E. Weir, and H. W. Schamp, Jr.

Some changes in double-bond structure during the vulcanization of natural rubber. F. J. Linnig, E. J. Parks, and J. E. Stewart.

Dislocations in polymer crystals. H. D. Keith and E. Passaglia.

Dependence of mechanical relaxation on morphology in isotactic polypropylene. E. Passaglia and G. M. Martin.

Precision density measurement of silicon. I. Henins.

Franck-Condon factors to high vibrational quantum numbers IV: NO band systems. R. W. Nicholls.

Volume 68A (Phys. and Chem.), No. 6 (Nov.-Dec. 1964)

The 1962 He^3 scale of temperatures. I. New vapor pressure comparisons. S. G. Sydoriak and R. H. Sherman.

The 1962 He^3 scale of temperatures. II. Deriviation. S. G. Sydoriak, T. R. Roberts, and R. H. Sherman.

The 1962 He^3 scale of temperatures. III. Evaluation and status. T. R. Roberts, R. H. Sherman, and S. G. Sydoriak.

The 1962 He^3 scale of temperatures. IV. Tables. R. H. Sherman, S. G. Sydoriak, and T. R. Roberts.

Absolute isotopic abundance ratio and the atomic weight of a reference sample of copper. W. R. Shields, T. J. Murphy, and E. L. Garner.

Absolute isotopic abundance ratio and the atomic weight of bromine. E. J. Catanzaro, T. J. Murphy, E. L. Garner, and W. R. Shields.

Optical properties of thin films on transparent surfaces by ellipsometry; internal reflection for film covered surfaces near the critical angle. E. Passaglia and R. R. Stromberg.

On the second-order transition of a rubber. E. A. DiMarizo.

Ionization constants and reactivity of isomers of eugenol. G. M. Brauer, H. Argentar, and G. Durany.

Near infrared spectrophotometric method for the determination of hydration numbers. R. A. Durst and J. K. Taylor.

Franck-Condon factors for the ionization of H_2, HD, and D_2. M. E. Wacks.

Calculation of the geometrical structure of some AH_n molecules. M. Krauss.

Preparation and heat of formation of a magnesium oxysulfate. E. S. Newman.

Heat capacity of potassium borohydride (KBH_4) from 15 to 375 °K. Thermodynamic properties from 0 to 700 °K. G. T. Furukawa, M. L. Reilly, and J. H. Piccirelli.

Heat of combustion and heat of formation of aluminum carbide. R. C. King and G. T. Armstrong.

Some elastic compliances of single crystal rutile from 25 to 1000 °C. S. Spinner and J. B. Watchman, Jr.

Energy dependence of the D–D reaction cross section at low energies, J. G. Brennan and J. J. Coyne.

Volume 69A (Phys. and Chem.), No. 1 (Jan.-Feb. 1965)

Heat of decomposition of sodium and potassium chlorate. A. A. Gilliland and D. D. Wagman.

Application of precise heat-capacity data to the analysis of the temperature intervals of the NBS–1955 and the International Practical Temperature Scales in the region of 90 °K. G. T. Furukawa and M. L. Reilly.

Heat capacity and thermodynamic properties of beryllium aluminate (chrysoberyl), $BeO{\cdot}AL_2O_3$, from 16 to 380 °K. G. T. Furukawa and W. G. Saba.

Thermodynamics of the ternary system: water-sodium chloride-barium chloride at 25 °C. R. A. Robinson and V. E. Bower.

Compressibility of eleven inorganic materials. C. E. Weir.

Determination of the intermolecular entanglement coupling spacings in polyisoprene by viscosity measurements. L. J. Fetters.

Electrical conductivity of dilute solutions of "sea water" from 5 to 120 °C. C. G. Malmberg.

Preparation of a carbonate-free complex calcium aluminate. H. A. Berman.

Synthesis and thermal stability of bis(8-hydoxyquinoline)-Schiff base coordination polymers. E. Horowitz and T. P. Perros.

Atomic absorption spectrum of praseodymium (Pr I). R. Zalubas and M. Wilson.

Volume 69A (Phys. and Chem.), No. 2 (Mar.-Apr. 1965)

Radiolysis of $N^{15}N^{14}O$. R. Gorden, Jr., and P. Ausloos.

Oscillator strengths for lines of Ni I. C. H. Corliss.

More wavelengths from thorium lamps. W. F. Meggers and R. W. Stanley.

Phase equilibria in the system vanadium oxide-niobium oxide. J. L. Waring and R. S. Roth.

Thermodynamics of the ternary system: water-glycine-potassium chloride at 25 °C from vapor pressure measurements. V. E. Bower and R. A. Robinson.

Heat of formation of aluminum fluoride by direct combination of the elements. E. S. Domalski and G. T. Armstrong.

Relative enthalpy of polytetrafluoroethylene from 0 to 440 °C. T. B. Douglas and A. W. Harman.

Anionic polymerization of isoprene at low concentrations of polyisoprenyllithium. L. J. Fetters.

One particle transitions and correlation in quantum mechanics. A. R. Ruffa.

Disaccommodation of magnetic spectra of two mangenese zinc ferrites. A. L. Rasmussen.

Splitting of a set of equivalent sites in centrosymmetric space groups into subsets under homogeneous stress. J. B. Watchman, Jr., and H. S. Peiser.

Volume 69A (Phys. and Chem.), No. 3 (May-June 1965)

Electronic structure and magnetic properties of the neptunyl ion. J. C. Eisenstein and M. H. L. Pryce.

Heats of transformations in bismuth oxide by differential thermal analysis. E. M. Levin and C. L. McDaniel.

Phase relations between iridium and the sesquioxides in air. S. J. Schneider, J. L. Waring, and R. E. Tressler.

Phase equilibrium relationships in the system Gd_2O_3–TiO_2. J. L. Waring and S. J. Schneider.

Acid-base behavior in 50 percent aqueous methanol: thermodynamics of the dissociation of protonated tris(hydroxymethyl) aminomethane and nature of the solvent effect. M. Woodhead, M. Paabo, R. A. Robinson, and R. G. Bates.

Observations of dislocations and surface features in corundum crystals by electron transmission microscopy. D. J. Barber and N. J. Tighe.

Low-frequency dielectric properties of liquid boric oxide. K. H. Stern.

Mass spectrometric study of the effects of nitric oxide and other additives on "purified" active nitrogen. J. T. Herron.

Synthesis and ring structure of 7-acetamido-7-deoxy-L-*galacto*-heptulose. E. J. McDonald.

Volume 68B (Math. and Math. Phys.), No. 3 (July-Sept. 1964)

Generation and composition of functions. A. J. Goldman.

Thermodynamics of perfect elastic fluids. B. Bernstein, E. A. Kearsley, and L. J. Zapas.

Zeros of polynomials in several variables and fractional order differences of their coefficients. B. Mond and O. Shisha.

Theory of radiation from sources immersed in anisotropic media. J. R. Wait.

Volume 68B (Math. and Math. Phys.), No. 4 (Oct.-Dec. 1964)

Hydrodynamic fluctuations and Stokes' Law friction. R. Zwanzig.

Equivalence of certain inequalities complementing those of Cauchy-Schwarz and Holder. J. B. Diaz, A. J. Goldman, and F. T. Metcalf.

Weak generalized inverses and minimum variance linear unbiased estimation. A. J. Goldman and M. Zelen.

Improvement of bonds to eigenvalues of operators of the form T^*T. N. W. Bazley and D. Fox.

The greatest crossnorm. R. Schatten.

Volume 69B (Math. and Math. Phys.), No. 1 and 2 (Jan.-June 1965)

Lectures on matroids. W. T. Tutte.

Menger's theorem for matroids. W. T. Tutte.

Single-element extensions of matroids. H. H. Crapo.

Minimum partition of a matroid into independent subsets. J. Edmonds.

Lehman's switching game and a theorem of Tutte and Nash-Williams. J. Edmonds.

On the connection between the properties of oriented linear graphs and analyses of lumped physical systems. H. M. Trent.

Character subgroups of F-groups. M. I. Knopp and M. Newman.

A note on multipliers of difference sets. R. A. Brualdi.

Modification of Edmonds' maximum matching algorithm. C. Witzgall and C. T. Zahn, Jr.

On measurable sets and functions. A. J. Goldman.

Characteristic relations for nonperiodic solutions of Mathieu's equation. T. Tamir and H. C. Wang.

On the surface duality of linear graphs. J. Edmonds.

Maximum matching and a polyhedron with 0,1-vertices. J. Edmonds.

Volume 68C (Engr. and Instr.), No. 3 (July-Sept. 1964)

Response of highly precise balances to thermal gradients. L. B. Macurdy.

A direct-reading two-knife 50-pound balance of high precision suitable for State weights and measures laboratories. H. E. Almer, H. A. Bowman, M. W. Jensen, L. B. Macurdy, H. S. Peiser, and B. Wasko.

Wave front shearing prism interferometer. J. B. Saunders.

A new high resolution small-angle x-ray camera. H. Brumberger and R. Deslattes.

Experimental determination of air drag on a textile yarn struck transversely by a high-velocity projectile. J. C. Smith, C. A. Fenstermaker, and P. J. Shouse.

Volume 68C (Engr. and Instr.), No. 4 (Oct.-Dec. 1964)

Theory of mirror spectrographs I. Astigmatic illumination of plane gratings and prisms. K. D. Mielenz.

Theory of mirror spectrographs II. General theory of focal surfaces and slit curvatures. K. D. Mielenz.

Theory of mirror spectrographs III. Focal surfaces and slit curvature of Ebert and Ebert-Fastie spectrographs. K. D. Mielenz.

Heat flow in a right circular cylinder with arbitrary temperature boundary conditions—applications to the determination of thermal conductivity. D. R. Flynn.

Digitized phasemeter. W. S. Epstein.

Active and passive direct-reading ratio sets for the comparison of audio-frequency admittances. R. D. Cutkosky.

Review of methods for the excitation of atomic and ionic spectra by means of high-frequency discharges and sliding sparks. L. Minnhagen.

Standards for the calibration of Q-meters 50 kHz to 45 MHz. R. N. Jones.

X-ray measurement of residual strains in individual grains of polycrystalline aluminum. C. J. Newton.

Ferrimagnetic resonance measurements using IF substitution techniques. W. E. Case, R. D. Harrington, and L. B. Schmidt.

A Pienkowsky-type calibration scheme for 5211Σ1 weight series using two knife-edge direct-reading balances. H. S. Peiser.

Reference tables for the Platinel II thermocouple. L. O. Olsen and P. D. Freeze.

Effects of cathodic currents on the corrosion of an aluminum alloy. W. J. Schwerdtfeger.

Photooxidation of asphalts in the presence of ozone. J. R. Wright and P. G. Campbell.

Designs for temperature and temperature gradient compensated capacitors smaller than ten picofarads. R. D. Cutkosky.

Volume 69C (Engr. and Instr.), No. 1 (Jan.-Mar. 1965)

Two picnometers of increased convenience and precision. A. Johnson.

Construction of a Michelson interferometer for Fourier spectroscopy. H. N. Rundle.

The National Bureau of Standards gas thermometer II. Measurement of capacitance to a grounded surface with a transformer ratio-arm bridge. L. A. Guildner and R. E. Edsinger.

An adiabatic calorimeter for the range, 10 to 360 °K. K. F. Sterrett, D. H. Blackburn, A. B. Bestul, S. S. Chang, and J. Horman.

A rugged null-type pressure transducer of high reproducibility for accurate gas phase PVT measurement. M. Waxman and W. T. Chen.

Detection and damping of thermal-acoustic oscillations in low-temperature measurements. D. A. Ditmars and G. T. Furukawa.

NBS free-air chamber for measurement of 10 to 60 kV x-rays. P. J. Lamperti and H. O. Wyckoff.

A compensated solenoid giving uniform magnetic field over a large volume. C. Snow and R. L. Driscoll.

Evaluation of a microwave phase measurement system. D. A. Ellerbruch.

Polarographic analysis of titantium (IV)—EDTA complex: application to paint pigments. H. W. Berger and B. C. Cadoff.

Soil resistivity as related to underground corrosion and cathodic protection. W. J. Schwerdtfeger.

Volume 69C (Engr. and Instr.), No. 2 (Apr.-June 1965)

Temperature of thermocouple reference junctions in an ice bath. F. R. Caldwell.

Superimposed birefactory plates. L. H. Adams and R. M. Waxler.

A self-calibrating instrument for measuring conductance at radio frequencies. L. E. Huntley.

Exact inductance equations for rectangular conductors with applications to more complicated geometeries. C. Hoer and C. Love.

Common volume of two intersecting cylinders. J. H. Hubbell.

Steady-state heat conduction in an exposed exterior column of rectangular cross section. B. A. Peavy.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 7 (July 1964)

Leader and junction processes in the lightning discharge as a source of VLF atmospherics. H. R. Arnold and E. T. Pierce.

The return stroke of the lightning flash to earth as a source of VLF atmospheres. A. S. Dennis and E. T. Pierce.

VLF propagation in a compressible ionosphere. R. B. Kieburtz.

A spectrographic interferometer. R. H. Lee and J. W. Warwick.

Effect of lossy earth on antenna gain, part II. W. L. Curtis.

Calculation of groundwave attenuation in the far diffraction region. L. E. Vogler.

Some numerical results based on the theory of radio wave propagation over inhomogeneous earth. K. Furutsu, R. E. Wilkerson, and R. F. Hartmann.

A note on VHF reflection from a tropospheric layer. J. R. Wait.

Some remarks on the use of statistics in radar astronomy. I. Kay.

A meteorological parameter for radioclimatological purposes. P. Misme.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 8 (Aug. 1964)

Extension of cosmic noise absorption measurements to lower frequencies, using polarized antennas. C. G. Little, G. M. Lerfald, and R. Parthasarathy.

Broadband radio-star scintillations, part I. Observations. D. G. Singleton.

F-region irregularities studied by scintillation of signals from satellites. K. C. Yeh and G. W. Swenson, Jr.

Angels, insects, and weather. A. H. LaGrone, A. P. Deam, and G. B. Walker.

Measurement of the attenuation of radio signals by jungles. J. W. Herbstreit and W. Q. Crichlow.

Influence of a circular ionospheric depression of VLF propagation. J. R. Wait.

An experimental study of mixed-path groundwave propagation. S. W. Maley and H. Ottesen.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 9 (Sept. 1964)

Symposium on Signal Statistics, Seattle, Washington, U.S.A., December 6-7, 1963:

Signal statistics, yesterday and today. F. L. H. M. Stumpers.

Rayleigh distribution and its generalizations. P. Beckmann.

Some nonlinear problems arising in the study of random processes. M. Rosenblatt.

An approach to empirical time series analysis. E. Parzen.

Effect of linear and nonlinear signal processing on signal statistics. A. V. Balakrishnan.

Random volume scattering. H. Bremmer.

Phase fluctuation statistics. J. B. Smyth.

Current topics in the stochastic theory of radiation. F. J. Zucker.

On the intensity distribution $\frac{2R}{\sqrt{a\beta}} \exp\left[-\frac{R^2}{2}\left(\frac{1}{a}+\frac{1}{\beta}\right)\right] I_0\left(\frac{R^2}{2}\left[\frac{1}{\beta}-\frac{1}{a}\right]\right)$ and its application to signal statistics. M. Nakagami.

Statistical inference for Rayleigh distributions. M. M. Siddiqui.

A probabilistic approach to the problem of large antenna arrays. Y. T. Lo.

Influence of data processing on the design and communication of experiments. S. W. Golomb.

Spectral measurement techniques in planetary radar. G. Pettengill.

Quantum statistics and lasers. J. P. Gordon.

Statistics of random surfaces. I. Kay and P. Swerling.

Modified gaussian distributions for slightly nonlinear variables. M. S. Longuet-Higgins.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 10 (Oct. 1964)

Theoretical heights and durations of echoes from large meteors. O. A. Manning.

Experimental determination of meteoric line densities and attachment rates. L. A. Manning.

Broadband radio-star scintillations, II. Interpretation. D. G. Singleton.

A discussion of the theory of ionospheric cross modulation. R. F. Benson.

Electron collision frequency in the ionospheric *D* region. R. F. Benson.

Theory of a slotted-sphere antenna immersed in a compressible plasma. Part I. J. R. Wait.

Theory of a slotted-sphere antenna immersed in a compressible plasma. Part II. J. R. Wait.

Electromagnetic scattering coefficients for concentric spheres and the problem of interference free enclosures. R. A. Eldred, H. A. Lasitter, and J. Roberts.

Ionospheric sounding using coded pulse signals. D. C. Coll and J. R. Storey.

Measurement of the complex time-frequency channel correlation function. P. A. Bello.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 11 (Nov. 1964)

Interaction of an antenna with a hot plasma and the theory of resonance probes. J. A. Fejer.

Observations of earth-ionosphere cavity resonances and their interpretation in terms of a two-layer ionosphere model. F. W. Chapman and D. Llanwyn Jones.

On the theory of reflection of electromagnetic waves from the interface between a compressible magnetoplasma and a dielectric. J. R. Wait.

Propagation over plane earth through an exponential atmosphere. I. H. Gerks and R. M. Anderson.

Propagation in nonuniform waveguides with impedance walls. R. L. Gallawa.

Some approximate formulas concerning the reflection of electromagnetic waves from a stratified semi-infinite medium. R. Burman.

A VLF timing experiment. A. H. Morgan and O. J. Baltzer.

Phase and time variations in VLF propagation over long distances. D. D. Crombie.

Geometrical optics convergence coefficient for whistler propagation. G. McK. Allcock.

Errors induced by the atmosphere in microwave range measurements. H. B. Janes and M. C. Thompson.

Some features of *Es*-ionization of the equatorial ionosphere. P. Bandyopadhyay and H. Montes.

A note on the insulated loop antenna immersed in a conducting medium. J. R. Wait and K. P. Spies.

Observation and analysis of transequatorial propagation. J. A. Thomas and B. A. McInnes.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 68D, No. 12 (Dec. 1964)

Experiment on the constancy of the velocity of electromagnetic radiation. P. Beckmann and P. Mandics.

Measurement of the phase velocity of VLF propagation in the earth-ionosphere waveguide. F. K. Steele and C. J. Chilton.

Wave hop theory of long distance propagation of low-frequency radio waves. L. A. Berry.

Wave propagation in a compressible ionosphere. Part I. S. R. Seshadri.
Wave propagation in a compressible ionosphere. Part II. S. R. Seshadri.
Spatial properties of the amplitude fading of continuous HF radio waves. J. Ames.
Physical properties of the polar winter mesosphere obtained from low-frequency propagation and partial reflection studies. J. S. Belrose, L. R. Bode, and L. W. Hewitt.
Reply to the "Remarks by Donald H. Menzel With Reference to Bailey's Comments on Solar Electric Fields." V. A. Bailey.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 1 (Jan. 1965)

Some problems of ionospheric nonlinearities. D. H. Menzel.
Some nonlinear phenomena in the ionosphere. V. A. Bailey.
An experimental study of gyro interaction in the ionosphere, at oblique incidence. F. H. Hibberd.
On some nonlinear phenomena in the ionospheric plasma. P. Caldirola and O. De Barbieri.
Ionospheric cross modulation: a microscopic theory. D. Layzer and D. H. Menzel.
VLF noise bands observed by the Alouette I satellite. J. S. Belrose and R. E. Barrington.
Excitation of optical radiation by high power density radio beams. L. R. Megill.
Alteration of the electron density of the lower ionosphere with ground-based transmitters. P. P. Lombardini.
Collision effects in hydromagneto-ionic theory. H. K. Sen and A. A. Wyller.
Electromagnetic wave reflection from an oscillating, collision-free magneto-ionic medium. O. E. H. Rydbeck.
Nonlinear propagation of electromagnetic waves in magnetoplasmas. II. (An invited abstract) M. S. Sodha and C. J. Palumbo.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 2 (Feb. 1965)

"Waves in Plasma" Papers

Electromagnetic wave penetration of reentry plasma sheaths. M. P. Bachynski.
On the use of refractive index diagrams for source-excited anisotropic regions. L. B. Felsen.
Surface waves along a perfectly conducting plane covered with semi-infinite magneto-plasma. S. Adachi and Y. Mushiake.
On the point of emergence of a microwave beam entering a linearly graded plasma. A. L. Cullen.
Self and mutual admittances of waveguides radiating into plasma layers. J. Galejs.

Effect of electron collisions on the formulas of magneto-ionic theory. K. G. Budden.

Momentum transfer collisions in oxygen for thermal electrons. M. H. Mentzoni.

Experimental studies of pertubations in ionospheric plasma. L. H. Heisler.

Electromagnetic scattering by gyrotropic cylinders with axial magnetic fields. W. C. Y. Lee, L. Peters, Jr., and C. H. Walter.

Radar cross sections of plasma bodies at the plasma frequency. L. Peters, Jr.

Electroacoustic waves excited by a space vehicle in ionized atmosphere and its effect on radar return. K-M. Chen.

Discussion on basic equations with source terms in compressive plasmas. K-M. Chen.

Scattering of electromagnetic and electroacoustic waves by a cylindrical object in a compressible plasma. J. R. Wait.

Regular Contributions

Multiphase periodic very-low-frequency emissions. N. Brice.

Radio studies of the high-latitude ionosphere during the solar eclipse of 20 July 1963. R. D. Hunsucker.

VLF and LF fields propagating near and into a rough sea. R. M. Lerner and J. Max.

Insulated and loaded loop antenna immersed in a conducting medium. R. H. Williams.

Capacitance of biconical antennas in magneto-ionic media; elliptic cone capacitance. V. P. Pyati and H. Weil.

Calculations of the bistatic scattering cross section of a sphere with an impedance boundary condition. J. R. Wait and C. M. Jackson.

Concept of differential reflectivity as applied to the reflection of beam-limited radiation by a convex body. A. Erteza, J. A. Doran, and D. H. Lenhert.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 3 (Mar. 1965)

"Waves in Plasma" Papers

Propagation in nonuniform gyrotropic media. S. H. Gross and L. B. Felsen.

Geometrical optics for gyrotropic bodies. W. C. Y. Lee, L. Peters, Jr., and C. H. Walter.

Attenuation of hydromagnetic waves in the ionosphere. S-I. Akasofu.

Self distortion of radio signals in the *D* region. L. R. Megill.

Atmosphere gravity waves: a new toy for the wave theorist. C. O. Hines.

Electromagnetic fluctuations in an equilibrium plasma. R. E. Burgess.

Hydromagnetic wave in an inhomogeneous, cylindrical plasma. C. K. McLane and T. Tsukishima.

Angular dependence of the refractive index in the ionosphere. G. A. Deschamps.

Electrodynamics of moving anisotropic media: the first-order theory. C. T. Tai.

Regular Contributions

Study of the phenomenon of whistler echoes. T. Laaspere, W. C. Johnson, and J. F. Walkup.

Multiple-frequency investigations of radio wave absorption during the dawn-breakup phase of auroras. R. Parthasarathy, and F. T. Berkey.

Sferic excitation of a two-layer conducting medium. M. B. Kraichman.

Currents, charges, and near fields of cylindrical antennas. R. W. P. King and T. T. Wu.

A note on the radiation conductance of an axial slot on a cylinder. C. M. Knop and C. T. Swift.

Analytical formulas for radio paths in spherically stratified ionospheres. E. Woyk (Chvojkova).

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 4 (Apr. 1965)

"Waves in Plasma" Papers

Dispersion of waves in a cold magneto-plasma from hydromagnetic to whistler frequencies. H. G. Booker and R. B. Dyce.

Study on the guiding mechanism of whistler radio waves. S. Adachi.

Electromagnetic waves along an infinitely long and thin conducting wire in a magneto-ionic medium. Y. Mushiake.

Use of the phase-integral method to determine the reflection properties of a stratified ionosphere. C. Altman.

E-mode propagation in a plane-stratified plasma. P. Hirsch and J. Shmoys.

Radiation from an infinite axial slot on a circular cylinder clad with magnetoplasma. P. de Marchin and G. Tyras.

Index of refraction surfaces for plasma waves. T. Yeh and M. H. Cohen.

Impedance of a short dipole in a compressible plasma. K. G. Balmain.

Waves circulating around a rigid cylindrical obstacle in a compressible plasma. J. R. Wait.

Wave propagation in a two component warm plasma. S. R. Seshadri.

Harmonic currents excited by an electromagnetic wave in a plasma. L. Wetzel and T. W. Tang.

Excitation of acoustic waves in plasmas. W. A. Saxon.

Wave interaction in oxygen magneto plasmas. K. V. N. Rao.

Regular Contributions

Test of the constancy of the velocity of electromagnetic radiation in high vacuum. P. Beckmann and P. Mandics.

Signal degeneration in laser beams propagated through a turbulent atmosphere. P. Beckmann.

High frequency backscatter from the earth measured at 1000 km altitude. R. C. Chia, A. K. Fung, and R. K. Moore.

Observation of NPG VLF transmissions at Tracy, California during path equinox. G. B. Carpenter and A. L. Whitson.

Small magnetic toroid antenna imbedded in a highly conducting half space. G. R. Swain.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 5 (May 1965)

"Waves in Plasma" Papers

On electromagnetic radiation from a magnetic diode with arbitrary orientation embedded in a lossless magneto-ionic medium. H. Motz.

A systematic study of the radiation patterns of a dipole in magnetoplasma based on a classification of the associated dispersion surfaces. R. Mittra and G. L. Duff.

Propagation of vertically polarized electromagnetic waves in a horizontally stratified magnetoplasma. R. Burman and R. N. Gould.

A note concerning the reflection of waves in inhomogeneous layers with asymmetric profiles. R. Burman.

On the terrestrial propagation of ELF and VLF waves in the presence of a radial magnetic field. J. Galejs.

Electron density profiles in cylindrical plasmas from microwave refraction data. B. A. Anicin.

A study of the waves supported by a warm plasma slab. P. R. Caron.

Transmission and reflection of electromagnetic waves by a hot plasma. E. C. Taylor.

Radiation from electrons in a magnetoplasma. H. B. Liemohn.

Radiation from a uniformly moving charge in an anisotropic, two component plasma. S. R. Seshadri and H. S. Tuan.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 6 (June 1965)

"Waves in Plasma" Papers

Preface to the fifth and final group of "Waves in Plasma" papers. J. R. Wait.

Cyclotron harmonic waves in warm plasmas. F. W. Crawford.

Propagation of waves across a magnetoplasma-vacuum boundary. R. L. Gallawa.

Phase velocities and attenuation distances in the ionosphere. D. R. Croley, Jr., and B. S. Tanenbaum.

Ionospheric effects of electrostatic fields generated in the outer magnetosphere. G. C. Reid.

An experimental study of plasma sheath effects on antennas. G. Tyras, P. C. Bargeliotes, J. M. Hamm, and R. R. Schell.

An approach to improve re-entry communications by suitable orientations of antenna and static magnetic field. S. N. Samaddar.

Concerning the mechanism of reflection of electromagnetic waves from an inhomogeneous lossy plasma. J. R. Wait.

Selection of Papers Presented at 1964 World Conference on Radio Meteorology Boulder, Colorado, September 14-18, 1964

Angels in focus. D. Atlas.

An investigation of clear air stratification with radar and elevated instruments. D. R. Hay and K. Naito.

On inferring the refractive-index structure of the troposphere from electromagnetic scattering experiments. P. L. Smith, Jr.

The biexponential nature of tropospheric gaseous absorption of radio waves. E. J. Dutton and B. R. Bean.

Complete scattering parameters of polydispersed hydrometeors in the $\lambda 0.1$ to $\lambda 10$ cm range. D. Deirmendjian.

Technical News Bulletin. This monthly publication summarizes the current research, development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; foreign, $2.25.)

Central Radio Propagation Laboratory Ionospheric Predictions: This is a monthly publication for those concerned with radio communication in determining the best skywave frequencies over any path at any time of day for average conditions for the month of prediction, which are made 3 months in advance. Charts of extraordinary-wave critical frequency for the *F*2 layer and of maximum usable frequency for a transmission distance of 4,000 km, of highest frequency of sporadic *E* in excess of 15 Mc/s are included. In addition, there are various maps, charts, diagrams, and monograms needed to make practical application of the world-contour charts, together with examples of their use. (Annual subscription: domestic, $2.50; foreign, $3.25.)

Monographs. These are usually contributions to the technical literature which are too lengthy for publication in the Journal of Research. They often provide extensive compilations of information on subjects related to the Bureau's technical program. Until July 1959 most of this type of material was published in the Circular series.

25. Standard X-ray diffraction powder patterns. Section 3. Data for 51 substances, H. E. Swanson, M. C. Morris, E. E. Evans, and L. Ulmer. July 31, 1964. 40 cents.

70. Vol. I. Microwave spectral tables. Diatomic molecules, P. F. Wacker, M. Mizushima, J. D. Peterson, and J. R. Ballard. Dec. 1, 1964. Supersedes in part C518. $2.00.

70. Vol. II. Microwave spectral tables. Line strengths of asymmetric rotors, P. F. Wacker and M. R. Pratto. December 15, 1964. Supersedes in part C518. $3.00.

71. Line parameters and computed spectra for water vapor bands at 2.7μ, D. M. Gates, R. F. Calfee, D. W. Hansen, and W. S. Benedict. August 3, 1964. $2.00.

76. An engineering method for calculating protection afforded by structures against fallout radiation, C. Eisenhauer. July 2, 1964. 20 cents.

77. Sound insulation of wall, floor, and door constructions, R. D. Berendt and G. E. Winzer. November 30, 1964. (Consolidated supplement to BMS 144 and supersedes supplements 1 and 2 of BMS 144.) 40 cents.

78. A complete mode sum for LF, VLF, ELF terrestrial radio wave fields, J. R. Johler and L. A. Berry. October 1, 1964. 20 cents.

79. On the statistical theory of electromagnetic waves in a fluctuating medium (II). Mathematical basis of the analogies to quantum field theory, K. Furutsu. December 7, 1964. 35 cents.

80. Ionospheric radio propagation, K. L. Davies. April 1, 1965. $2.75.

81. Tables of electron radial functions and tangents of phase shifts for light nuclei ($Z = 1$ through 10), C. P. Bhalla. August 6, 1964. $3.25.

83. Project FIST. Fault isolation by semi-automatic techniques, G. Shapiro, O. B. Laug, G. J. Rogers, and P. M. Fulcomer, Jr. September 17, 1964. 55 cents.

84. Standard cells their construction, maintenance, and characteristics, W. J. Hamer. January 15, 1965. 35 cents.

85. A study of lunar surface radio communication, L. E. Vogler. September 14, 1964. 70 cents.

86. Investigation of the hydraulics of horizontal drains in plumbing systems, R. S. Wyly. December 18, 1964. 35 cents.

89. Effects of thermal shrinkage on built-up roofing, W. C. Cullen. March 4, 1965. 10 cents.

90. Calibration of liquid-in-glass thermometers, J. F. Swindells. February 12, 1965. Supersedes Circular 600. 25 cents.

91. Automatic indexing: A state-of-the-art report, M. E. Stevens. March 30, 1965. $1.50.

Handbooks. These are recommended codes of engineering and industrial practices, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.

94. The examination of weighing equipment, M. W. Jensen and R. W. Smith. March 1, 1965. Supersedes Handbook 37. $3.00.
95. United States standard for the colors of signal lights, F. C. Breckenridge. August 21, 1964. 25 cents.
97. Shielding for high-energy electron accelator installations. July 1, 1964. 30 cents.
99. Examination of liquefied petroleum gas liquid-measuring devices, a manual for weights and measures officials, M. W. Jensen. April 23, 1965. 35 cents.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Reports will fall into eight categories: general; nuclear properties; atomic and molecular properties; solid state properties; thermodynamic and transport properties; chemical kinetics; colloid and surface properties; and mechanical properties of materials.

1. National Standard Reference Data System. Plan of operation, E. L. Brady and M. B. Wallenstein. December 30, 1964. 15 cents.
2. Thermal properties of aqueous uni-univalent electrolytes, V. B. Parker. April 1, 1965. 45 cents.
3. Section I. Selected tables of atomic spectra. Atomic energy levels and multiplet tables Si II, Si III, Si IV, C. E. Moore. June 25, 1965. 35 cents.

Miscellaneous Publications. As the name implies, this series includes material which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series.

236. (1965 Edition.) Standard frequency and time services of the National Bureau of Standards. January 15, 1965. 15 cents. (Supersedes the editions of December 1, 1960 and July 1, 1961).
256. Ellipsometry in the measurement of surfaces and thin films. Symposium proceedings Washington 1963, Ed. E. Passaglia, R. R. Stromberg, and J. Kruger. September 15, 1964. $2.25.
258. Foreign-language and English dictionaries in the physical sciences and engineering. A selected bibliography 1952 to 1963, T. W. Marton. July 24, 1964. $1.25.
260-2. Standard Reference Materials: Preparation of NBS copper-base spectrochemical standards, R. E. Michaelis, L. L. Wyman, and R. Flitsch. October 15, 1964. 35 cents.
260-3. Standard Reference Materials: Metallographic characterization of an NBS spectrometric low-alloy steel standard, R. E. Michaelis, H. Yakowitz, and G. A. Moore. October 22, 1964. 20 cents.
260-4. Standard Reference Materials: Sources of information, J. L. Hague, T. W. Mears, and R. E. Michaelis. February 1965. 20 cents.

260-5. Standard Reference Materials: Accuracy of solution x-ray spectrometric analysis of copper-base alloys, R. Alvarez and R. Flitsch. March 15, 1965. 25 cents.

261. Hydraulic research in the United States, 1964, H. K. Middleton. August 14, 1964. $1.25.

262-1. Legibility of alphanumeric characters and other symbols. I. A permuted title index and bibliography. D. Y. Cornog, F. C. Rose, and J. L. Walkowicz. December 15, 1964. 60 cents.

263. Report of the 49th National Conference on Weights and Measures 1964. February 1, 1965. $1.00.

264. Technical highlights of the National Bureau of Standards, Annual Report 1964. December 1964.

266. Computer literature bibliography 1946 to 1963, W. W. Youden. March 31, 1965. $3.75.

267. Systems engineering in ceramics. Proceedings of a symposium April 19, 1964. May 1, 1965. $2.00.

268. Electrical engineering units and constants. June 1965. 10 cents; $6.25 per 100.

Commercial Standards. Define quality levels for products in accordance with the principal needs of the trade. Their use is voluntary.

5-65. Pipe nipples: Brass, copper, steel, and wrought-iron. January 15, 1965. Supersedes CS5-46. 10 cents.

9-65. Builders' template hinges. January 15, 1965. Supersedes CS9-33. 10 cents.

163-64. Ponderosa pine windows, sash, and screens (using single glass and insulating glass). March 17, 1964. Supersedes CS163-59 and CS193-53. 15 cents.

190-64. Wood double-hung window units. March 17, 1964. Supersedes CS190-59. 10 cents.

204-64. Wood awning window units. March 17, 1964. Supersedes CS204-59. 10 cents.

205-64. Wood casement window units. March 17, 1964. Supersedes CS205-59. 10 cents.

227-59. Polyethylene film. June 1, 1963 (reprinted 1964 with amendments). 15 cents.

262-63. Water-repellent preservative non-pressure treatment for millwork. December 31, 1963. 10 cents.

263-63. Aluminum nails. November 1, 1964. 10 cents.

264-64. Wood horizontal-sliding window units (all sash operating). March 17, 1964. 10 cents.

265-64. Wood horizontal-sliding window units (one or more non-operating sash). March 17, 1964. 10 cents.

266-64. Wood single-hung window units. March 17, 1964. 10 cents.

267-65. Steel medicine cabinets. March 1, 1965. 10 cents.

268-65 Hide trim pattern for domestic cattlehides. April 4, 1965. 10 cents.

269-65. Aluminum alloy chain link fencing. March 1, 1965. 10 cents.

271-65. Grading of abrasive grain for grinding wheels. April 12, 1965. (Supersedes SPR118-50.) 10 cents.

Technical Note Series. This series was initiated in 1959 to supplement the Bureau's regular publications program. Technical Notes provide a means for making available scientific data that are of transient or limited interest.

18-18 Quarterly radio noise data March, April, May, 1963, W. Q. Crichlow, R. T. Disney and M. A. Jenkins. July 25, 1964. 50 cents.

18-19. Quarterly radio noise data June, July, August, 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. August 21, 1964. 50 cents.

18-20. Quarterly radio noise data September, October, November 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. October 23, 1964. 50 cents.

18-21. Quarterly radio noise data December, January, February, 1963-64, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. January 25, 1965. 50 cents.

40-11. Mean electron density variations of the quiet ionosphere, No. 11—January 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. August 30, 1963. 40 cents.

40-12. Mean electron density variations of the quiet ionosphere, No. 12—February 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. December 6, 1963. 35 cents.

40-13 (PB151399-13). Mean electron density variations of the quiet ionosphere, No. 13—summary of one year of data May 1959-April 1960, J. W. Wright. April 15, 1962. $1.50.

101. Vol. I. Transmission loss predictions for tropospheric communication circuits, P. L. Rice, A. G. Longley, K. A. Norton, and A. P. Barsis. May 7, 1965. $1.00.

101. Vol. II. Transmission loss predictions for tropospheric communication circuits, P. L. Rice, A. G. Longley, K. A. Norton, and A. P. Barsis. May 7, 1965. $1.00.

206-3. The normal phase variations of the 18 kc/s signals from NBA observed at Boulder, Colorado, U. S. A., A. H. Brady, A. C. Murphy, and D. D. Crombie. April 10, 1964. 25 cents.

218. The electrical properties of aluminum for cryogenic electromagnets, R. J. Corruccini. August 30, 1964. 30 cents.

219. Radio path length stability of ground-to-ground microwave links, M. C. Thompson, Jr., and H. B. Janes. November 15, 1964. 45 cents.

220. Some modifications in methods of calibration of universal ratio sets, D. Ramaley. August 30, 1964. 25 cents.

* This Technical Note is available by purchase from The Clearinghouse for Federal Scientific and Technical information, 5285 Port Royal Road, Springfield, Virginia, 22151. Order by PB number.

221. Demagnetizing factors for oblate spheroids used in ferrimagnetic resonance measurements, L. B. Schmidt, W. E. Case, and R. D. Harrington. September 4, 1964. 20 cents.

222. A minimum telemetry receiving system for the Alouette topside sounder satellite, E. E. Ferguson and R. G. Green. October 9, 1964, 30 cents.

223. Concerning the theory of radiation from a slotted conducting plane in a plasma environment, J. R. Wait. September 28, 1964. 20 cents.

224. Computation of a modified Fresnel integral arising in the theory of diffraction by a variable screen, L. C. Walters and J. R. Wait. October 14, 1964. 20 cents.

225. Optical scintillation; A survey of the literature, J. R. Meyer-Arendt and C. B. Emmanuel. April 5, 1965. 70 cents.

226. An atlas of VLF emission spectra observed with the "hiss recorder", J. A. Koch and V. C. Edens. November 13, 1964. 40 cents.

227. The Joule-Thomson process in cryogenic refrigeration systems, J. W. Dean and D. B. Mann. February 14, 1965.

228. A tabulation of Airy functions, H. T. Dougherty and M. E. Johnson. September 18, 1964. 20 cents.

229. Table of attenuation as a function of vane angle for rotary-vane attenuators ($A = -40_{10} \cos \theta$), W. Larson. January 7, 1965. $1.25.

230. VHF ionospheric scatter system loss measurements European-Mediterranean area, V. H. Goerke and O. D. Remmler. December 25, 1964. 40 cents.

232. Bibliography on the measurement of bulk resistivity of semiconductor materials for electron devices, J. C. French. October 31, 1964. 60 cents.

244. A helicopter battery service simulator, W. G. Eicke, Jr. August 28, 1964. 20 cents.

245. Factors influencing the design of original-document scanners for input to computers, prepared by E. S. Stein and Assoc. for RICASIP at NBS. August 19, 1964. 35 cents.

247. Survey of magnetic thin film materials, G. W. Reimherr. September 25, 1964. 40 cents.

248. Radiochemical analysis: Activation analysis, instrumentation, radiation techniques, and radioisotope techniques July 1963 to June 1964, Ed. J. R. DeVoe. August 21, 1964. 50 cents.

249. A program for plotting circles of constant overpressure around targeted points, M. L. Joel and D. D. Lottridge. October 28, 1964. 40 cents.

250. A nomogram for computing $\frac{a + jb}{c + jd}$ and a nonogram for computing $\left|\frac{a + jb}{c + jd}\right|$, H. S. Bowman. October 2, 1964.

251. Research on crystal growth and characterization at the National Bureau of Standards, January to June 1964, Ed. H. F. McMurdie. October 19, 1964. 45 cents.

252. Procedures for precise determination of thermal radiation properties, November 1962 to October 1963, J. C. Richmond, D. P. DeWitt, and W. D. Hayes, Jr. November 20, 1964. 40 cents.

253. Disclosures on various subjects: a plumbing vent manifold, a micro-adjuster, a glass joint or stopcock, and a miniature puller, Ed. D. Robbins. November 30, 1964. 10 cents.

254. One the pictorial structure of Chinese characters, B. K. Rankin, III, W. A. Sillars, and R. W. Hsu. January 4, 1965.

256. Microwave reflection techniques for dense plasma diagnostics, S. Takeda and T. Tsukishima. March 10, 1965. 25 cents.

257. Practical aspects of the use of AC-DC transfer instruments, E. S. Williams. March 9, 1965. 15 cents.

258. A prerequisite to the utility of microgrammars, W. C. Watt. April 19, 1965. 25 cents.

259. A FORTRAN program for determining an empirical expression for a quantity measured at combinations of several levels of each of two variables, M. N. Steel, F. L. McCrackin, and J. Mandel. April 12, 1965. 40 cents.

260. Research on crystal growth and characterization at the National Bureau of Standards July to December 1964, Ed. H. F. McMurdie. May 8, 1965. 50 cents.

261. Summary of current research on archival microfilm, C. S. McCamy and C. I. Pope. April 16, 1965. 25 cents.

300. Characteristics of the earth-ionosphere waveguide for VLF radio waves, J. R. Wait and K. P. Spies. December 30, 1964. 50 cents.

301. On the formulation and numerical evaluation of a set of two-phase flow equations modelling the cooldown process, S. Jarvis, Jr. January 4, 1965. 55 cents.

302. Bibliography of fading on microwave line of sight tropospheric propagation paths and associated subjects, H. T. Dougherty. August 31, 1964. 60 cents.

303. Extension of programs for calculations of great circle paths and sunrise-sunset times, J. H. Crary. February 18, 1965. 25 cents.

304. Bibliography on tropospheric propagation of radio waves, W. Nupen. April 1, 1965. $2.00.

305. Atlas of Fourier coefficients of diurnal variation of foF2. Part II. Distribution of amplitude and phase, W. B. Jones and R. M. Gallet. February 14, 1965. 60 cents.

306. Studies of solar flare effects and other ionospheric disturbances with a high frequency Doppler technique, V. Agy, D. M. Baker, and R. M. Jones. April 28, 1965. 75 cents.

307. Phase and amplitude diversity in over-water transmissions at two microwave frequencies, H. B. Janes, A. W. Kirkpatrick, D. M. Waters, and D. Smith. April 12, 1965. 40 cents.

308. Data reduction for stable auroral red arcs observed at Rapid City, South Dakota, J. E. Cruz, R. Davies, L. K. Droppleman, E. Marovich, L. R. Megill, M. H. Rees, L. Reisbeck, and F. E. Roach. May 3, 1965. 50 cents.

309. A bibliography of experimental saturation properties of the cryogenic fluids, N. A. Olien and L. A. Hall. April 9, 1965. 60 cents.

310. Attenuation of the ground wave of a low frequency electromagnetic pulse, J. C. Morgenstern and J. R. Johler. April 1965. 30 cents.

313. On the effect of heavy ions on LF propagation, with special reference to a nuclear environment, J. R. Johler and L. A. Berry. June 7, 1965. 45 cents.

314. Stability of two-phase annular flow in a vertical pipe, S. Jarvis, Jr. June 7, 1965. 55 cents.

PUBLICATIONS IN OUTSIDE JOURNALS

Chemistry

Ausloos, P., Gordon, R., Jr., Effects of electrical fields in the gamma radiolysis of propane, J. Chem. Phy. *41*, No. 5, 1278-1284 (Sept. 1, 1964).

Ausloos, P., Lias, S. G., Gas-phase radiolysis of n-pentane. A study of the decompositions of the parent ion and neutral excited pentane molecule, J. Chem. Phys. *41*, No. 12, 3962-3970 (Dec. 15, 1964).

Ausloos, P., Lias, S. G., Proton-transfer reactions between H_3^+ and saturated hydrocarbons, J. Chem. Phys. *40*, No. 12, 3599-3605 (June 15, 1964).

Ausloos, P., Rebbert, R. E., Photoelimination of ethylene from 2-pentanone, J. Am. Chem. Soc. *86*, No. 20, 4512 (Oct. 20, 1964).

Ausloos, P., Rebbert, R. E., Lias, S. G., Direct and inert-gas-sensitized radiolysis and photolysis of methane in the solid phase, J. Chem. Phys. *42*, No. 2, 540-548 (Jan. 15, 1965).

Bates, R. G., Acids and bases in alcohol-water solvents, Chem. Chem. Ind. (Japan) *18*, 680-685 (May 1965).

Bay, Z., McLernon, F. D., Absolute measurement of W for polonium-210 alpha particles in nitrogen, argon, and an argon-methane mixture, Radiation Res. *24*, No. 1, 1-8 (Jan. 1965).

Becker, D. A., Okabe, H., McNesby, Jr., Vacuum ultraviolet photochemistry. VIII. Propylene, J. Phys. Chem. *69*, No. 2, 538-542 (Feb. 1965).

Berger, H. W., Cadoff, B. C., The polarographic analysis of titanium (IV) —EDTA complexes, J. Paint Technol. Eng. Official Digest *37*, No. 480, 28-34 (Jan. 1965).

Berger, H. W., Cadoff, B. C., The polarographic analysis of white lead and zinc oxide in white paint pigments, J. Paint Technol. Eng. Official Digest *37*, No. 480, 35-42 (Jan. 1965).

Billick, I. H., On the effect of heterogeneity in molecular weight on the sedimentation equilibrium second virial coefficient of polymers in good solvents, J. Phys. Chem. *68*, No. 7, 1798-1800 (July 1964).

Block, S., Weir, C. E., Piermarini, G. J., High pressure single crystal studies of ice VI, Science *148*, 947 (1965).

Bosburgh, W. C., Bates, R. G., Constancy of a modified Weston standard cell over long periods, J. Electrochem. Soc. *111*, No. 8, 997-998 (Aug. 1964).

Bowen, R., The effect of particle shape and size distribution in a reinforced polymer, J. Am. Dental Assoc. *69*, No. 4, 481-495 (Oct. 1964).

Brady, E. L., Rossmassler, S. A., National standard reference data program, D. C. Libraries *35*, No. 4, 57-61 (Oct. 1964).

Brauer, G. M., Prolytic techniques, J. Polymer Sci. *8*, Pt. C, 3-26 (1965).

Brenner, A., Determination of the composition of complexes and their instability constant by calorimetry. I. The cuprocyanide complexes, J. Electrochem. Soc. *112*, No. 6, 611-621 (June 1965).

Brenner, M., Brenner, A., Method of obtaining a range of current densities with a resistive cathode, Plating *56*, No. 6, 527-530 (June 1965).

Brown, D. W., Fearn, J. E., Lowry, R. E., Radiation-induced polymerization and other reactions of n-perfluoropentadiene-1,4 at high temperature and pressure, J. Polymer Sci. *3*, Pt. 2, No. 4, 1641-1660 (Apr. 1965).

Brown, L. M., Darwent, B., Spectrophotometric determination of the rate of dissociation of tetrafluorohydrazine behind a shock wave, J. Chem. Phys. *42*, No. 6, 2158-2165 (Mar. 15, 1965).

Brown, R. L., Broida, H. P., Spectral study of active nitrogen flames exhibiting CN "tail" bands, J. Chem. Phys. *41*, No. 7, 2053-2060 (Oct. 1, 1964).

Carmichael, H. H., Gordon, R., Jr., Ausloos, P., Effect of electrical fields and density in the radiolysis of ethane, J. Chem. Phys. *42*, No. 1, 343-351 (Jan. 1, 1965).

Carpenter, F. G., Deitz, V. R., Larry, D., The role of carbon dioxide in the bone char process, Proc. 1963 Sugar Industry Technologist *22*, No. 2, 27-45 (Chemistry Institute, New York, N. Y., 1963).

Carrington, T., Angular momentum distribution and emission spectrum of OH ($^2\Sigma^+$) in the photodissociation of H_2O, J. Chem. Phys. *41*, No. 7, 2012-2018 (Oct. 1, 1964).

Chang, S. S., Bestul, A. B., Change in the heat capacity of boron trioxide during the glass transformation, J. Phys. Chem. *68*, No. 10, 3082 (Oct. 1964).

Currie, L. A., France, G. M., III, Mullen, P. A., Radiochemical determination of uranium of low activity, Health Phys. *10*, 751-755 (1964).

Currie, L. A., France, G. M., III, Steinberg, H. L., Radioisotope dilution and its application to the radioassay of Ce^{144}, Intern. J. Appl. Radiation Isotopes *16*, No. 1, 1-8 (Jan. 1965).

Curtis, A. J., Electrical properties, Book, Crystalline Olefin Polymers, ed. R. A. V. Raff, 2, 105-130 (Interscience Publ. Inc., New York, N. Y., 1964).

Deitz, V. R., Carpenter, F. G., Arnold, R. G., Interaction of carbon dioxide with carbon adsorbents below 400 °C, Carbon *1*, 245 (1964).

DeVoe, J. R., Discussion on the Mossbauer effect, (Proc. Intern. Atomic Energy Agency Symp. Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964), Book, Radiochemical Methods of Analysis I, 19-20 (Intern. Atomic Energy Agency, Vienna, Austria, 1965).

Diamond, J. J., The solubility of water vapor in molten alumina, (Proc. Conf. Arthur D. Little, Inc., Cambridge, Mass., Oct. 4-5, 1962), Book, Thermal Imaging Techniques, ed. P. E. Glaser and R. F. Walker, Chapt. 17, pp. 225-228 (Plenum Press Inc., New York, N. Y., 1964).

Dibeler, V. H., Krauss, M., Reese, R. M., Harllee, F. N., Mass spectrometric study of photoionization. III. Methane and methane-d_4, J. Chem. Phys. *42*, No. 11, 3791-3796 (June 1965).

Dibeler, V. H., Reese, R. M., Krauss, M., Mass spectrophotometric study of photoionization. II. H_2, HD, and D_2, J. Chem. Phys. *42*, No. 6, 2045-2048 (Mar. 15, 1965).

Doepker, R. D., Ausloos, P., Gas-phase photolysis of cyclohexane in the far ultraviolet: modes of decomposition of the neutral excited cyclohexane molecular and reactions of the parent cyclohexane ion, J. Chem. Phys. *42*, No. 11, 3746 (June 1, 1965).

Doepker, R. D., Ausloos, P., Gas-phase photolysis of methyl iodide. Reactions of hot methyl radicals with added organic compound, J. Chem. Phys. *41*, No. 6, 1865-1871 (Sept. 15, 1964).

Duecker, H. C., Lippincott, E. R., Pressure-induced trapping phonomenon in silver iodide, Science *146*, 1295-1297 (1964).

Eagles, D. M., Polaron coupling constants in $SrTiO_3$, J. Phys. Chem. Solids *26*, No. 3, 672 (Mar. 1965).

Eagles, D. M., Polar modes of lattice vibration and polaron coupling constants in rutile (TiO_2), J. Phys. Chem. *25*, No. 11, 1243-1251 (Nov. 1964).

Edmiston, C., Krauss, M., Configuration interaction in H_3 and H_2, J. Chem. Phys. *42*, No. 4, 1119 (Feb. 1965).

Farrar, T. C., Coyle, T. D., Proton and fluorine NMR spectra of HBF_2, J. Chem. Phys. *41*, No. 9, 2612-2613 (Nov. 1, 1964).

Finegold, H. R., NMR studies of asymmetric ethanic rotators: 1,2-disubstituted propanes, J. Chem. Phys. *41*, No. 6, 1808-1818 (Sept. 1964).

Gadsden, M., On the twilight sodium emission—1: Observations from a southern hemisphere station, Ann. Geophys. *20*, No. 3, 261-272 (1964).

Gadsden, M., On the twilight sodium emission—2: A theoretical model of sodium abundance, Ann. Geophys. *20*, No. 4, 383-396 (Oct.-Dec. 1964).

Gary, R., Bates, R. G., Robinson, R. A., Second dissociation constant of deuteriophosphoric acid in deuterium oxide from 5 to 50°. Standardization of a pD scale, J. Phys. Chem. *68*, No. 12, 3806-3809 (Dec. 1964).

Gates, D. M., Keegan, H. J., Schleter, J. C., Weidner, V. R., Spectral properties of plants, Appl. Opt. *4*, No. 1, 11-20 (Jan. 1965).

Gornick, F., Mandelkern, L., Diorio, A. F., Roberts, A. E., Evidence for a cooperative intramolecular transition in poly-L-proline, J. Am. Chem. Soc. *86*, No. 13, 2549-2555 (July 1964).

Graminski, E. L., The National Bureau of Standards, Capital Chem. *14*, No. 9, 278-281 (Dec. 1964).

Hall, L. H., The molecular symmetry of iodopentaborane, J. Am. Chem. Soc. Commun. to Editor *86*, No. 21, 4729 (Nov. 5, 1964).

Hamer, W. J., Presidental address before the Electrochemical Society Meeting, Toronto, Canada, May 5, 1964, J. Electrochem. Soc. *111*, No. 7, 145C-147C (July 1964).

Hampson, R. F., Jr., McNesby, J. R., Vacuum-ultraviolet photolysis of ethane at high temperature, J. Chem. Phys. *42*, No. 6, 2200-2208 (Mar. 15, 1965).

Herron, J. T., Rosenstock, H. M., Shields, W. R., Negative surface ionization of complex molecules, Nature *206*, No. 4984, 611 (May 1965).

Hoeve, C. A. J., DiMarzio, E. A., Peyser, P., Adsorption of polymer molecules at low surface coverage, J. Chem. Phys. *42*, No. 7, 2558-2563 (Apr. 1965).

Hoffman, J. D., Weeks, J. J., X-ray study of isothermal thickening of lamellae in bulk polyethylene at the crystallization temperature, J. Chem. Phys. Note *42*, No. 2, 4301 (June 15, 1965).

Hoover, T. B., Conductance of copper m-benzenedisulfonate hexahydrate in N-methlpropionamide from 20 to 40°, J. Phys. Chem. *68*, No. 10, 3003-3008 (Oct. 1964).

Horowitz, E., Tryon, M., Christensen, R. G., Thermogravimetric study of some new transition metal-Schiff base coordination polymers, J. Appl. Polymer Sci. *9*, 2321-2336 (1965).

Hughes, E. E., Mann, W. B., The half-life of carbon-14; comments on the mass-spectrometric method, (Proc. Radio-Carbon Dating Conf., Cambridge, Mass., 1962), Intern. J. Appl. Radiation Isotopes *15*, 97-100 (1964).

Inscoe, M. N., Photochemical changes in thin-layer chromatograms of polycyclic, aromatic hydrocarbons, Anal. Chem. *36*, No. 13, 2505-2506 (Dec. 1964).

Isbell, H. S., Determination of reducing end-groups by reaction with C^{14}-labeled cyanide, Book, Methods in Carbohydrate Chemistry, ed. R. L. Whistler, 5, 249-250 (Academic Press Inc., New York, N. Y., 1965).

Jacox, M. E., Milligan, D. E., Low-temperature infrared studies of the chemistry of free radicals, Appl. Opt. *3*, 873-876 (July 1964).

James, T. C., Rotation-vibration interaction and other corrections to the spin doublet separation in $^2\Pi$ diatomic molecules, J. Chem. Phys. *41*, No. 3, 631-641 (Aug. 1964).

James, T. C., Thibault, R. J., Infrared emission spectrum of HBr excited in an electric discharge. Determination of molecular constants, J. Chem. Phys. *42*, No. 4, 1450-1457 (Feb. 1965).

Jefferson, C. F., The constitution of $CuFe_5O_8$, J. Appl. Phys. *36*, No. 3, 1165-1166 (Mar. 1965).

Johnson, W. H., Sunner, S., The heats of solution and oxidation of sulfur dioxide, Acta Chem. Scand. *17*, 1917-1924 (1963).

Kanagy, J. R., The application of Archimedes' principle to determination of the apparent volume of leather, J. Am. Leather Chem. Assoc. *LIX*, No. 11, 636-649 (Nov. 1964).

Keller, R. A., Second order effects in the phosphorescence of benzophenone crystals at 77 °K, J. Chem. Phys. *42*, No. 11, 4050-4051 (June 1965).

Kelley, R. D., Klein, R., Scheer, M. D., Hydrogen atom addition to olefins: relative rates at the two carbon positions and derived heats of formation of several alkyl radicals, J. Phys. Chem. *69*, No. 3, 905-908 (Mar. 1965).

Klein, F. S., Herron, J. T., Mass spectrometric study of the reactions of O atoms with NO and NO_2, J. Chem. Phys. *41*, No. 5, 1285-1290 (Sept. 1, 1964).

Klein, R., Little, J. W., Carbon monoxide on niobium, Surface Sci. *2*, 167-176 (North-Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Klein, R., Scheer, M. D., Oxygen atoms reaction with condensed olefins, Science *144*, 1214 (1964).

Kline, G. M., Standardization of plastics in the U. S., Courrier de la Normalisation No. 182, pp. 280-282 (Mar.-Apr. 1965); Mod. Plastics *42*, No. 9, 176 (May 1965).

Kokoszka, G. F., Allen, H. C., Jr., Gordon, G., Electron paramagnetic resonance spectra of zinc-doped copper acetate monohydrate, J. Chem. Phys. *42*, No. 10, 3693-3697 (May 15, 1965).

Kokoszka, G. F., Allen, H. C., Jr., Gordon, G., Electron paramagnetic resonance spectrum of bis-8-hydroxyquinolate-copper (II) dihydrate, J. Chem. Phys. *42*, No. 10, 3730-3731 (May 15, 1965).

Kolthoff, I. M., Bruckenstein, S., Bates, R. G., Acid bases in analytical chemistry, Reprint from Kolthoff-Elving "Treatise on Analytical Chemistry", Pt. I, Sec. B, Chapt. 10, pp. 361-542 (Interscience Publ., New York, N. Y., 1965).

Kruger, J., Calvert, J. P., The oxide films formed on copper single crystal surfaces in water. III. Effect of light, J. Electro. Chem. Soc. *111*, No. 9, 1038-1041 (Sept. 1964).

Lafferty, W. J., Lide, D. R., Rotational constants of excited vibrational states of $^{14}N_2$ ^{16}O, J. Mol. Spectry. *14*, No. 4, 407-408 (Dec. 1964).

Lafferty, W. J., Maki, A. G., The structure of carbon suboxide, Chemistry *37*, No. 7, 19 (July 1964).

Lafferty, W. J., Thibault, R. J., High resolution infrared spectra of $C^{12}H_2$, $C^{12}C^{13}H_2$, and $C^{13}H_2$, J. Mol. Spectry. *14*, No. 1, 79-96 (Sept. 1964).

Landgrebe, A. R., McClendon, L. T., DeVoe, J. R., Substoichiometric radiometric analysis: determination of trace amounts of cobalt, (Proc. Intern. Atomic Energy Agency Symp. Radiochemical Methods of Analysis, Saltzburg, Austria, Oct. 19-23, 1964), Book, Radio Chemical Methods of Analysis II, 321-333 (Intern. Atomic Energy Agency, Vienna, Austria, 1965).

Larsen, S. Y., Mountain, R. D., Zwanzig, R., On the validity of the Lorentz-Lorenz equation near the critical point, J. Chem. Phys. *42*, No. 6, 2187-2190 (Mar. 15, 1965).

Laufer, A. H., McNesby, J. R., Photolysis of ethane at the argon resonance lines 1067 and 1048A, J. Chem. Phys. 42, No. 9, 3329-3330 (May 1, 1965).

Lide, D. R., High temperature microwave spectroscopy: Alf and AlCl, J. Chem. Phys. *42*, No. 3, 1013-1018 (Feb. 1965).

Lide, D. R., Microwave spectroscopy, Ann. Rev. Phys. Chem. *15*, 225-250 (1964).

Lide, D. R. Mann, D. E., Comeford, J. J., The vibrational assignment of sulfuryl fluoride, Spectrochim. Acta *21*, 497-501 (1965).

Linevsky, M. J., White, D., Mann, D. E., Infrared spectrum and structure of gaseous Al_2O, J. Chem. Phys. *41*, No. 2, 542-545 (July 15, 1964).

Linnig, F. J., Parks, E. J., Wood, L. A., Ethylene-propylene copolymers: crystallinity, infrared, and creep studies, J. Appl. Polymer Sci. *8*, 2645-2651 (Nov. 1964).

McDonald, E. J., Complexes of diols with cuprammonium reagent, J. Org. Chem. *25*, 111 (1960).

McDonnell, P. M., Pasternack, R. F., A line-formula notation system for coordination compounds, J. Chem. Doc. *5*, No. 1, 56-60 (Feb. 1965).

McIntyre, D., Gornick, F., Editors, Book, Light Scattering from Dilute Polymers Solutions, International Science Review Series 3 (Gordon and Breach, New York, N. Y., July 1964).

McKinley, J. D., Mass spectrometric investigation of the yttrium-chlorine surface reaction, J. Chem. Phys. *41*, No. 9, 2814-2817 (Nov. 1, 1964).

McKinley, J. D., The mass spectrum of yttrium chloride vapor, J. Chem. Phys. *42*, No. 6, 2245-2246 (Mar. 15, 1965).

McNesby, J. R., Okabe, H., Vacuum ultraviolet photochemistry, Book, Advances in Photochemistry, ed. W. A. Noyes, Jr., G. S. Hammond, and J. N. Pitts, Jr., 3, 157-240 (Interscience Publ. Inc., New York, N. Y., 1964).

McPherson, A. T., Food for tomorrow's billions, Proc. Forum "Food in the Future: Concepts for Planning", Chicago, Ill., Oct. 8-9, 1964, pp. 51-73 (Dairy and Food Industries Supply Assoc., 1964).

MacGregor, J., Brown, W. E., Blood: bone equilibrium in calcium homeostasis, Nature *205*, No. 4969, 359-361 (Jan. 1965).

Madey, T. E., Yates, J. T., Jr., Stern, R. C., Isotopic mixing in CO chemisorbed on tungsten, J. Chem. Phys. *42*, No. 4, 1372-1378 (Feb. 1965).

Maki, A. G., Plyler, E. K., Thibault, R., Vibration-rotation bands of deuterium cyanide and hydrogen cyanide, J. Opt. Soc. Am. *54*, No. 7, 869-876 (July 1964).

Mancewicz, S. A., Hoerman, K. C., Characteristics of insoluble protein of tooth and bone—I, Fluorescence of some acidic hydrolytic fragments, Arch. Oral Biol. *9*, 535-544 (Oct. 1964).

Mandel, J., Kanagy, J. R., Sampling of leather for physical and chemical examination, Book, The Chemistry and Technology of Leather *4*, chapt. 59, 223-242 (Reinhold Publ. Corp., New York, N. Y., 1965).

Mann, D. E., Comeford, J. J., Formation of NF and NF_2 by photolysis, Spectrochim. Acta *21*, 197-198 (1965).

Marden, E. C., Koller, H. R., Present status of project HAYSTAQ, (Proc. 3d Annual Meeting Comm. Intern. Cooperation and Information Retrieval Among Examining Patent Offices, Vienna, Austria, Sept. 17-26, 1963), Book, Information Retrieval Among Examining Patent Offices, ed. H. Pfeffer, pp. 163 (Spartan Books Inc., Baltimore, Md., 1964).

Martin, K. G., Influence of radiant energy source on bitumen oxidation J. Appl. Chem. (London) *14*, No. 11, 514-524 (Nov. 1964).

Meinke, W. W., Radiochemical methods of analysis (report on Salzburg conference), Science *147*, No. 3654, 182-183 (Jan. 1965).

Meinke, W. W., The place of radiochemical methods of analysis: today and tomorrow, (Proc. Intern. Atomic Energy Agency Symp. Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964), Book, Radiochemical Methods of Analysis I, 13-19 (Intern. Atomic Energy Agency, Vienna, Austria, 1965).

Metzger, W. H., Jr., Sherfey, J. M., Electrochemical calorimetry. III. Thermal effects of nickel-cadmium batteries, Electrochem. Technol. *2*, No. 9-10, 285-289 (Sept.-Oct. 1964).

Milligan, D. E., Jacox, M. E., Infrared spectrum of HCO, J. Chem. Phys. *41*, 3032-3036 (Nov. 1964).

Milligan, D. E., Jacox, M. E., Infrared studies of the photolysis of HN_3 in inert and reactive matrices. The infrared spectrum of NH, J. Chem. Phys. *41*, No. 9, 2838-2841 (Nov. 1964).

Milligan, D. E., Jacox, M. E., McKinley, J. D., Spectra of matrix isolated Nif_2 and $NiCl_2$, J. Chem. Phys. *42*, No. 3, 902-905 (Feb. 1965).

Milligan, D. E., Mann, D. E., Jacox, M. E., Infrared spectrum of CF_2, J. Chem. Phys. *41*, No. 5, 1199-1203 (Sept. 1, 1964).

Murphy, T. J., Taylor, J. K., Precise assay of copper using small samples, Anal. Chem. *37*, No. 7, 929-931 (June 1965).

Myers, A. L., Prausnitz, J. M., Thermodynamics of solid carbon dioxide solubility in liquid solvents at low temperatures, Ind. Eng. Chem. *4*, No. 2, 209-212 (May 1965).

Ogburn, F., Growth twins and branching of electrodeposited copper dendrites, J. Electrochem. Soc. *111*, No. 7, 870-872 (July 1964).

Ogburn, F., Bechtoldt, C., Morris, J. B., DeKoranyi, A., Structure of electrodeposited lead dendrites, J. Electrochem. Soc. *112*, No. 6, 574-577 (June 1965).

Ondik, H. M., The structure of the triclinic form of sodium tetrametaphosphate tetrahydrate, Acta Cryst. *17*, No. 9, 1139-1145 (Sept. 1964).

Ondik, H. M., The structures of anhydrous sodium trimetaphosphate $Na_3P_3O_9$, and the monohydrate, $Na_3P_3O_9 \cdot H_2O$, Acta Cryst. *18*, Pt. 2, 226-232 (Feb, 1965).

Ong, K. C., Robinson, R. A., Bates, R. G., Interpretation of potentiometric titrations of weak acids in methanol-water solvents, Anal. Chem. *36*, No. 10, 1971-1972 (Sept. 1964).

Otto, E. M., Equilibrium pressures of oxygen over MnO_2-Mn_2O_3 at various temperatures, J. Electrochem. Soc. *112*, No. 4, 367-370 (Apr. 1965).

Paabo, M., Bates, R. G., Robinson, R. A., Standardization of analytical data obtained with the silver-silver chloride electrode in methanol water solvents, Anal. Chem. *37*, No. 4, 462-464 (Apr. 1965).

Paabo, M., Robinson, R. A., Bates, R. G., Reference buffer solutions for pH measurements in 50% methanol. Dissociation constants of acetic acid and dihydrogen phosphate ion from 10 to 40°, J. Am. Chem. Soc. *87*, No. 3, 415-418 (Feb. 1965).

Paabo, M., Robinson, R. A., Bates, R. G., Standard electromotive force of the hydrogen-silver chloride cell and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 °C, J. Chem. Eng. Data *9*, No. 3, 374-376 (July 1964).

Pasternack, R. F., McDonnell, P. M., Designation of Ligand positions in inorganic complexes, Inorg. Chem. *4*, No. 4, 600-602 (Apr. 1965).

Piermarini, G. J., High-pressure x-ray diffraction studies, Proc. 13th Chemical Engineering Conf., Montreal, Canada, Oct. 19-23, 1963, pp. 182-185 (Chemical Institute of Canada, 1963).

Pirog, J. A., McNesby, J. R., Vacuum-ultraviolet photolysis of ethane in liquid-nitrogen solution, J. Chem. Phys. *42*, No. 7, 2490-2494 (Apr. 1, 1965).

Porter, T. L., Mann, D. E., Acquista, N., Emission spectrum of CF, J. Mol. Spectry. *16*, 228 (June 1965).

Powell, F. X., Lide, D. R., Improved measurement of the electric dipole moment of the hydroxyl radical, J. Chem. Phys. *42*, No. 12, 4201-4202 (June 1965).

Powell, F. X., Lide, D. R., Microwave spectrum of the SO radical, J. Chem. Phys. *41*, No. 5, 1413-1419 (Sept. 1964).

Rebbert, R. E., Ausloos, P., Quenching of the triplet state of acetone and biacetyl by azoalkanes, J. Am. Chem. Soc. *87*, 1847-1852 (May 5, 1965).

Rebbert, R. E., Ausloos, P., Triplet-state energy transfer from acetone to aliphatic aldehydes in the gas phase, P. Am. Chem. Soc. *86*, No. 22, 4803-4807 (Nov. 1964).

Reid, W. E., Kruger, J., Optical investigations of film formation and removal on gold anodes in acidic oxalate solutions, Nature *203*, No. 4943, 402-403 (July 25, 1964).

Reimann, C., Gordon, C., Some new co-ordination compounds of copper (II) chloride, Nature *205*, No. 4974, 902-903 (Feb. 27, 1965).

Robinson, R. A., Bower, V. E., Osmotic and activity coefficients of tris (hydroxymethyl) aminomethane and tis hydrochloride in aqueous solution at 25 °C, J. Chem. Engr. Data *10*, No. 3, 246-247 (1965).

Rosholt, J. N., Butler, A. P., Garner, E. L., Shields, W. R., Isotopic fractionation of uranium related to roll features in Sandstone, Power River Basin, Wyoming and Colorado Plateau, Econ. Geology *60*, No. 2, 199-213 (Mar.-Apr. 1965).

Rosholt, J. N., Harshman, E. N., Shields, W. R., Garner, E. L., Isotopic Fractionation of uranium related to roll features in Sandstone, Shirley Basin, Wyoming, Econ. Geology *59*, 570-585 (1964).

Roth, R. S., Phase equilibria studies in mixed systems of rare earth and other oxides, Book, Progress in Science and Technology of the Rare Earths, ed. L. Ewring, 1, 167-202 (Pergamon Press Inc., New York, N. Y., 1964).

Ruff, A. W., Jr., Morphology of thermally evaporated zinc cleavage surfaces, J. Chem. Phys. *41*, No. 5, 1204-1213 (Sept. 1, 1964).

Scheer, M. D., Fine, J., The kinetics of positive ion desorption from polycrystalline tungsten and rhenium, (Proc. Intern. Symp. Condensation and evaporation of solids, Dayton, Ohio, Sept. 12-14, 1962), Book, Condensation and Evaporation of solids, ed. E. Rutner, P. Goldfinger, and J. P. Huth, Paper 20, pp. 327 (Gordon and Breach, New York, N. Y., 1963).

Scheer, M. D., Jackson, W. M., Xenon photosensitized formation of metastable nitrogen, Science *148*, 3678 (1965).

Scheer, M. D., Klein, R., Oxygen atom reactions with condensed olefins, Science *144*, No. 3623, 1214 (June 1964).

Schmidt, A. F., Recommended materials and practices for use with cryogenic propellants, AIR 839, 29 pages (SAE, Inc., New York, N. Y., Jan. 1965).

Schoen, L. J., Mann, D. E., Flash-photolysis spectroscopy of matrices, J. Chem. Phys. *41*, No. 5, 1514 (Sept. 1964).

Schwebel, A., The determination of beta-emitting radionuclides in aqueous formamide solutions, Proc. Bioassay and Analytical Chemistry Meeting,

Argonne Natl. Lab., Argonne, Ill., Oct. 1962, ANL Publ. 6637, pp. 29 (1962).

Scribner, B. F., Margoshes, M., Emission spectroscopy, Treatise on Analytical Chemistry, ed. I. M. Kolthoff and P. J. Elving, 6, Pt. 1, chapt. 64, 3347-3461 (Interscience Publ. Inc., New York, N. Y., 1965).

Sharnoff, M., Electron paramagnetic resonance and the primarily 3d wavefunctions of the tetrachlorocuprate ion, J. Chem. Phys. *42*, No. 10, 3383-3395 (1965).

Sharnoff, M., Electron paramagnetic resonance of tetrahedrally coordinated copper^{++}: the tetrachlorocuprate ion, J. Chem. Phys. *41*, No. 7, 2203-2204 (Oct. 1964).

Sharp, T. E., Rosenstock, H. M., Franck-Condon factors for polyatomic molecules, J. Chem. Phys. *41*, No. 11, 3453 (Dec. 1, 1964).

Shields, W. R., Goldich, S. S., Garner, E. L., Murphy, T. J., Natural variation of copper isotopes and the atomic weight of copper, J. Geophys. Res. *70*, No. 2, 479-491 (Jan. 1965).

Shimanouchi, T., Suzuki, I., Method of adjusting force constants and its application to H_2O, H_2CO, CH_2Cl, and their deuterated molecules, J. Chem. Phys. *42*, No. 1, 296-308 (Jan. 1, 1965).

Shuler, K. E., Carrington, T., Light, J., Nonequilibrium chemical excitation and chemical pumping of lasers, Appl. Opt. Suppl. 2. Chemical Lasers, pp. 81-104 (1965).

Smith, D. K., Majumdar, A., Ordway, F., Crystal structure of gamma-dicalcium silicate, Acta Cryst. *18*, 787 (Apr. 1965).

Stern, K. H., Reid, W. E., Jr., Electrode potentials in fused systems. VIII. Oxidation kinetics of silver in sodium chloride, J. Phys. Chem. *68*, No. 12, 3757-3764 (Dec. 1964).

Stern, K. H., Stiff, J. A., Electrode potentials in fused systems. VII. Effect of ion size on membrane potentials, J. Electrochem. Soc. *111*, No. 8, 893-897 (Aug. 1964).

Taylor, J. K., Marinenko, G., High-precision coulometric titrations with special reference to the determination of uranium, (Proc. Conf. High-Precision Analysis of Substances of Interest to Nuclear Energy, Jan. 18-22, 1965), Euratom, Bureau Central de Mesures Nuclaires, pp. 147-161 (Brussels, Belgium, 1965).

Torgesen, J. L., Jackson, R. W., Growth layers on ammonium dihydrogen phosphate, Science *148*, No. 3672, 952-954 (May 14, 1965).

Torgesen, J. L., Strassburger, J., Growth of oxalic acid single crystals from solution: solvent effect on crystal habit, Science *146*, No. 3640 53-55 (1964).

Tsang, W., Decyclization of cyclohexene, 4-methylcyclohexene, and 4-vinylcyclohexene in a single-pulse shock tube, J. Chem. Phys. *42*, No. 5, 1805-1809 (Mar. 1, 1965).

Tsang, W., Thermal decomposition of some alkyl halides by a shock-tube J. Chem. Phys. *41*, No. 8, 2487-2494 (Oct. 15, 1964).

Van Brunt, R. J., Wacks, M. E., Electron impact studies of aromatic hydrocarbons. III. Anzulene and naphthalene, J. Chem. Phys. *41*, No. 10, 3195-3199 (Nov. 15, 1964).

Wacks, M. E., Electron impact studies of aromatic hydrocarbons. II. Naphthacene, naphthaphene, chrysene, triphenylene, and pyrene, J. Chem. Phys. *41*, No. 6, 1661-1666 (Sept. 1964).

Wacks, M. E., Mass spectrometric study of the production of methylamine from azomethane, J. Phys. Chem. *68*, No. 9, 2725-2726 (Sept. 1964).

Walker, R. F., High Temperature measurements and standards: 1000-3000°C, (Proc. Intern. Symp. High temperature technology, International Union of Pure and Applied Chemistry, Asilomar, Pacific Grove, Calif., Sept. 1963), Book, High Temperature Technology, Suppl. to Pure and Applied Chem., pp. 7 (Butterworths Inc., Washington, D. C., 1964).

Wall, L. A., Ingalls, R. B., Reaction of deuterated polystyrenes with hydrogen and deuterium atoms, J. Chem. Phys. *41*, No. 4, 1112-1120 (Aug. 1964).

West, E. D., Ishirhara, S., A calorimetric determination of the enthalpy of graphite from 1200 to 2600°K, (Proc. 3d Symp. Thermal Physical Properties, Purdue Univ., Lafayette, Ind., Mar. 22-26, 1965), Book, Advances in Thermophysical Properties at Extreme Temperatures and Pressures, pp. 146-151 (American Society of Mechanical Engineers, New York, N. Y., 1965).

Wolford, R. K., Kinetics of the acid-catalyzed hydrolysis of acetal in dimethyl sulfoxide-water solvents at 15, 25, and 35°, J. Phys. Chem. *68*, No. 11, 3392-3398 (1964).

Wolock, I., Newman, S.B., Fracture processes in polymeric solids. Book, Fracture Processes in Polymeric Solids. Phenomena and Theory, ed. B. Rosen, chapt. IIC, pp. 235-290 (Interscience Publ. Inc., New York, N. Y., Jan. 1965)

Wright, J. R., Weathering: theoretical and practical aspects of asphalts, Book, Bituminous Materials: Asphalts, Tars, and Pitches, ed. A. J. Hoiberg, Vol. *2*. Asphalts, Pt. 1, Chapt. 8, pp. 249-306 (John Wiley and Sons, New York, N. Y., 1965).

Wright, J. R., Campbell, P. G., Oxidation of asphalt in the presence of ozone, Am. Chem. Soc. Div. Petroleum Chem. Preprint *9*, No. 2, B99 (Apr. 1964).

Wright, J. R., Campbell, P. G., Photooxidation of asphalts in the presence of ozone, Am. Chem. Soc. Div. Petroleum Chem. Preprint *9*, No. 3, 161-174 (Aug. 1964).

Yamamoto, N., Hiatt, C. W., Haller, W., Mechanism of inactivation of bacteriophages by metals, Biochim. Biophys. Acta *91*, 257-261 (1964).

Yoshida, T., Florin, R. E., Wall, L. A., Stress relaxation of γ-irradiated fluorocarbon elastomers, J. Polymer Sci. *A3*, No. 5, 1685-1712 (May 1965).

Yu, H., Wall, L. A., Radilytic stress relaxation of an ethylene-propylene copolymer, J. Phys. Chem. *69*, 2072-2078 (June 1965).

Engineering and Instrumentation

Abramowitz, S., Bass, A. M., Ledford, A. E., Jr., Application of cooled IR detector in an optical system, Appl. Opt. *4*, 255 (Feb. 1965).

Achenbach, P. R., A survey of reesarch on frozen food transport refrigeration, ASHRAE J. *6*, No. 11, 29-36 (Nov. 1964).

Akima, H., On the optimum frequency deviation in an FM system over a scatter-propagation path, Proc. IEEE *53*, No. 2, 182-183 (Feb. 1965).

Alexander, S. N., Doyle, P. E., Computer control of precision instrument inventory, Research/Develop. pp. 38-43 (May 1965).

Allred, C. M., Lawton, R. A., Precision detector for complex insertion ratio measuring systems, IEEE Trans. Instr. Meas. *IM-13*, No. 2 & 3, 76-81 (June-Sept. 1964).

Bagg, T. C., The rapid selector as currently used for information search and replica copy retrieval, (Proc. 26th Annual Meeting American Documentation Institute, Chicago, Ill., Oct. 1963), Automation and Scientific Commun. Pt. 2, 227-228 (Oct. 1963).

Bandy, W. C., Current programs in the U. S. Department of Commerce for advancing state science and technology, Mid-Continent Research and Development Council, Report Proc. 11th Annual Meeting, Denver, Colo., Oct. 19-20, 1964, pp. 70-76 (1965).

Bates, A. A., Composites in construction, Stanton Walker Lecture Series on the Materials Sciences, Nov. 20, 1963, Lecture No. *1*, p. 15 (University of Maryland, College Park, Md., 1964).

Bean, B. R., McGavin, R. E., The use of the radio refractometer to measure water vapor turbulence, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *2*. Applications, Sec. VII, Paper 67, pp. 561-568 (Reinhold Publ. Corp., New York, N. Y., 1965).

Beatty, R. W., A two-channel nulling method for measuring attenuation constants of short sections of waveguide and the losses in waveguide joints, Proc. IEEE *53*, No. 6, 642-643 (June 1965).

Beatty, R. W., An automatic method for obtaining data in the Weissflock-Feenberg node-shift technique, Proc. IEEE *53*, No. 1, 79-80 (Jan. 1965).

Beatty, R. W., Effects of connectors and adapters on accurate attenuation measurements at microwave frequencies, IEEE Trans. Instr. Meas. *IM-13*, No. 4, 272-284 (Dec. 1964).

Beatty, R. W., Measuring impedance through an adapter without introducing additional error, Proc. IEEE *53*, No. 6, 656-657 (June 1965).

Beatty, R. W., Radio standards and measurements, microwaves, a progress review from 1960, Book, Progress in Radio Science, 1960-1963. Vol. *I*.

Radio Standards and Measurements, pp. 71-81 (Elsevier Publ. Co., Amsterdam, The Netherlands, 1965).

Beehler, R. E., Mockler, R. C., A comparison of atomic frequency standards, Book, Progress in Radio Science. 1960-1963, Vol. *I*. Radio Standards and Measurements, pp. 20-26 (Elsevier Publ. Co., Amsterdam, The Netherlands, 1965).

Beers, Y., New mode of operation of a phase sensitive detector, Rev. Sci. Instr. *36*, No. 5. 696-700 (May 1965).

Bennett, J. A., The effect of a fatigue crack on the fatigue strength of an aluminum alloy, Mater. Res. Std. *5*, No. 5, 235-239 (May 1965).

Bjorklund, W. R., Nonspattering solder flux, Rev. Sci. Instr. *35*, No. 10, 1369-1370 (Oct. 1964).

Bloss, R. L., Strain gage research at the National Bureau of Standards, (ISA 18th Annual Conference and Exhibit. Chicago, Ill., Sept. 9-12, 1963), ISA Preprint 48.4.63 (1963).

Brauer, G. M., Plastics and the dental market, Plastics World *22*, No. 10, 12 (Oct. 1964).

Brodd, R. J., DeWane, H. J. Impedance of sealed nickel-cadmium dry cells, J. Electrochem. Technol. *3*, No. 1-2, 12-17 (Jan.-Feb. 1965).

Bryson, J. O., Skoda, L. F., Walstein, D., Flexural behavior of prestressed split-beam composite concrete sections, J. Prestressed Concrete Inst. *10*, No. 3, 77-91 (June 1965).

Burdick, M. D., Standard test for determining alkali resistance of porcelain enamels, Proc. Porcelain Enamel Inst. Forum *26*, 227-236 (Oct. 14-16, 1964).

Campbell, P. G., Wright, J. R., Oxidation of asphalt flux with oxides of nitrogen, Am. Chem. Soc. Div. Petroleum Chem. Preprint *10*, No. 1, 79-89 (Mar. 1965); Ind. Eng. Chem. Product Res. Develop. 4, No. 2, 121-128 (June 1965).

Campbell, P. G., Wright, J. R., Ozonation of asphalt flux, Am. Chem. Soc. Div. Petroleum Chem. Preprint *9*, No. 3, 147-160 (Aug. 1964); Ind. Eng. Chem. Product Res. Develop. 3, No. 3, 186-194 (Sept. 1964).

Candela, G. A., Mundy, R. E., Technique for spin-lattice relaxation times, Rev. Sci. Instr. *36*, No. 3, 338-342 (Mar. 1965).

Carter, T. J., Comparisons of tearing-strength for leather. J. Am. Leather Chem. Assoc. *LX*, No. 1, 4-14 (Jan. 1965).

Caul, H. J., Crowell, W. E., Kimmel, W. D., Paffenbarger, G. C., Early strength, flow and dimensional changes obtained on amalgam prepared with a standardized mechanical technic, J. Am. Dental Assoc. *69*, No. 6, 742-748 (Dec. 1964).

Cezairliyan, A., A high-speed (milliseconds) method for the simultaneous measurement of enthalpy, specific heat, and resistivity of electrical conductors at high temperatures, (Proc. 3d Symp. Thermophysical Properties, Purdue Univ., Lafayette, Ind., Mar. 22-25, 1965), Book, Advances in Thermophysical Properties at Extreme Temperatures and Pressures,

pp. 253-263 (American Society of Mechanical Engineers, New York, N. Y., Mar. 1965).

Cezairliyan, A., Touloukian, Y. S., Correlation and prediction of thermal conductivity of metals through the application of the principle of corresponding states, (Proc. 3d Symp. Thermophysical Properties, Purdue Univ., Lafayette, Ind., Mar. 22-25, 1965), Book, Advances in Thermophysical Properties at Extreme Temperatures and Pressures, pp. 301-313 (American Society of Mechanical Engineers, New York, N. Y., Mar. 1965).

Chelton, D. B., Safety in the use of liquid hydrogen, Book, Technology and Uses of Liquid Hydrogen, pp. 359-378 (Pergamon Press Inc., New York, N. Y., 1964).

Civijan, S., Brauer, G. M., Clinical behavior of *o*-ethoxybenzoic acid-eugenol-zinc oxide cements, J. Dental Res. *44*, No. 1, 80-83 (Jan.-Feb. 1965).

Clark, H. E., Moore, D. G., Method and equipment for measuring thermal emittance of ceramic oxides from 1200° to 1800°. (Symp. Thermal Radiation of Soils, San Francisco, Calif., Mar. 4-5, 1964), NASA Spec. Publ. SP-55, Session III, Paper 26, pp. 241-257 (1965).

Cones, H. N., Discussion of paper 63-39 I, "The measurement of short duration impulse voltages, IEEE Trans. Commun. Elec. *EC-69*, 629 (Nov. 1963).

Corliss, E. L. R., A mechanistic model for the limits of auditory preception, Proc. Symp. Models for the Preception of Speech and Visual Form, Boston, Mass., Nov. 11-14, 1964 (Air Force Research Center, Cambridge, Mass., 1964).

Cross, J. R., Comments on the paper "A liquid-medium step-function pressure calibrator," by R. O. Smith, Am. Soc. Mech. Eng. Series *D*. No. 86, pp. 729 (1964).

Davis, J. C., Achenbach, P. R., An investigation of psychrometric measurement techniques in air conditioning calorimetry, (Proc. 1963 Intern. Symp. Humidity and Moisture, Wash., D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *2*. Applications, Sec. IV, Paper 37, pp. 303-313 (Reinhold Publ. Corp., New York, N. Y., 1965).

DeWit, R., Displacement of dislocation images formed in transmission electron microscopy, J. Appl. Phys. *36*, No. 1, 329-330 (Jan. 1965).

DeWitt, D. P., Comments on the surface characterization of real metals, (Symp. Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-5, 1964), NASA Spec. Publ. SP-55, Session II, Paper 12, pp. 141-144 (1965).

Dickson, G., Waterstrat, R. M., Dimensional changes of dental amalgam associated with strain release in the silver alloy particles, J. Dental Res. Annotation), *44*, No. 3, 620 (May-June 1965).

Dise, J. R., The cement and concrete reference laboratory inspection service for concrete testing laboratories, Concrete Construction. *9*, No. 8, 234 (Aug. 1964).

Eberhard, J. P., Changes in living, Proc. Conf. Environment of Change, Sterling Forest, Tuxedo, N. Y., June 14, 17, 1964, pp. 62-67 (1964).

Eberhard, J. P., Research for architecture, Res. News *II*, No. 1, 10-19 (Jan. (1965).

Eckert, C. A., Prausnitz, J. M., Statistical surface thermodynamics of simple liquid mistures, A.I.Ch.E. J. *10*, No. 5, 677-683 (Sept. 1964).

Ehrlich, M., Characteristics of dosimeter films processed in phenidone-thiosulfate monobaths, J. Phot. Sci. Eng. *9*, No. 1, 1-9 (Jan.-Feb. 1965).

Ellerbruch, D. A., Analysis of a differential phase shifter, IEEE Trans. Microwave Theory Tech. *MTT-12*, No. 4, 453-459 (July 1964).

Engen, G. F., A DC-RF substitution error in dual element bolometer mounts, IEEE Trans. Instr. Meas. *IM-13*, No. 2 & 3, 58-64 (June-Sept. 1964).

Engen, G. F., International intercomparison of standards and MW power measurements, (Proc. 3d Intern. Measurements Conf., Stockholm, Sweden, 1964) Acta Imeko *1*, 337-346 (1964).

Fehsenfeld, F. C., Evenson, K. M., Broida, H. P., Microwave discharge cavities operating at 2450 MHz, Rev. Sci. Instr. *36*, 295-298 (Mar. 1965).

Fussell, W. B., Stair, R., Preliminary studies directed toward determination of spectral absorption coefficients of homogeneous materials in the infrared at elevated temperatures, (Symp. Measurement of Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-6, 1964), NASA Spec. Publ. *SP-55*, Session III, Paper 29, pp. 287-292 (1965).

Gammon, W. H., Evaluating computer systems analysis and design work in the Federal Government, Book, Ideas for Management, Systems, and Procedures 1964, pp. 319-322 (1964).

Gates, D. M., Stratospheric moisture measurements using infrared spectroscopy, (Proc. 1963 Intern. Symp. Humidity and Moisture, Wash., D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. 2. Applications, sec. VI, Paper 1, pp. 446-449 (Reinhold Publ. Corp., New York, N. Y., 1965).

Hakkarinen, W., The world of NOMAD-1, Proc. Buoy Technology Symp., Wash., D. C., Mar. 24-25, 1964, pp. 443 (Marine Technology Society, 1964).

Haller, F. B., All-glass-sorption vacuum trap, Rev. Sci. Instr. *35*, No. 10, 1356-1357 (Oct. 1964).

Harris, F. K., Code for electricity metering, revised, Mag. Std. *36*, No. 5, 143-145 (May 1965).

Hasko, S., Weight checking of aerosols, Mod. Packaging *38*, No. 11, 141 (July 1965).

Hermach, F. L., Advances in electrical instrumentation, Ind. Res. pp. 60-66 (June 1965).

Hernandez, H. P., Birmingham, B. W., Liquid hydrogen bubble chambers, Book, Technology and Use of Liquid Hydrogen, chapt. 8, pp. 228-284 (Pergamon Press Inc., New York, N. Y., 1964).

Hertelendy, P., Reynard, P., "Thumbtack" accelerometer for the 1.5-150 KC range, Rev. Sci. Instr. *35*, No. 10, 1305-1306 (Oct. 1964).

Hogue, E. W., A magnetic amplifier for use with diode logic, IEEE Trans. Commun. Electron. *83*, No. 75, 803-808 (Nov. 1964).

Hord, J., Jacobs, R. B., Robinson, C. C., Sparks, L. L., Nucleation characteristics of static liquid nitrogen and liquid hydrogen, J. Eng. Power *86*, 485-494 (Oct. 1964).

Hornbeck, G. A., High temperature seal of sapphire windows to ceramics, Rev. Sci. Instr. *36*, No. 6, 845 (June 1965).

Hunt, C. M., Woolf, A. R., Sieve techniques for obtaining small amounts of narrowly classified particles, Mater. Res. Std. *4*, No. 7, 364-365 (July 1964).

Jacobs, R. B., Theory of boil-off calorimetry, Rev. Sci. Instr. *35*, No. 7, 828-832 (July 1964).

Jones, F. E., A study of the variation of the surface electrical resistance of lead iodide films with RH at room temperature, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol *1*. Principles and Methods of Measuring Humidity in Gases, ed. R. E. Ruskin, sec. III, Paper 37, pp. 361-365 (Reinhold Publ. Corp., New York, N. Y., 1965).

Judd, D. B., Spectral distribution of typical daylight as a function of correlated color temperature (condenced version), Illum. Eng. *60*, No. 4, 272-278 (Aug. 1965).

Judd, D. B., MacAdam, D. L., Wyszecki, G., Spectral distribution of typical daylight as a function of correlated color temperature, J. Opt. Soc. Am. *54*, No. 8, 1031-1040 (Aug. 1964).

Keegan, H. J., Schleter, J. C., Weidner, V. R., Effect of surface texture on diffuse spectral reflectance. Part A. Diffuse spectral reflectance of metal surfaces, (Symp. Measurement of Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-6, 1964), NASA Spec. Publ. *SP-55*, Session II, Paper 17, pp. 165-169 (1965).

Kerper, J. J., Scuderi, T. G., Comparison of single-point and two-point loading for determining the strength of flat glass, Proc. Am. Soc. Testing Materials *64*, 1037-1043 (1964).

Kerper, J. J., Scuderi, T. G., Modulus of rupture of glass in relation to fracture pattern, Am. Ceram. Soc. Bull. *43*, No. 9, 622-625 (Sept. 7, 1964).

Kirsch, R. A., Computer interpretation of English text and picture patterns, IEEE Trans. Electron. Computers, *EC-13*, No. 4, 363-376 (Aug. 1964).

Kusuda, T., Calculation of the temperature of a flat-plate wet surface under adiabatic conditions with respect to the Lewis relation, (Proc. 1963

Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *1*. Principles and Methods of Measuring Humidity in Gases, ed. R. E. Ruskin, sec. I, Paper 2, pp. 16-32 (Reinhold Publ. Corp., New York, N. Y., 1965).

Larsen, S., Levelt-Sengers, J. M. H., On the behavior of the compressibility along the critical isotherm, Book, Advances in Thermophysical Properties at Extreme Temperatures and Pressures, pp. 74-75 (American Society of Mechanical Engineers, New York, N. Y., Mar. 1965).

Larson, R. E., Microwave and high frequency calibration services of the National Bureau of Standards (Parts I-IV), IEEE Trans. Microwave Theory Tech. Part I, *MTT-12*, No. 4, 480-482 (July 1964); Part II, *MTT-12*, No. 5, 572-576 (Sept. 1964); Part III, *MTT-12*, No. 6, 623-624 (Nov. 1964); Part IV *MTT-13*, No. 1, 138-139 (Jan. 1965).

Lide, D. R., Versatile stark waveguide for microwave spectroscopy, Rev. Sci. Instr. *35*, No. 9, 1226 (Sept. 1964).

Little, W. E., Further analysis of the modulated subcarrier technique of attenuation measurement, IEEE Trans. Instr. Meas. *IM-13*, No. 2 & 3, 71-76 (June-Sept. 1964).

Little, W. E., Niesen, E., A multistub coaxial line tune, IEEE Trans. Microwave Theory Tech. *MTT-12*, No. 5, 570-571 (Sept. 1964).

Lloyd, E. C., Giardini, A., Measurement of very-high pressures, Acta Imeko *2*, 305 (1964).

Logan, H. L., Fracture in corrosive media, Book, Fracture of Engineering Materials, chapt. 8, pp. 143-161 (American Society for Metals, Metals Park, Ohio, Nov. 1964).

Logan, H. L., Stress corrosion cracking of metals, Metals Eng. Quart. *5*, No. 2, 32-38 (May 1965).

Logan, H. L., Ugiansky, G. M., Two cases of stress corrosion cracking in copper tubing, Mater. Protect. *4*, No. 5, 79-80 (May 1965).

Lowrie, P. H., Jr., Human engineering in the design of a console for the comparison of volt boxes, 19th Annual Instrument Society of America Conference and Exhibit, Preprint 12.1-3-64, pp. 1-8 (Oct. 12-15, 1964).

Ludtke, P. R., Recent developments in using elastomers for static cryogenic seals, Proc. Seventh National Society of Aerospace Materials Process Engineering Symp., pp. 25-1—25-14 (Western Periodicals, Los Angeles, Calif., 1964).

McCamy, C. S., Color filter nomograph, Am. Cinematographer *46*, No. 5 314-315 (May 1965).

McCamy, C. S., On the information in a microphotograph, Appl. Opt. *4*, No. 4, 405-411 (Apr. 1965).

McGavin, R. E., Vetter, M. J., Radio refractometry and its potential for humidity studies, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and

Control in Science and Industry. Vol. 2. Applications, sec. VII, Paper 66, pp. 553-560 (Reinhold Publ. Corp., New York, N. Y., 1965).

McLaughlin, W. L., Latensification in radiographic emulsions, J. Phot. Sci. *13*, 1-11 (1965).

McPherson, A. T., Are our neighbors from abroad aware of standards and what standards can do for them? Proc. 13th Annual Meeting Standard Engineering Society, New York, N. Y., Sept. 3, 1964, pp. 11A1-11A2 (1965).

McPherson, A. T., Letter to the Editor of Industrial Research in answer to letters regarding "Synthesis of food," Ind. Res. Feedback Col. *4*, No. 5, 15-16 (May 1962).

Margoshes, M., Scribner, B. F., Simple arc device for spectral excitation in controlled atmospheres, Appl. Spectry. *18*, No. 5, 154-155 (1964).

Mason, H. L., Standards—still a continuing project, Control Eng. *12*, No. 1, 74, (Jan. 1965).

Mason, H. L., The evolution of control system standards, 1965 Joint Automatic Control Conf., June 22-25, 1965, Session VII, Paper 1, pp. 76-78 (Renssalaer Polytechnic Inst., Troy, N. Y., 1965).

Mason, H. L., What's new in control standards, Control Eng. *11*, No. 6, 85-87 (June 1964).

Mayo-Wells, J. F., Aspects of the National Bureau of Standards instrumentation literature reference file, 19th Annual Instrument Society of America Conference and Exhibit, Preprint 20.6-5-64 (Oct. 12-15, 1964).

Meyer-Arendt, J. R., Optical instrumentation for the biologist: microscopy, Appl. Opt. *4*, No. 1, 1-9 (Jan. 1965).

Miller, C. E., Dean, J. W., Flynn, M. T., Commercial carbon composition resistors as pressure transducers, Rev. Sci. Instr. *36*, No. 2, 231-232 (Feb. 1965).

Miller, C. K. S., Daywitt, W. C., Campbell, E., A waveguide noise-tube mount for use as an interlaboratory noise standard, (Proc. Intern. Measurements Conf.), Acta Imeko *3*, 371-382 (1964).

Moore, R. T., Stark, M. C., Cahn, L., Digitizing pictorial information with a precision optical scanner, Phot. Eng. *XXX*, No. 6, 923 (Nov. 1964).

Mordfin, L., Halsey, N., Programmed maneuver-spectrum fatigue test of aircraft beam specimens, Am. Soc. Testing Mater. Spec. Tech. Publ. *338*, 251-272 (1963).

Mullen, L. O., Hiza, M. J., The role of cryogenics in the production of high and ultra-high vacuum, Cryogenics *4*, No. 6, 387-394 (Dec. 1964).

Newman, S. B., Resionography with 8-A X-rays, (Symp. Resionographic Methods), Am. Soc. Testing Mater. Spec. Tech. Publ. No. 348 (1963).

Norton, M. T., A miniature helium turbo-expander for cryogenic refrigeration systems, (Proc. XI Intern. Congress Refrigeration, Munich, Germany, Aug. 1963), Prog. Refrig. Sci. Technol. *1*, 131-135 (1963).

Ohashi, M., Paffenbarger, G. C., Stanford, J. W., Some physical characteristics of agar impression materials, J. Nihon Univ. Sch. Dent. *7*, No. 1, 1-11 (Mar. 1965).

Okabe, H., Intense resonance line sources for photochemical work in the vacuum ultraviolet region, J. Opt. Soc. Am. *54*, 478 (Apr. 1964).

Paffenbarger, G. C., Some activities of the cooperative dental research between the Federal Government and the American Dental Association at the National Bureau of Standards, Ann. Dentistry, *23*, No. 4, 111-126 (Dec. 1964).

Paffenbarger, G. C., Stanford, J. W., Sweeney, W. T., Guide to dental materials 1964-1965, Am. Dental Assoc. 2d ed., 159 pages (Chicago, Ill., 1964).

Paffenbarger, G. C., Woelfel, J. B., Sweeney, W. T., Resins and technics used in constructing dentures, Book, Dental Clinics of North America, pp. 251-262 (W. B. Saunders, Philadelphia, Pa., Mar. 1965).

Reed, R. P., Guntner, C. J., Stress-induced martensitic transformations in 18Cr-8Ni steel, Trans. Met. Soc. *AIME 230*, 1713-1720 (Dec. 1964).

Richmond, J. C., Importance of surface films, (Symp. Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-5, 1964), NASA Spec. Publ. *SP-55*, Session II, Paper 15, pp. 157-158 (1965).

Robertson, A. F., Experimental fires in enclosures, Tenth Symp. (Intern.) on Combustion, Cambridge, England, Aug. 1964, pp. 931-942 (1965).

Rogers, G. J., Project FIST: fault isolation by semi-automatic techniques, Design Disclosure Workbook (Packaging), U. S. Naval Applied Science Lab., Brooklyn, N. Y., Draft #5 (June 1965).

Rogers, J. H., Triggered fuse for load protection, Rev. Sci. Instr. *35*, No. 12, 1715 (Dec. 1964).

Romanoff, M., Exterior corrosion of cast iron pipe, J. Am. Water Works, Assoc. *56*, No. 9, 1129-1143 (Sept. 1964).

Rosberry, F. W., The performance of lenses made from inhomogeneous glasses, Appl. Opt. *4*, No. 1, 21-24 (Jan. 1965).

Roth, F. L., Stiehler, R. D., Control of relative humidity and temperature in rubber laboratory of National Bureau of Standards, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry, Vol. *2*. Applications, sec. III, Paper 35, pp. 287-292 (Reinhold Publ. Corp., New York, N. Y., 1965).

Rubin, S., Sensitivity indices for Hall generators, Solid State Design Mag. *5*, No. 12, 38-39 (Dec. 1964).

Rubin, S., Standardization of definitions for Hall effect devices, Proc. Rotating and Static Precision Components Symp., Apr. 1964, pp. 344-360 (Bureau Naval Weapons, Washington, D. C., 1964).

Rushmer, M. A., Burdick, M. D., Weather resistance of porcelain enamels exposed for seven years at various sites, Proc. Porcelain Enamel Inst. Forum *26*, 214-226 (Oct. 14-16, 1964).

Russell, D. H., An unmodulated twin channel microwave attenuation measurement system, ISA Trans. *4*, 162-169 (Apr. 1965).

Ryan, J. V., Comments on three papers on fire tests, (Am. Soc. Testing Materials Fire Test Symp., Oct. 1, 1962), Am. Soc. Testing Mater. Spec. Tech. Publ. *344*, 52 (Oct. 1963).

Ryan, J. V., Fire endurance of small gypsum slabs, (Proc. Am. Soc. Testing Materials Annual Meeting on Moisture Influence on Material Behavior During Fire Test, Chicago, Ill., June 1964), Am. Soc. Testing Mater. Spec. Tech. Publ. *385*, 96-111 (May 1965).

Saunders, J. B., Interferometer test of the 26-inch refractor at Leander McCormick Observatory, Astron. J. *69*, No. 6, 449 (Aug. 1964).

Schafft, H. A., Breakdown characteristics of semi-conductor materials, Electro-Technol. *75*, No. 6, 77-82 (June 1965).

Schon, D. A., The Institute for Applied Technology, Engineer *V*, No. 2, 3 (1964).

Schwartz, R. B., Richardson, A. C. B., Behavior of coaxial cable connectors for pulses with nanosecond risetimes, Nuclear Instr. Methods. *29*, 83-88 (North-Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Schwerdtfeger, W. J., Soil corrosion, Encyclopedia of Electrochmeistry pp. 1068-1071 (Reinhold Publ. Corp., New York, N. Y., Mar. 1965).

Scott, A. H., Metallized polymer film guard rings, Mater. Res. Std. *5*, No. 2, 76-78 (Feb. 1965).

Scott, R. B., Editor, Book, Technology and Uses of Liquid hydrogen, Pergamon Press Ltd., London, England, 1964.

Sengers, J. V., Thermal conductivity and viscosity of simple fiuids. Am. Chem. Soc. Div. Petroleum Chemistry, Symp. Molecular Transport Properties of Liquids *9*, No. 4, C-57 to C-70 (Sept. 1964).

Shapiro, G., Rogers, G. J., Maintenance of marine electronics equipment by personnel not trained in electronic maintenance, Proc. Annual Tankers Conf. Am. Petroleum Inst., pp. A1-A48 (June 1965).

Shapiro, G., Rogers, G. J., Laug, O. B., Fulcomer, P. M., Jr., Project FIST: fault isolation by semi-automatic techniques, IEEE Spectrum pp. 98-111 (Aug. 1964); pp. 130-144 (Sept. 1964).

Simpson, J. A., High-resolution, low-energy electron spectrometer, Rev. Sci. Instr. *35*, No. 12, 1698-1704 (Dec. 1964).

Smith, R. O., A liquid-medium step-function pressure calibrator, J. Basic Eng. *86*, No. 4, 723-727 (Dec. 1964).

Spangenberg, D. B., Strang, A. G., Chamberlin, J. L., Effect of surface texture on diffuse spectral reflectance. Part B. Surface texture measurement on metal surfaces, (Symp. Measurement of Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-6, 1964), NASA Spec. Publ. *SP-55*, Session II, Paper 17, pp. 169-177 (1965).

Stair, R., Schneider, W. E., Waters, W. R., Jackson, J. K., Some factors affecting the sensitivity and spectral response of thermoelectric (radiometric) detectors, Appl. Opt. *4*, No. 6, 703-710 (June 1965).

Stark, M. C., What is needed next in the simulation of the arterial street? Proc. Highway Conf. Progress Related to the Future of Research and Development in Traffic Surveillance, Simulation and Control, Washington, D. C., Sept. 14-15, 1964, pp. 144 (Bureau of Public Roads, Washington, D. C., 1964).

Stavroudis, O. N. Automatic optical design, Book, Advances in Computers, ed. F. L. Alt and M. Rubinoff, IV, 227-255 (Academic Press Inc., New York, N. Y., 1964).

Stewart, R. B., Roder, H. M., Properties of normal and parahydrogen, Book, Technology and Uses of Liquid Hydrogen, pp. 379-404 (Pergamon Press, Inc., New York, N. Y., 1964).

Sweeney, W. T., Burns, C. L., Gold in dentistry, American Society for Metals Monograph on Gold. Recovery, Properties, and Applications, chap. 13, pp. 227-235 (D. Van Nostrand Co. Inc., Princeton, N. J., 1964).

Takuma, H., Jennings, D. A., Characteristics of a Raman laser excited by an ordinary ruby laser, Proc. IEEE *53*, No. 2, 146-149 (Feb. 1965).

Taylor, J. K., Moderation in instrumentation, Sci. Teacher *32*, No. 3, 18-19 (Mar. 1965).

Timmerhaus, K. D., editor, Book, Advances in Cryogenic Engineering. Proceedings of the 1963 Cryogenic Engineering Conference, Plenum Press Inc., New York, N. Y., 1964.

Tsai, D. H., Flow field in a swirl chamber, AIAA J. Tech. Note *2*, No. 8, 1504-1505 (Aug. 1964).

Tutas, D. J., Stromberg, R. R., Passaglia, E., Studies of the thickness of adsorbed glass finishes by ellipsometry, SPE Trans. *4*, No. 4, 1-7 (Oct. 1964).

Vander Arend, P. C., Chelton, D. B., The liquefaction of hydrogen. 3A. Basic principles, Book, Technology and Uses of Liquid Hydrogen, chapt. 3, pp. 38-55 (Pergamon Press, Inc., New York, N. Y., 1964).

Vander Arend, P. C., Chelton, D. B., The liquefaction of hydrogen. 3B-2. Large-scale hydrogen liquefaction facilities, Book, Technology and Uses of Liquid Hydrogen, chapt. 3, pp. 79-105 (Pergamon Press Inc., New York, N. Y., 1964).

Waterstrat, R. M., Longton, R. W., Gallium-palladium alloys as dental filling materials, Public Health Reports *79*, No. 7, 638-642 (July 1964).

Weitzel, D. H., Ludtke, P. R., Robbins, R. F., Design of static elastomeric seals for cryogenic temperatures, Proc. Conf. Design of Leak-Tight Separable Fluid Containers *2*, 139-165 (NASA, Huntsville, Ala., Mar. 1964).

Wildhack, W. A., Perls, T. A., Kissinger, C. W., Hayes, J. W., Continuous-absorption hygrometry with a pneumatic bridge utilizing critical flow, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *1*. Principles and Methods of Measuring Humidity in Gases, sec. VI, Paper 53, pp. 552-570 (Jan. 1965).

Woelfel, J. B., Paffenbarger, G. C., Pressure-indicator-paste patterns in duplicate dentures made by different processing technics for the same patent, J. Am. Dental Assoc. *70*, No. 2, 339-343 (Feb. 1965).

Woelfel, J. B., Paffenbarger, G. C., Sweeney, W. T., Clinical evaluation of complete dentures made of eleven different types of denture base materials, J. Am. Dental Assoc. *70*, No. 7, 1170-1188 (May 1965).

Wollin, H. F., Hasko, S., Progress report on aerosol packaged products, Aerosol Age Mag. *9*, No. 9, 20 (Sept. 1964).

Wolock, I., Newman, S. B., Fracture topography, Book, Fracture Processes in Polymeric solids, Phenomena and Theory, ed. B. Rosen, chapt. IIC, pp. 235-290 (Interscience Publ., New York, N. Y., 1964).

Wyman, L. L., Summary of symposium on methods of metallographic specimen preparation, Am. Soc. Testing Mater. Spec. Tech. Publ. *285*, 130 (May 1961).

Youden, W. J., Statistical design of experiments, Handbook on Metals Engineering—Design, American Society of Mechanical Engineers, chapt. 3, pt. 5, pp. 583-585 (McGraw-Hill Book Co. Inc., New York, N. Y., 1965).

Young, J. P., Watermarks for papermaking by electroforming, Metal Finishing *63*, No. 4, 79-82 (Apr. 1965).

Young, R. W., Newman, S. B., Capott, R. J., Strength of fingernails, J. Invest. Dermatol. *44*, No. 5, 358-360 (May 1965).

Mathematics

Alexander, S. N., The current status of graphic storage techniques: their potential application to library mechanization, (Proc. Conf. Library Automation, Airlie Foundation, Warrington, Va., May 26-30, 1963), Book, Libraries and Automation, ed B. E. Markuson, pp. 111-140 (Library of Congress, Washington, D. C., 1964).

Alt, F. L., Mechanical translation: U. S.—Japan joint conference, Science *147*, No. 3665, 1599-1600 (Mar. 1965).

Alt. F. L., Some unorthodox predictions, Computers and Automation *XIV*, No. 1, 11 (Jan. 1965).

Alt, F. L., The standardization of programming languages, Proc. 19th Natl. Conf. Association for Computing Machinery, Philadelphia, Pa., Aug. 1964, pp. B2-1 (1964).

Barut, A. O., Complex Lorentz group with a real metric. I. Group structure, J. Math. Phys. *5*, 1652-1656 (Nov. 1964).

Bowman, H. S., Nomographs for computing real, imaginary and absolute values of vector ratios, J. Acoust. Soc. Am. *37*, No. 4, 751 (Apr. 1965).

Bracken, H. J., Mathematical programming models for selection of diets to minimize weighted radionuclide intake, Environmental Health Series: Radiological Health, Public Health Serv. Publ. 999-R-4 (Dept. Health, Education, and Welfare, Washington, D. C., Aug. 1963).

Brualdi, R. A., Newman, M., Inequalities for permanents and permanental minors, Proc. Cambridge Phil. Soc. *61*, pt. 3, 741-746 (Jan. 26, 1965).

Cameron, J. M., Hilsenrath, J., Use of general purpose coding systems for statistical calculations, Proc. IBM Scientific Computing Symp. Statistics, Thomas J. Watson Research Center, Yorktown Heights, N. Y., Oct. 21-23 1963, pp. 281-299 (IBM, White Plains, N. Y., 1965).

Cornog, J. R., How people influence experimental results, Proc. Social Statistics Section Convention, American Statistical Association, Cleveland, Ohio, pp. 119-122 (1964).

Cornog, J. R., Hockman, J. F., Craig, J. C., Address encoding—a study of the double-binary keyboard as a link in the machine-sorting of mail, (Proc. Winter Annual Meeting, American Society of Mechanical Engineers, Philadelphia, Pa., Nov. 17-22, 1963), ASME Publ. 63-WA-338 (1964).

DeMar, R. F., A uniqueness theorem for entire functions, Proc. Am. Math. Soc. *16*, No. 1, 6971 (Feb. 1965).

DeMar, R. F., On a theorem concerning existence of interpolating functions, Trans. Am. Math. Soc. *114*, No. 1, 23-29 (Jan. 1965).

Edmonds, J. Paths, trees, and flowers, Can. J. Math. 17, 449-467 (May 1965).

Edmonds, J., Goldman, A. J., Witzgall, C., Zahn, C. T., Jr., On matching problems, Proc. ARO Working Group on Computers, ARO-D Report 65-1, pp. 46-50 (Office, Chief Res. & Develop., Feb. 1964).

Eisenhart, C., The needs of the statistical engineering program of the National Bureau of Standards, Proc. 9th Conf. Design of Experiments in Army Research Development and Testing, Directorate of Research and Development, U. S. Army Missile Command, Redstone Arsenal, Ala., Oct. 23-25, 1963, ARO-D Report 64-2, pp. 550-556 (U. S. Army Res. Office, Durham, N. C., Dec. 1964).

Fell, H., Goldman, A. J., Realization of semi-multipliers as multipliers, Am. Math. Mo. *72*, No. 6, 639-641 (June-July 1965).

Green, M. S., Surface integral form for three-body collision in the Boltzmann equation, Phys. Rev. *136*, No. 4A, A905-A910 (Nov. 16, 1964).

Judd, D. B., Relation between normal trichromatic vision and dichromaitc vision representing a reduced form of normal vision, Acta Chromatica *1*, No. 3, 89-92 (Oct. 1964).

Lagnese, J. E., A new differential operator of the pure wave type, J. Differential Equations *1*, No. 2, 171-187 (Apr. 1965).

Ma, M. T., An application of the inverse Z-transform theory to the synthesis of linear antenna arrays, IEEE Trans. Ant. Prop. *AP-12*, No. 6, 798-799 (Nov. 1964).

Ma, M. T., Analogies between theories of antenna arrays and passive networks, IEEE Intern. Conv. Record *13*, pt. 5, 150-154 (Mar. 1965).

Ma. M. T., Application of Bernstein polynomials and interpolation theory

to linear array synthesis, IEEE Trans. Ant. Prop. *AP-12*, 668-677 (Nov. 1964).

Ma, M. T., Comments on "The use of transforms to sum array factors," IEEE Trans. Ant. Prop. *AP-13*, No. 1, 174 (Jan. 1965).

Mandel, J., The statistical analysis of experimental data, 410 pages (Interscience Publ. Inc., New York, N. Y., 1964).

Mertz, D. B., Park, T., Youden, W. J., Mortality patterns in eight strains of flour beetles, Biometrics *21*, No. 1, 99-144 (Mar. 1965).

Nesenbergs, M., A combinatorial problem and a single decoding method for cyclic codes, IEEE Trans. Inform. Theory, *IT-10*, 250-252 (July 1964).

Newman, M. A theorem on the automorphs of a skew-symmetric matrix, Mich. Math. J. *12*, 61-63 (1965).

Newman, M., Bounds for class numbers, Proc. Am. Math. Soc. Symp. Number Theory, pp. 70-77 (1965).

Newman, M., Note on the partition function, Am. Math. Mo. *71*, 1022 (1964).

Newman, M., Smart, J. R., Symplectic modular groups, Acta Arithmetica *9*, 83-89 (1964).

Oliver, F. W. J., Error bounds for asymptotic expansions in turning-point problems, Soc. Ind. Appl. Math. *1*, No. 1, 200-214 (Mar. 1964).

Oliver, F. W. J., Error bounds for asymptotic expansions with an application to cylinder functions of large argument, Book, Asymptotic Solutions of Differential Equations and their Applications, ed. C. H. Wilcox, pp. 163-183 (John Wiley & Sons, Inc., New York, N. Y., 1964).

Rademacher, H., Some remarks on certain generalized Dedekind sums, Acta Arithmetica *9*, Sec. 1, 97-105 (1964).

Rosenblatt, D., Aggregation in matrix models of resource flows, Am. Stat. *19*, No. 3, 36-39 (June 1965).

Shisha, O., On the structure of infrapolynomials with prescribed coefficients, Pacific J. Math. *14*, No. 3, 1039-1051 (1964).

Shisha, O., Walsh, J. L., On the location of the zeros of some infrapolynomials with prescribed coefficients, Pacific J. Math. *14*, No. 3, 1103-1109 (1964).

Siddiqui, M. M., Approximations to the distribution of quadratic forms, Ann. Math. Stat. *36*, No. 2, 677-682 (Apr. 1965).

Siddiqui, M. M., Distribution to Students t in samples from a rectangular universe, Rev. Intern. Stat. Inst. *32*, No. 3, 242-250 (Dec. 1964).

Speckman, J. A., Cornell, R. G., Estimation for a one-parameter exponential model, J. Am. Stat. Assoc. *60*, 560-572 (1965).

Stevens, M. E., Urban, G. H., Training a computer to assign descriptors to documents, Proc. Spring AFIP Joint Computer Conf., Washington, D. C., April 1964, pp. 563-575 (1964).

Strand, O. N., A method for the computation of the error function of a complex variable, Math. Comp. *XIX*, No. 89, 127-129 (Jan. 1965).

Tchen, C. M., Plasma oscillations with collective correlations, Proc. 6th Intern. Conf. Ionization Phenomena in Gases, Paris, France, July 8-13, 1963, I, 195-199 (P. Hubert Assoc. EURATOM-CEA Centra-d-Etudes Nucleaires de Fontenay-aux-Roses, Paris, France, 1963).

Tchen, C. M., Stochastic theory of diffusion in a plasma across a magnetic field, Proc. Intern. Symp. Plasma Diffusion, Feldafing, Germany, June 29-July 3, 1964, pp. 118-123 (1964).

Watt, W. C., Some remarks on microgrammers, Proc. Washington Linguistics Club *2*, No. 1, 13-17 (Oct. 26, 1964).

Wegstein, J. H., You can always tell a computer but you can't tell it much, Proc. ARO Working Group on Computers, Harry Diamond Laboratories, Washington, D. C., Feb. 4-5, 1964, pp. 129-151 (Feb. 1965).

Youden, W. J., Sampling and statistical design, Proc. Symp. Environmental Measurements, U. S. Public Health Service, pp. 35-39 (July 1964).

Youden, W. J., The evolution of designed experiments, Proc. IBM Scientific Computing Symp. Statistics, Thomas J. Watson Research Center, Yorktown Heights, N. Y., Oct. 21-23, 1963, pp. 59-67 (IBM, White Plains, N. Y., 1965).

Zahn, C. T., Jr., Approximating symmetric relations by equivalence relations, J. Soc. Ind. Appl. Math. *12*, No. 4, 840-847 (Dec. 1964).

Metrology

Anderson, R. L., Guildner, L. A., National Bureau of Standards gas thermometer. III. Constant volume value, Rev. Sci. Instr. *36*, No. 5, 615-616 (May 1965).

Bay, Z., Boyne, H. S., The use of terahertz photobeats for precise velocity-of-light measurements, Proc. Enrico Fermi International School of Physics: Course No. XXXI, Quantum Electronics and Coherent Light 1963, pp. 352-371 (1964).

Bender, P. L., Owens, J. C., Correction of optical distance measurements for the fluctuating atmospheric index of refraction, J. Geophys. Res. *70*, No. 10, 2461-2462 (May 1965).

Brown, N. L., Simultaneous dielectric constant and volume measurements on liquids at high pressures, (Proc. Electrical Insulation Conf. Cleveland, Ohio, Oct. 1964), Natl. Acad. Sci.-Natl. Res. Council Publ. 1238, pp. 36-40 (1965).

Cones, H. N., Discussion of paper 63-39 I, "The measurement of short duration impulse voltages," by F. C. Creed and M. M. C. Collins, IEEE Trans. Commun. Electron. *EC-69*, 629 (Nov. 1963).

Crown, E. L., The statistical construction of a single standard from several available standards, IEEE Trans. Instr. Meas. *IM-13*, No. 4, 180-185 (Dec. 1964).

Cutkosky, R. D., Lee, L. H., Construction and behavior of a transportable ten picofarad capacitor, Comite Consultatif d'Electricite 10^{e} Session, May 2-3, 1963, pp. 44-48 (Gauthier-Villars, Paris, France, 1963).

Driscoll, R. L., Electronic g factor of rubidium, Phys. Rev. *136*, No. 1A A54-A57 (Oct. 5, 1964).

Eicke, W. G., Jr., Comments on Zener diodes as voltage standards, Comite Consultatif d'Electricite 10e Session, May 2-3, 1963, pp. 27-30 (Gauthier-Villars, Paris, France, 1963).

Eicke, W. G., Jr., Making precision voltage measurements on Zener diodes, IEEE Trans. Commun. Electron. *83*, No. 74, 433-438 (Sept. 1964).

Eisenstein, J. C., Hudson, R. P., Mangum, B. W., A magnetic fixed point for thermometry below 1 °K, Appl. Phys. Letters *5*, No. 11, 231 (Dec. 1, 1964).

Gary, R., Robinson, R. A., Standard potential of the Ag-AgCl electrode in 5% aqueous mannitol, J. Chem. Eng. Data *9*, No. 3, 376-378 (July 1964).

Gates, D. M., The measurement of water vapor boundary layers in biological systems, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *2*. Applications, sec. I, Paper 5, pp. 33-38 (Reinhold Publ. Corp., New York, N. Y., 1965).

Gilmer, R. O., McGavin, R. E., Bean, B. R., The response of microwave refractometer cavities to atmospheric variations, Proc. 1964 World Conf. Radio Meterology and 11th Weather Radar Conf., pp. 244-247 (Sept. 1964).

Ginnings, D. C., West, E. D., Heater lead problem in calorimetry, Rev. Sci. Instr. *35*, No. 8, 965-967 (Aug. 1964).

Greenspan, L., A pneumatic bridge hygrometer for use as a working humidity standard, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *3*. Fundamentals and Standards, sec. II, Paper 20, pp. 433-443 (Reinhold Publ. Corp., New York, N. Y., 1965).

Hamer, W. J., Standards of electromotive force, J. Wash. Acad. Sci. *54*, No. 7, 297-315 (Oct. 1964).

Hamer, W. J., Craig, D. N., The value of the Faraday, J. Electrochem. Soc. *111*, No. 12, 1434 (Dec. 1964).

Harris, F. K., Units and standards of electrical measure, Electron. World *72*, No. 2, 29-32 (Aug. 1964).

Hasegawa, S., Hyland, R. W., Rhodes, S. W., A comparison between the National Bureau of Standards two-pressure humidity generator and the National Bureau of Standards standard hygrometer, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *3*, Fundamentals and Standards, sec. II, Paper 22, pp. 455-459 (Reinhold Publ. Corp., New York, N. Y., 1965).

Hermach, F. L., Griffin, J. E., Williams, E. S., A system for accurate D-C and A-C voltage measurements, IEEE Intern. Conv. Record *13*, pt. 11, 172-182 (Mar. 1965).

Hockersmith, T. E., Ku, H. H., Uncertainties associated with proving ring calibration error, ISA J. *12*, No. 6, 73-77 (June 1965).

Hudson, G. E., Frequency and time standards, Electron. World 72, 20-23 (Aug. 1964).

Hudson, G. E., Spacetime coordinate systems, Proc. Intern. Conf. Chronometry, pp. 197-221 (Lausanne, Switzerland, June 1964).

Huntoon, R. D., Our measurement system and its future, Research/Develop. *16*, No. 1, 16-21 (Jan. 1965).

Huntoon, R. D., Wildhack, W. A., Planning for better measurement accuracy, ISA J. *12*, No. 1, 57-60 (Jan. 1965).

Jensen, M. W., Weights and measures—a challenge to industry, Proc. 50th Mid-Year Meeting Chemical Specialties Manufacturers Assoc., Chicago, Ill., May 18-20, 1964, pp. 24-26 (Chem. Specialties Mfg. Assoc. Inc., New York, N. Y., 1964).

Kelly, K. L., A universal color language, Color Eng. *3*, No. 2, 16-21 (Mar.-Apr. 1965).

Lance, H. W., Electromagnetic measurements, Space/Aeron. R&D Handb. 42, No. *4*, 199-202 (Sept. 1964).

Larson, R. E., Microwave calibration techniques at the National Bureau of Standards, (Proc. 3d Intern. Measurements Conf.), Acta IMEKO *3*, 383-393 (1964).

Lashof, T. W., APPA-TAPPI reference material program. III. A discussion of lambda varience and its application to TAPPI standard T 414 m-49 for internal tearing resistance of paper, Tappi *47*, No. 8, 445 (Aug. 1964).

Lashof, T. W., Ranking laboratories and evaluating methods of measurement in round-robin tests, Mater. Res. Std. *4*, No. 8, 397-407 (Aug. 1964).

Linnig, F. J., Mandel, J., Which measure of precision? The evaluation of the precision of analytical methods involving linear calibration curves, Anal. Chem. *36*, No. 13, 25A-32A (Dec. 1964).

Lisle, R. V., Zapf, T. L., Comparison calibration of inductive voltage dividers, ISA Trans. *3*, No. 3, 238-242 (July 1964).

McNish, A. G., Lasers for length measurement, Science *146*, No. 3641, 177-182 (Oct. 1964).

McNish, A. G., The international system of units, Am. Soc. Quality Control Annual Tech. Conf. Trans. pp. 431-438 (1965).

Meyerson, M. R., The temporal dimensional stability of surface-hardened steels, Metal Treating *15*, No. 6, 5 (Dec. 1964-Jan. 1965).

Mielenz, K. D., Cook, H. D., Gillilland, K. E., Stephens, R. B., Accurate length measurement of meter bar with helium-neon laser, Science Letter *146*, No. 3652, 1672-1673 (Dec. 25, 1964).

Moore, G. A., Direct quantitative analysis of microstructures by a digital computer, Am. Soc. Metals Tech. Report No. 16.3 (1964); (condensed

version) Book, Computer Applications in Metallurgical Engineering, pp. 111 (Am. Soc. Metals, Metals Park, Ohio, 1964).

Nimeroff, I., Spectral tristimulus values for the CIE (u, v, w) uniform spacing system, J. Opt. Soc. Am. *54*, No. 11, 1365-1367 (Nov. 1964).

Nimeroff, I., Yurow, J. A., Degree of metamerism, J. Opt. Soc. Am. *55*, No. 2, 185-190 (Feb. 1965).

Ohashi, M., Paffenbarger, G. C., Stanford, J. W., The definition of alginate impression materials by a specification, J. Nihon Univ. School of Dentistry *7*, No. 1, 12-28 (Mar. 1965).

Owens, J. C., Bender, P. L., Correction of optical distance measurements for the fluctuating atmospheric index of refraction, J. Geophys. Res. *70*, No. 10, 2461-2462 (May 15, 1965).

Page, C. H., Definition of "ampere" and "magnetic constant," Proc. IEEE Letter to Editor *53*, No. 1, 100-101 (Jan. 1965).

Page, C. H., Letter to the Editor, Metrologia *1*, No. 2, 73-74 (Apr. 1965).

Saylor, C. P., A study of errors in the measurement of microscopic spheres, Appl. Opt. *4*, No. 4, 477-486 (Apr. 1965).

Selby, M. C., Measurement and standardization of LF to UHF electrical quantities. Sketch of recent world-wide developments, Book, Progress in Radio Science 1960-1963. Vol *I*. Radio Standards and Measurements, pp. 45-55 (Elsevier Publ. Co., Amsterdam, The Netherlands, 1965).

Stair, R., Fussell, W. B., Schneider, W. E., A standard for extremely low values of spectral irradiance, Appl. Opt *5*, No. 1, 85-89 (Jan. 1965).

Stair, R., Schneider, W. E., Standards, sources, and detectors in radiation measurements, (Symp. Measurement of Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-6, 1964), NASA Spec. Publ. SP-55, Session III, Paper 24, pp. 217-231 (1965).

Stiehler, R. D., Standards—the foundation of industrial growth, Ind. Times *VI*, No. 22 (Bombay, India, Nov. 15, 1964).

Sze, W. C., Dunn, A. F., Zapf, T. L., An international comparison of inductive voltage divider calibrations at 400 and 1000 Hertz, IEEE Intern. Conv. Record *13*, pt. 11, 126-135 (Mar. 1965).

Thaxter, R. T., Hubbe, P. D., Mendel, J., Comments on "Application of experimental design to the study of a test method," Tappi *46*, No. 12, 193A–194A (Dec. 1963).

Thompson, C. L., A cimple method for measuring the amount of granular materials in sulfur mortars, Mater. Res. Std. *5*, No. 5, 242-243 (May 1965).

Vosburgh, W. C., Bates, R. G., Constancy of a modified Weston standard cell over long periods, J. Electrochem. Soc. *111*, No. 8, 997-998 (Aug. 1964).

Weise, E. L., Burke, R. W., Taylor, J. K., Gas chromatographic determination of the moisture content of grain, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Vol. *4*. Principles and Methods of Measuring Moisture in Liquids and

Solids, sec. I, Paper 1, pp. 3-6 (Reinhold Publ. Corp., New York, N. Y., 1965).

Wexler, A., Hyland, R. W., The NBS standard hygrometer, (Proc. 1963 Intern. Symp., Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Vol *3*. Fundamentals and Standards, sec. II, Paper 19, pp. 389-342 (Reinhold Publ. Corp., New York, N. Y., 1965).

Wildhack, W. A., Measurement—R&D looks to future, Control Eng. *12*, No. 1, 75-76 (Jan. 1965).

Young, T. R., Educating metrologists, Ordnance *XLIX*, No. 268, 432-435 (Jan.-Feb. 1965).

Young, T. R., Metrology as related to microminiaturization processes, Proc. Microminiaturization Congress, New York, N. Y., Mar. 10-13, 1962 (American Watchmakers Inst., New York, N. Y., Mar. 1963).

Zapf, T. L., The accurate measurement of voltage ratios of inductive voltage dividers, Acta IMEKO *3*, 317-331 (1964).

Physics

Abbott, R. L., Width of the microwave lines of oxygen and their relationship to the thermal noise emission spectrum of the atmosphere, Proc. 3d Symp. Remote Sensing of the Environment, Infrared Phys. Lab., Inst. Sci. Tech. Univ. Michigan, Ann Arbor, Mich., Feb. 1965, pp. 257-269 (Mar. 1965).

Alley, C. O., Bender, P. L., Dicke, R. H., Faller, J. E., Plotkin, H. H., Wilkerson, D. T., Optical radar using a corner reflector on the moon, J. Geophys. Res. *70*, No. 9, 2267-2269 (May 1, 1965).

Ambler, E., Fuller, E. G., Marshak, H., Direct observation of the optical anisotropy of the holmium nucleus, Phys. Rev. *138*, No. 1B, B117-B126 (Apr. 1965).

Andersen, H., Shuler, K. E., Oppenheim, I., Weiss, G., Nonequilibrium thermodynamics of canonically invariant relaxation processes, J. Chem. Phys. *41*, No. 10, 3012-3019 (Nov. 1964).

Arms, R. J., Hama, F. R., Localized-induction concept on a curved vortex and motion of an elliptic vortex ring, Phys. Fluids *8*, No. 4, 553-559 (Apr. 1965).

Armstrong, G. T., Thermodynamic data compilation and review at the National Bureau of Standards, Svensk Kem. Tidskr. *76*, No. 8, 419-427 (1964).

Barber, D. J., Electron microscopy and diffraction of aluminum oxide whiskers, Phil. Mag. *10*, No. 103, 75-94 (May 1965).

Barber, D. J., Tighe, N. J., Electron microscopy and diffraction of synthetic cordunum crystals. I. Pure aluminum oxide grown by the Verneuil process, Phil. Mag. *11*, No. 111, 495-512 (May 1965).

Barkas, W. H., Berger, M. J., Tables of energy losses and ranges of heavy charged particles, Natl. Aeronaut. Space Admin. NASA *SP-3113*, 1-131 (1964).

Barloutaud, M., Caswell, R. S., Gastebois, J., de Pinho, A. G., Quidort, J., Reaction $^{59}Co(p, \&)$ ^{56}Fe, Proc. Intern. Congress Nuclear Physics, Paris, France, July 2-8, 1964), Compt. Rend. Cong. Intern. Phys. Nucleaire *II*, 717-719 (Centre National de la Recherche Scientifique, Paris, France, 1964).

Bay, Z., Papp, G., Determination of the probability distribution of the number of secondary electrons, IEEE Trans. Nuclear Sci. *NS-11*, No. 3, 160-168 (June 1964).

Bean, B. L., Mulligan, B. W., X-ray spectrochemical analysis of materials: cement and dental alloys, Am. Soc. Testing Mater. Spec. Tech. Publ. *373*, Application of Advanced and Nuclear Physics to Testing Materials, pp. 25-45 (June 17, 1965).

Beaty, E. C., Patterson, P. L., Mobilities and reaction rates of ions in helium, Phys. Rev. *137*, No. 2A, A346-357 (Jan. 4, 1965).

Becker, J. H., Hosler, W. R., Multiple-band conduction in *n*-type rutile (TiO_2), Phys. Rev. *137*, No. 6A, A1872-A1877 (Mar. 15, 1965).

Bennett, L. H., Pressure dependence of the internal field at the ^{59}Co nucleus in a 99.5% Ni-0.5% Co alloy, J. Appl. Phys. *36*, No. 3, Pt. 2, 942-943 (Mar. 1965).

Ben-Reuven, A., Shift of the R(0) and P(1) infrared lines of HCl perturbed by noble gases, J. Chem. Phys. *42*, No. 6, 2037-2042 (Mar. 15, 1965).

Ben-Reuven, A., Transition from resonant to non-resonant line shape in microwave absorption, Phys. Rev. Letters *14*, No. 10, 249-351 (Mar. 8, 1965).

Berger, M. J., Seltzer, S. M., Tables of energy losses and ranges of electrons and positrons, Natl. Aeronaut. Space Admin. NASA *SP-3012*, 1-127 (1964).

Bestul, A. B., Volume relaxation of As_2O_3 in the glass transformation, Proc. Intern. Conf. Physics of Non-Crystalline Solids, Delft, Netherlands, July 1964 (1965).

Birnbaum, G., Maryott, A. A., Nonresonant absorption and collision diameters in the foreign-gas broadening of symmetric top molecules, J. Chem. Phys. *41*, No. 1, 154-157 (July 1, 1964).

Block, S., Piermarini, G. J., Alkaline earth cation distribution in vitreous borates, Phys. Chem. Glasses *5*, No. 5, 138-144 (Oct. 1964).

Bozman, W. R., Is life possible on other planets? Sci. Children *2*, No. 4, 7 (Dec. 1964).

Branscomb, L. M., Observatory report—Joint Institute for Laboratory Astrophysics of the National Bureau of Standards and University of Colorado, Boulder, Colo., Astron. J. *69*, No. 9, 700-703 (Nov. 1964).

Brenner, A., Catey, S. L., Electrochemical calorimetry. IV. Measurement of the reversible heat effect attending the passage of electric current across a liquid junction, J. Electrochem. Soc. *111*, No. 11, 1225-1230 (Nov. 1964).

Broadhurst, M. G., A dumbbell model for dielectric dispersion in paraffin-like solids, (Proc. Electrical Insulation Conf., Cleveland, Ohio, Oct. 1964), Natl. Acad. Sci.-Natl. Res. Council Publ. 1238, pp. 129-132 (1965).

Brower, W. S., Jr., Farabaugh, E. N., Etch pits in chromic oxide, J. Appl. Phys. *36*, No. 4, 1489-1490 (Apr. 1965).

Brown, R. L., James, T. C., Isotopic determination of the vibrational numbering for the $B^3\Pi_{O+}$, J. Chem. Phys. *42*, No. 1, 33-38 (Jan. 1965).

Bur, A. J., Experimental verification of the WLF superposition technique, Insulation Mag. pp. 38 (Dec. 1964).

Burley, G., Ice nucleation by photolyzed silver iodide, Phil. Mag. *10*, 527 (Sept. 1964).

Cahoon, B. A., Riggs, L. P., Climatology of elevated super-refractive layers arising from atmospheric subsidence, Proc. 1964 World Conf. Radio Meteorology and 11th Weather Radar Conf., pp. 52-55 (Sept. 1964).

Candela, G. A., Influence of paramagnetic resonance on the static susceptibility. Spin-lattice relaxation time of cupric sulfate pentahydrate, J. Chem. Phys. *42*, No. 1, 113-117 (Jan. 1, 1965).

Carter, J. C., Coyne, J. J., Meshkov, S., SU(6) Clebsch-Gordan coefficients for the product 35x56, Phys. Rev. Letters *14*, No. 13, 523-526 (Mar. 1965).

Chamberlain, G. E., Multichannel resonances in the forward scattering of electrons by helium, Phys. Rev. Letters *14*, No. 15, 581-582 (Apr. 12, 1965).

Chang, T-T., Electron spin resonance of Mo^{5+} in rutile, Phys. Rev. *136*, No. 5A, A1413 (Nov. 30, 1964).

Chelton, D. B., Safety in the use of liquid hydrogen, Book, Technology and Uses of Liquid Hydrogen, ed. R. B. Scott, W. H. Denton, and C. M. Nicholls, chapt. 10, 359-378 (Pergamon Press Inc., New York, N. Y. 1964).

Codling, K., Madden, R. P., Characteristics of the "synchrotron light" from the NBS 180 MeV machine, J. Appl. Phys. *36*, No. 2, 380-387 (Feb. 1965).

Codling, K., Madden, R. P., New Rydberg series in molecular oxygen near 500A, J. Chem. Phys. *42*, No. 11, 3935-3938 (June 1965).

Cook, R. K., Wood, G. W., Report of the acoustics research survey committee, J. Acoust. Soc. Am. *37*, No. 2, 392-395 (Feb. 1965).

Cooper, J. W., Interpretation of maxima in the absorption of soft X-ray, Phys. Rev. Letters *13*, No. 25, 764 (Dec. 21, 1964).

deWit, R., Howard, R. E., Relation of the stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries in F. C. C. binary alloys, Acta Met. *13*, 655-661 (June 1965).

Diller, D. E., Measurements of the viscosity of parahydrogen, J. Chem. Phys. *42*, No. 6, 2089-2100 (Mar. 1965).

DiMarzio, E. A., Proper accounting of conformations of a polymer near a surface, J. Chem. Phys. *42*, No. 6, 2101-2106 (Mar. 1965).

Dodge, W. R., Domen, S. R., Hirshfeld, A. T., Hoppes, D. D., Investigation of the anomaly in the response of silicon semiconductor radiation detectors at low temperatures, IEEE Trans. Nuclear Sci. *NS-12*, 295 (Feb. 1965).

Drayer, D. E., Nucleate boiling of hydrogen, Ind. Eng. Chem. Fundamentals *4*, No. 2, 167-171 (May 1965).

Eby, R. K., Determination of the propagation constants for ultrasonic waves in melting and molten polyethylene, J. Acoust. Soc. Am. Letter *36*, No. 8, 1485-1487 (Aug. 1964).

Eby, R. K., Diffusion in a polymer with lamellar morphology, polyethylene, J. Appl. Phys. *35*, No. 9, 2720-2724 (Sept. 1964).

Eisenhart, C., Albert Einstein, as I remember him. (Commencement Address, Albert Einstein Senior High School, Kensington, Md., June 15, 1964), J. Wash. Acad. Sci. *54*, 325-328 (1964).

Eisenhart, C., Expertise or experiments, Science *146*, No. 3647, 997-998 (Nov. 1964).

Eisenstein, J. C., Hudson, R. P., Mangum, B. W., Low temperature magnetic transitions in lanthanon trichlorides, Physics Letters *12*, No. 1, 5 (Sept. 1, 1964).

Costrell, L., Standard nuclear instrument modules, U. S. Atomic Energy Commission TID Report 20893, 12 pages (July 1964).

Danos, M., Greiner, W., Coupling of particle-hole states and two particle-two hole states: damping, Comptes Rendus du Congres Intern. de Physique Nucleaire, ed. P. Gugenberger, II, 615-616 (Editions du Centre National de la Recherche Scientific, Paris, France, 1964).

Danos, M., Greiner, W., Damping of the giant resonance in heavy nuclei, Phys. Rev. *138*, No. 4B, B876-891 (May 1965).

Danos, M., Greiner, W., Dynamic theory of the nuclear collective model, Phys. Rev. *134*, B285 (1964).

Danos, M., Greiner, W., Shell model treatment of nuclear reactions, Phys. Rev. *138*, No. 1B, B93-B103 (Apr. 1965).

Danos, M., Greiner, W., Kohr, C. B., On the possibility of the measurement of the nuclear 2^4-pole deformation, Physics Letters *2*, No. 4, 344 (1964).

Danos, M., Greiner, W., Kohr, C. B., The dynamic collective theory of odd A nuclei, Phys. Rev. *138*, No. 5B, B1055-B1066 (June 1965).

Danos, M., Maximon, L. C., Multipole matrix elements of the translation operator, J. Math. Phys. *6*, 766 (1965).

Davis, J. C., Faison, T. K., Achenbach, P. R., Plans for proposed new tables of the thermodynamic properties of moist air, (Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *3*.

Fundamentals and Standards, chapt. 11, pp. 315-320 (Reinhold Publ. Corp., New York, N. Y., 1965).

Deslattes, R. D., Torgensen, J. L., Paretzkin, B., Horton, A. T., Preliminary studies on the characterization of solution-grown ADP crystals, Advan. X-ray Anal. *8*, 315-324 (1965).

Eisenstein, J. C., Hudson, R. P., Mangum, B. W., Low temperature magnetic transitions in some rare-earth trichlorides, Phys. Rev. *137*, No. 6A, A1886-A1895 (Mar. 1965).

Engel, O. G., Hypervelocity cratering data and a crater depth model for the regime of partial fluidity, Proc. 6th Hypervelocity Impact Symp., Cleveland, Ohio, Apr. 30-May 1, 1963, II, pt. II, 337-366 (U. S. Army Ballistics Res. Lab., Aberdeen Proving Ground, Md., Aug. 1963).

Engelmann, F., Felix, M., Minardi, E., Connection between shielding and stability in a collisionless plasma, Il Nuovo Cimento, Serie X, *30*, 830-836 (Nov. 1963).

Evenson, K. M., Dunn, J. L., Broida, H. P., Optical detection of microwave transitions between excited electronic states of CN and the identification of the transitions involved, Phys. Rev. *136*, No. 6A, A1566-A1571 (Dec. 14, 1964).

Fang, P. H., The spin lattice relaxation time of some paramagnetic dispersions, (Proc. XI Colloque Ampere, Eindhoven, The Netherlands, June 1962), Book, Magnetic and Electric Resonance and Relaxation, pp. 123–128 (1963).

Fano, U., Exclusion of parity unfavored transitions in forward scattering, Phys. Rev. *135*, No. 3B, B863-B864 (Aug. 1964).

Fano, U., Liouville representation of quantum mechanics with application to relaxation, (Proc. Lectures on the Many-Body Problems 5th Intern. School of Physics, Revello, Italy, Apr. 17-May 4, 1963), Book, Lectures of the Many-Body Problems 2, 1-294 (Academic Press Inc., New York, N. Y., 1964).

Fano, U., Copper, J. W., Line profiles in the far ultraviolet absorption spectra of the rare gases, Phys. Rev. *137*, No. 5A, A1364-A1379 (Mar. 1965).

Fano, U., Cooper, J. W., On the identification of energy levels of negative ions, Phys. Rev. *138*, No. 2A, A400-A402 (Apr. 1965).

Fano, U., Lichten, W., Interpretation of Ar^+-Ar collisions at 50 keV, Phys. Rev. Letters *14*, No. 16, 627-629 (Apr. 1965).

Fano, U., Turner, J. E., Contribution to the theory of shell corrections, Natl. Acad. Sci.-Natl. Res. Council Report *1133*, No. 39, pp. 49-67 (1964).

Fehsenfeld, F. C., Goldan, P. D., Schmeltekopf, A. L., Ferguson, E. E., Laboratory measurement of the rate of the reaction $0^+ + 0_2 \rightarrow 0_2^+ + 0$ at thermal energy, Planet Space Sci. *13*, 579-582 (Mar. 1965).

Fehsenfeld, F. C., Schmeltekopf, A. L., Ferguson, E. E., Some measured rates for oxygen and nitrogen ion-molecule reactions of atmospheric

importance, including $0^+ + N_2NO^+ + N$, Planetary Space Sci. *13*, 219-223 (1965).

Ferguson, E. E., Broida, H. P., A possible mechanism for light absorption by interstellar grains, Astrophys. J. *141*, No. 2, 807-809 (Feb. 1965).

Ferguson, E. E., Fehsenfeld, F. C., Schmeltekopf, A. L., Dissociative recombination in helium afterglows, Phys. Rev. *138*, A381 (Apr. 1965).

Ferguson, R. E., McCulloh, K. E., Rosenstock, H. M., Observation of the products of ionic collision processes and ion decomposition in a linear, pulsed time-of-flight mass spectrometer, J. Chem. Phys. *42*, No. 1, 100-106 (Jan. 1, 1965).

Fine, J., Madey, T. E., Sheer, M. D., The determination of work function from the ratio of positive to negative surface ionization of an alkali halide, Surface Sci. *3*, 277 (1965).

Fowler, F. A., Kikuchi pattern from a silicon wedge, Acta Cryst. *17*, No. 7, 869-871 (July 1964).

Fowler, F. A., Marton, L., Widths of transmission Kikuchi lines in silicon and diamond, J. Appl. Phys. *36*, No. 6, 1986-1995 (June 1965).

Franklin, A. D., Energy of the formation of the anion Frenkel pair in calcium fluoride, J. Phys. Chem. Solids *26*, 933-934 (1965).

Franklin, A. D., Impurity controlled properties of ionic solids, (Proc. Symp. Physics and Chemistry of Ceramics, Pennsylvania State Univ., University Park, Pa., May 28-30, 1963), Book, Physics and Chemistry of Ceramics, pp. 77-109 (Gordon and Breach, New York, N. Y., 1963).

Frenkiel, F. N., Klebanoff, P. S., Higher-order skewnesses in a turbulent field, Compt. Rend. *260*, 6026-6029 (1965).

Garfinkel, S. B., Mann, W. B., Medlock, R. W., Yura, O., The calibration of the NBS tritiated-toluene standard of radioactivity, Intern. J. Appl. Radiation Isotopes *16*, 27-33 (1965).

Gates, D. M., Characteristics of soil and vegetated surfaces to reflected and emitted radiation, Proc. 3d Symp. Remote Sensing of Environment, Infrared Phys. Lab., Inst. Sci. Tech., University of Michigan, Ann Arbor, Mich., Feb. 1965, pp. 573-600 (Mar. 1965).

Gates, D. M., Leaf temperature and energy exchange, Arch. Meteorol. Geophys. Bioklimatol. *12*, No. 2, 321-336 (1964).

Geltman, S., Continuum states of H^- and the free-free absorption coefficient, Astrophys. J. *141*, No. 2, 376-394 (Feb. 15, 1965).

Geltman, S., Takayanagi, K., Excitation of molecular rotation by slow electrons, Physics Letters *13*, No. 2, 135-137 (Nov. 15, 1964).

Goertz, A. E., Empirical relations for energy levels of atoms and ions, J. Opt. Soc. Am. *55*, 742-743 (June 1965).

Goodwin, R. D., Roder, H. M., Pressure-density-temperature relations of freezing liquid parahydrogen to 350 atmospheres, Cryogenics *3*, No. 1, 12-15 (Mar. 1, 1963).

Grabner, L., Optical quenching of photoconductivity near the band edge in CdS, Phys. Rev. Letters *14*, No. 14, 551-554 (Apr. 5, 1965).

Greiner, W., Danos, M., Coupling of particle-hole states and two particle-two hole states: splitting, Compt. Rend. Congres Intern. de physique Nucleaire, ed. P. Gugenberger, II, 617 (Editions du Centre National de la Recherche Scientific, Paris, France, 1964).

Gross, D., Robertson, A. F., Experimental fires in enclosures, Proc. 10th Symp. (Intern.) Combustion, Cambridge, England, Aug. 1964, pp. 931-942 (1965).

Guildner, L. A., Gas thermometer, Encyclopaedic Dictionary of Physics, pp. 405-406 (Pergamon Press Inc., New York, N. Y., 1961).

Gurney, P., Jr., Hutchinson, F., Young, R. D., Condensation of tungsten on tungsten in atomic detail: observation with the field ion microscope, J. Chem. Phys. *42*, No. 11, 3939-3943 (June 1965).

Gygax, S., Kropschot, R. H., Temperature and mean free path dependence of the Ginzburg-Landau parameter, Physics Letters *12*, No. 1, 7-9 (Sept. 1964).

Hall, J. L., Robinson, E. J., Branscomb, L. M., Laser double-quantum photodetachment of I^-, Phys. Rev. Letters *14*, No. 25, 1013-1016 (June 21, 1965).

Haller, W., Chromatography on glass of controlled pore size, Nature *206*, 693-696 (1965).

Haller, W., Rearrangement kinetics of the liquid-liquid immiscible microphases in alkali borosilicate melts, J. Chem. Phys. *42*, 686-693 (1965).

Harari, H., Lipkin, H. J., Meshkov, S., Γ_0 selection rules in SU(12) $-pp$ annihilation, Phys. Rev. Letters *20*, No. 14, 845-847 (May 1965).

Hayward, E., Photonuclear reactions, Book, Nuclear Structure and Electromagnetic Transitions, ed. N. MacDonald, pp. 141 (Oliver and Boyd, Edinburgh and London, England, 1965).

Herron, J. T., Rosenstock, H. M., Shields, W. R., Negative surface ionization of complex molecules, Nature *206*, No. 4984, 611 (May 1965).

Hilsenrath, J., Klein, M., Tables of thermodynamic properties of air in chemical equilibrium including second virial corrections from 1500 °K to 15,000 °K, Air Force Systems Command, AEDC-TR-65-58 (Arnold Engr. Develop. Center, Arnold Air Force Station, Tenn., Mar. 1965).

Hinchman, W. R., Buck, A. L., Fluctuations in a laser beam over 9- and 90-mile paths, Proc. *IEEE 52*, No. 3, 305-306 (Mar. 1964).

Hoffman, J. D., Theoretical aspects of polymer crystallization with chain folds: bulk polymers, SPE Trans. *4*, No. 4, 315-362 (Oct. 1964).

Horn, D., Kugler, M., Lipkin, H. J., Mechkov, S., Carter, J. C., Coyne, J. J., W-spin analysis of weak decays in U(12), Phys. Rev. Letters *14*, No. 17, 717-719 (Apr. 1965).

Howard, R. E., Lidiard, A. B., Matter transport in solids, Rept. Progr. Phys. *XXVII*, 161-240 (1964).

Howard, R. E., Lidiard, A. B., The annealing of vacancies in dilute alloys, Phil. Mag. *11*, No. 114, 1179-1187 (June 1965).

Hust, J. G., Gosman, A. L., Functions for the calculation of entropy, enthalpy, and internal energy for real fluids using equations of state and specific heats, (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19-21, 1963), Book, Advances in Cryogenic Engineering 9, Paper D-8, 227-233 (Plenum Press Inc., New York, N. Y., 1964).

Jackson, J. L., Coriell, S. R., On trapped trajectories in Brownian motion, J. Math. Phys. *5*, No. 8, 1075-1078 (Aug. 1964).

James, T. C., Thibault, R. J., Spin-orbit coupling constant of nitric oxide. Determination from fundamental and satellite band origins, J. Chem. Phys. *41*, No. 9, 2806-2813 (Nov. 1964).

Jefferies, J. T., Orrall, F. Q., Loop prominences and coronal condensations. I. Non-thermal velocities within loop prominences, Astrophys. J. *141*, No. 2, 505-518 (Feb. 15, 1965).

Jefferies, J. T., Orrall, F. Q., Loop prominences and coronal condensations. II. The source of mass and energy and a model of the loop prominence mechanism, Astrophys. J. *141*, No. 2, 519-525 (Feb. 15, 1965).

Jefferson, C. F., West, R. G., Magnetic properties of illmenite-hematite solid solutions, J. Am. Ceramic Soc. *47*, No. 11, 544-548 (Nov. 1964).

Jennings, D. A., Takuma, H., Optical heterodyne detection of the forward-stimulated Brillouin scattering, Appl. Phys. Letters *5*, 241-242 (Dec. 1964).

Johnson, E. G., Use of the index of refraction as a means for study of plasma configurations, Phys. Fluids *7*, No. 9, 1551-1552 (Sept. 1964).

Kahn, A. H., Leyendecker, A. J., Electronic energy bands in $SrTiO_3$ and related oxide semiconductors, Proc. 1964 Intern. Conf. Physics of Semiconductors, Paris, France, pp. 33-39 (Physique des Semiconductors, Paris, France, 1964).

Kahn, A. H., Leyendecker, A. J., Electronic energy bands in strontium titanate, Phys. Rev. *135*, No. 5A, A1321-A1325 (Aug. 31, 1964).

Kamper, R. A., Collier, R. S., Ohori, Y., Influence of spin paramagnetism on superconductivity, Phys. Rev. *137*, No. 1A, A75-A77 (Jan. 1965).

Kelly, F. J., Moore, D. G., A test of analytical expressions for the thermal emittance of shallow cylindrical cavities, (Symp. Thermal Radiation of Solids, San Francisco, Calif., Mar. 4-5, 1964), NASA Spec. Publ. *SP-55*, Session 1, Paper 10, pp. 117-131 (1965); Appl. Opt. *4*, No. 1, 31-40 (Jan. 1965).

Kessler, K. G., Schweitzer, W. G., Zeeman filter, J. Opt. Soc. Am. *55*, No. 3, 284-288 (Mar. 1965).

King, R. B., Corliss, C. H., Olsen, K. H., Oscillator strengths for lines of Fe I between 2500 and 3200A, Astrophys. J. *141*, No. 2, 354-363 (Feb. 1965).

Kirchhoff, W. H., Farren, J., Linnett, J. W., Calculation of electronic energies in HCO^+_2, HCO_2 and HCO^-_2, J. Chem. Phys. *42*, No. 4, 1410-1422 (Feb. 15, 1965).

Klein, L. S., Jackson, J. L., Continuum description of a high temperature plasma, Proc. VI Intern. Conf. Ionization Processes in Gases, Paris, France, 1963, II, No. 11, 215-216 (June 1964).

Klein, R., Observations of carbon monoxide and oxygen on tantalum with the field emission microscope, J. Chem. Phys. *41*, No. 2, 571 (July 1964).

Klose, J. Z., Atomic lifetimes in neon I, Astrophys. J. *141*, No. 2, 814-818 (Feb. 1965).

Koch, H. W., Eisenhower, E. H., Electron accelerators for food processing, (Proc. Intern. Conf. Radiation Preservation of Foods, Boston, Mass., Sept. 27-30, 1964), Natl. Acad. Sci.-Natl. Res. Council Publ. 1273, pp. 149-180 (1965).

Koidan, W., Siegel, S., Free-field correction for condenser microphones, J. Acoust. Soc. Am. *36*, No. 11, 2233-2234 (Nov. 1964).

Krauss, M., Miles, F. H., Interaction potential between He and H_2, J. Chem. Phys. *42*, No. 8, 2703-2708 (Apr. 15, 1965).

Kuyatt, C. E., Simpson, J. A., Mielczarek, S. R., Elastic resonances in electron scattering from He, Ne, Ar, Kr, Xe, and Hg, Phys. Rev. *138*, No. 2A, A385-A399 (Apr. 19, 1965).

Larsen, D. M., Energy levels of polarons in a magnetic field, Phys. Rev. *135*, No. 2A, A419-A426 (July 1964).

Laufer, A. H., Pirog, J. A., McNesby, J. R., Effect of temperature on the vacuum ultraviolet transmittance of lithium fluoride, calcium fluoride, barium fluoride, and sapphire, J. Opt. Soc. Am. *55*, No. 1, 64-66 (Jan. 1965).

Laufer, J. S., High silica glass, quartz, and vitreous silica, J. Opt. Soc. Am. *55*, No. 4, 458-460 (Apr. 1965).

Leavens, W. M., On the nature of plasma resonance, Physics Letters *15*, No. 4, 310-311 (Apr. 1965).

Lee, T. G., Loftus, J. L., Gross, D., Effect of moisture on surface flammability of coated and uncoated cellulosic materials, Am. Soc. Testing Materials Spec. Tech. Publ. *385*, 112-123 (May 1965).

Leiss, J. E., Beam loading in linear accelerators, IEEE Trans. Nuclear Sci. *NS-12*, No. 3, 566-579 (June 1965).

Lester, W. A., Krauss, M., Gaussian correlation functions: two-electron systems, J. Chem. Phys. *41*, No. 5, 1407-1413 (Sept. 1, 1964).

Lincoln, J. V., Geomagnetic and solar data, J. Geophys. Res. *69*, No. 13, 28-41 (July 1, 1964).

Lipkin, H. J., Meshkov, S., The W-spin and B-spin subgroups of SU(12), Phys. Rev. Letters *14*, No. 16, 670-672 (Apr. 1965).

Little, J. W., Madey, T. E., Klein, R., Work function measurements on field emitters with prescribed orientation, J. Appl. Phys. *36*, No. 4, 1491-1492 (Apr. 1965).

McCarty, R. D., Stewart, R. B., Thermodynamic properties of neon from 25 to 300 °K between 0.1 and 200 atmospheres, Book, Advances in

Thermophysical Properties at Extreme Temperatures and Pressures, pp. 84-97 (Am. Soc. Mech. Eng., New York, N. Y., 1965).

McCulloh, K. E., Sharp, T. E., Rosenstock, H. M., Direct observation of the decomposition multiply charged ions into singly charged fragments, J. Chem. Phys. *42*, No. 10, 3501-3509 (May 15, 1965).

McLane, C. K., Takeda, S., Thompson, R. C., Thomas, W. E., Jr., Electron density measurements in the magnetically confined arc, J. Appl. Phys. *36*, No. 2, 337-341 (Feb. 1965).

McLaughlin, W. L., Chalkley, L., Low atomic number dye systems for ionizing radiation measurement, J. Photo. Sci. Eng. *9*, No. 3, 159-166 (May-June 1965).

McLaughlin, W. E., Chalkley, L., Measurement of radiation dose distributions with photochromic materials, Radiology *84*, No. 1, 124-125 (Jan. 1965).

Macedo, P. B., Capps, W., Wachtman, J. B., Jr., Elastic constants of single crystal ThO_2 at 25 °C, J. Am. Ceram. Soc. *47*, No. 12, 651 (Dec. 1964).

Macedo, P. B., Litovitz, T. A., On the relative roles of free volume and activation energy in the viscosity liquids, J. Chem. Phys. *42*, No. 1, 245-256 (Jan. 1, 1965).

Madden, R. P., Codling, K., Two-electron excitation states in helium, Astrophys. J. *141*, No. 2, 364-375 (Feb. 1965).

Mann, W. B., The National Bureau of Standards tritiated water standards, J. Appl. Radiation Isotopes *15*, 628 (1964).

Manning, J. R., Correlation factors for impurity diffusion—Bcc, diamond, and Fcc structures, Phys. Rev. *136*, No. 6A, A1758-A1766 (Dec. 14, 1964).

Martin, J. B., Weiss, A. W., Calculations of the hyperfine splitting for the lithium atom, J. Chem. Phys. Letter *39*, No. 6, 1618-1620 (Sept. 15, 1963).

Marton, L. L., APS division of electron physics—the first 20 years, Phys. Today pp. 44-50 (Oct. 1964).

Marton, L. L., Experiments in electron scattering, Lab. Invest. *14*, pt. II, No. 6, 754 (1965).

Marton, L. L., Historical background of image formation, Lab. Invest. *14*, pt. I, No. 6, 739 (1965).

Marton, L. L., Optical constants in the vacuum ultraviolet and electron energy losses, J. Quant. Spectry. Radiative Transfer *2*, 671-678 (May 1964).

Marvin, R. S., McKinney, J. E., Volume relaxations in amorphous polymers, Book, Physical Acoustics, ed. W. P. Mason, IIB, chapt. 9, 165-229 Academic Press Inc., New York, N. Y., 1965).

Maryott, A. A., Kryder, S. J., Collision induced microwave absorption in compressed gases. III. CO_2-foreign-gas mixtures, J. Chem. Phys. *41*, No. 6, 1580-1582 (Sept. 15, 1964).

Mauer, F. A., Keffer, C. J., Reeves, R. B., Robinson, D. W., Polymorphism

in hydrogen iodide, J. Chem. Phys. *42*, No. 4, 1465-1466 (Feb. 15, 1965).

Maximon, L. C., Isabelle, D. B., Calculation of the radioactive tail in the inelastic scattering electrons, Proc. Intern. Conf. Nuclear Physics, Paris, France, July 2-8, 1964, 2, 1031-1033 (1964).

Maximon, L. C., Isabelle, D. B., Radiative tail for inelastic electron scattering, Phys. Rev. *136*, No. 3B, B674-683 (Nov. 1964).

Mazur, J., Application of the theory of absorbing Markov chains to the statistical thermodynamics of polymer chains in a lattice, J. Chem. Phys. *41*, No. 8, 2256-2266 (Oct. 1964).

Meshkov, S., Snow, G. A., Yodh, G. B., "U-spin equalities" and octet symmetry breaking, Phys. Rev. Letters *13*, No. 6, 212-217 (Aug. 1964).

Meyer-Arendt, J. R., Optical depolarization and scintillation measurements over a terrestrial path, Proc. 3d Tropospheric Refraction Effects Meeting 1, 115-123 (Nov. 1964).

Meyer-Arendt, J. R., Shettle, E. P., Calibration of Schlieren systems, J. Appl. Opt. Letter to Editor *4*, No. 6, 757 (June 1965).

Mielenz, K. D., Nefflen, K. F., Gas mixtures and pressures for optimum output power of RF excited helium-neon gas lasers at 632.8 nm, Appl. Opt. Letter *4*, 565 (May 1965).

Mies, F. H., Critical examination of vibrational energy transfer theory, J. Chem. Phys. *42*, No. 8, 2709-2720 (Apr. 15, 1965).

Mies, F. H., Impact parameter treatment of vibrational excitation, J. Chem. Phys. *41*, No. 3, 903-904 (Aug. 1, 1964).

Milligan, D. E., Jacox, M. E., Bass, A. M., Comeford, J. J., Mann, D. E. Matrix-isolation study of the reaction of F atoms with CO. Infrared and ultraviolet spectrum of the free radical FCO, J. Chem. Phys. *42*, No. 9, 3187-3195 (May 1965).

Minardi, E., Englemann, F., Feix, M., Connection between shielding and stability in a collisionless plasma, Il Nuovo Cimento Serie X *30*, 830-836 (Nov. 1963).

Mockler, R. C., Richardson, J. M., Some considerations relative to an atomic definition for the unit of time, Proc. Consultative Committee for the Definition of the Second of the Intern. Comm. of Weights and Measures, Paris, France, Apr. 1961, pp. 58-65 (Dec. 1964).

Moore, C. E., Annual observatory report from the National Bureau of Standards, Astron, J. *69*, No. 9, 696-698 (Nov. 1964).

Moore, C. E., Minutes of the meeting at Tokyo, Japan, of the triple commission for spectroscopy, Sept. 9, 1962, J. Opt. Soc. Am. *53*, No. 7, 883-893 (July 1963).

Moore, C. E., Report of subcommittee D-atomic spectra, J. Opt. Soc. Am. Tech. Notes *55*, No. 6, 745 (1965).

Mopsik, F. I., Tables of dielectric constants, diopole moments and dielectric relaxation times, 1963 Digest Lit. Dielectrics Publ. 1230, 27, 23-55 (1964).

Morgan, A. H., Blair, B. E., Crow, E. L., International comparison of atomic frequency standards via VLF radio signals, Book, Progress in Radio Science 1960-1963. Vol. *I*. Radio Standards and Measurements, pp. 40 (Elsevier Publ. Co., Amsterdam, The Netherlands, 1965).

Mosburg, E. R., Persson, K.-B., Nonlinear ambipolar diffusions of an isothermal plasma across magnetic field, Phys. Fluids *7*, No. 11, 1829-1833 (Nov. 1964).

Motz, J. W., Olsen, H., Koch, H. W., Electron scattering without atomic or nuclear excitation, Rev. Mod. Phys. *36*, No. 4, 881-928 (Oct. 1964).

Motz, J. W., Placious, R. C., K-ionization cross sections for relativistic electrons, Phys. Rev. *136*, No. 3A, A662-A665 (Nov. 2, 1964).

Nettleton, R. E., Non-equilibrium thermodynamics of creep in polycrystals, Physica *20*, 1989-2002 (1964).

Norton, R. B., A theoretical study of the Martian and Cytherian ionospheres, Natl. Aero. Space Admin. Tech. Note *D-2333* (July 1964).

Olsen, H., Maximon, L. C., Polarized electrons and positrons by tagging technique, Phys. Rev. Letters *13*, No. 3, 112-114 (July 1964).

O'Malley, T., Geltman, S., Compound-atom states for two-electron systems, Phys. Rev. *137*, No. 5A, A1344-A1352 (Mar. 1, 1965).

Oppenheim, I., Shuler, K. E., Master equations and Markov processes, Phys. Rev. *138*, No. 4B, B1007-B1011 (May 1965).

Orentlicher, M., Prausnitz, J. M., Thermodynamics of hydrogen solubility in cryogenic solvents at high pressures, Chem. Eng. Sci. *19*, 775-782 (Oct. 1964).

Oser, H. J., Shuler, K. E., Weiss, G., Relaxation of a Lorentz gas with a repulsive r^{-s} force law, J. Chem. Phys. *41*, No. 9, 2661-2666 (Nov. 1964).

Paretzkin, B., Peiser, H. S., High voltage Laue X-ray photography of large single crystals, Science *146*, 260 (1964).

Parker, R. L., Coriell, S. R., Stability of the shape of a solid cylinder growing in a diffusion field, J. Appl. Phys. *36*, No. 2, 632-637 (Feb. 1965).

Parker, R. L., Hardy, S. C., Vapor-phase growth kinetics of potassium and mercury crystals, (Proc. Intern. Symp. Condensation and Evaporation of Solids, Dayton, Ohio, Sept. 12-14, 1962), Book, Condensation and the Evaporation of Solids, Section II. Condensation of Solids, pp. 649-664 (Gordon and Breach, New York, N. Y., 1964).

Passaglia, E., Mechanical and dielectric relaxation of crystalline polymers in relation to degree of crystallinity and morphology, SPE Trans. *4*, No. 3, 169-177 (July 1964).

Payne, R. D., Forman, R. A., Kahn, A. H., Nuclear magnetic resonance in $RbMnF_3$, J. Chem. Phys. *42*, No. 11, 3806-3808 (June 1965).

Pecker-Wimel, C., Thomas, R. N., Possible implications of the observed profile of [λ6374] Fe X, Astrophys. J. *141*, No. 2, 834-836 (Feb. 15, 1965).

Peterson, R. L., Effects of finite lattice heat capacity on spin-lattice relaxation, Phys. Rev. *137*, No. 5A, A1444-A1448 (Mar. 1965).

Petree, B., Humphreys, J. C., The intensity and spectral distribution of scattered radiation from Co^{60} sources, Radiology *84*, No. 1, 129-130 (Jan. 1965).

Pollack, G. L., The solid state of rare gases, Rev. Mod. Phys. *36*, No. 3, 748-792 (July 1964).

Pollack, G. L., Farabaugh, E. N., Crystal growth and thermal etching of argon, J. Appl. Phys. *36*, 513 (1965).

Polack, G. L., Pellam, J. R., Wave mode modification in liquid helium with clamped normal fluid, Proc. 9th Intern. Conf. Low Temperature Physics, Columbus, Ohio, Sept. 1964, pp. 166 (Plenum Press Inc., New York, N. Y., 1965); Phys. Rev. *137*, A1676-A1684 (Mar. 1965).

Prat, F., Fano, U., Metastable levels in the continuum and the independent particle model, Proc. III Intern. Conf. Physics of Electronics and Atomic Collisions, London, England, pp. 600-605 (July 22-26, 1963).

Pruitt, J. S., High energy X-ray photon albedo, Nuclear Instr. Methods *27*, 23 (1964).

Radford, H. E., 18 cm spectrum of OH, Phys. Rev. Letters *13*, No. 17, 534-535 (Oct. 1964).

Radford, H. E., Hyperfine structure of the $B^2\Sigma^+$ state of CN, Phys. Rev. *136*, No. 6A, A1571-1575 (Dec. 14, 1964).

Rauth, A. M., Simpson, J. A., The energy loss of electrons in solids, Radiation Res. *22*, No. 4, 643-661 (1964).

Reader, J., Sugar, J., Nuclear magnetic moment of Pr^{141} from the hyperfine structure of doubly ionized praseodymium, Phys. Rev. *137*, No. 4B, B784-B789 (Feb. 1965).

Reber, M. J., Potential distribution in a rectangular semiconductor bar for use with four-point probe measurements, Solid State Electron. *7*, No. 7, 525-529 (July 1964).

Roder, H. M., Weber, L. A., Goodwin, R. D., The correlation of experimental pressure-density-temperature and specific heat data for parahydrogen, (Proc. XI Intern. Congress Refrigeration, Munich, Germany, Aug. 1963), Prog. Refrig. Sci. Technol. *1*, 187-191 (1963).

Ruegg, F. C., Spijkerman, J. J., DeVoe, J. R., Drift-free Mossbauer spectrometer, Rev. Sci. Instr. *36*, No. 3, 356-359 (Mar. 1965).

Seltzer, S. M., Berger, M. J., Energy loss straggling of protons and mesons: tabulation of the Vavilov distribution, Natl. Acad. Sci.-Natl. Res. Council Publ. 1133. Studies in the Penetration of Charged Particles in Matter, chapt. 9, pp. 187-203 (1964).

Shafer, A. B., Megill, L. R., Droppleman, L. A., Optimization of the Czerny-Turner spectrometer, J. Opt. Soc. Am. *54*, No. 7, 879-887 (July 1964).

Shimazaki, T., Nighttime variations of F-region electron density profiles at Puerto Rico, J. Geophys. Res. *69*, No. 13, 2781-2797 (July 1, 1964).

Shorb, A. M., Schroeder, R., Lippincott, E. R., Wave functions for anharmonic oscillators by perturbation methods, J. Chem. Phys. *37*, 1043 (Sept. 1, 1962).

Sickafus, E. N., Winder, D. R., Growth spirals on $NiBr_2$ platelets, J. Appl. Phys. 35, No. 8, 2541-2545 (Aug. 1964).

Simmons, J. A., Parker, R. L., Howard, R. E., Theory of whisker growth and evaporation, J. Appl. Phys. *35*, No. 7, 2271-2272 (July 1964).

Slutz, R. J., Winkelman, J. R., Shape of the magnetosphere boundary shape under solar wind pressure, J. Geophys. Res. *69*, No. 23, 4933-4948 (Dec. 1964).

Smith, L. L., Roach, F. E., Owen, R. W., The absolute photometry of the zodiacal light, Planet Space Sci. *13*, 207-217 (Mar. 1965).

Smith, W. W., Hyperfine structure of Hg^{193*}, Hg^{195} and Hg^{195*} by Zeeman level crossings, Phys. Rev. *137*, No. 2A, A330-A339 (Jan. 18, 1965).

Solarski, J. E., Wiese, W. L., Experimental transition probabilities for six oxygen multiplets, Phys. Rev. *135*, No. 5A, A1236-A1241 (Aug. 1964).

Ruff, A. W., Jr., Wilsdorf, H. G. F., Observations of dislocation sources in stainless steel, Acta Met. *13*, No. 6, 694-695 (1965).

Scheer, M. D., Fine, J., The surface ionization of niobium, J. Chem. Phys. *42*, 3645 (1965).

Schiff, H. I., Megill, L. R., The influence of metastable oxygen molecules on ozone and airglow, J. Geophys. Res. *69*, No. 23, 5120-5121 (Dec. 1, 1964).

Schooley, J. R., Hoppes, D. D., The gamma-ray distribution from oriented cerium-141 and its application to thermal contact at low temperature, (Proc. 8th Intern. Conf. Low Temperature Physics, Queen Mary College, London, England, Sept. 1963), Book, Low Temperature Physics, ed. R. O. Davies, pp. 435-436 (Butterworth Inc., Washington, D. C., 1963).

Schooley, J. F., Hosler, W. R., Ambler, E., Becker, J. H., Cohen, M. L., Koonce, C. S., Dependence of the superconducting transition temperature on carrier concentration in semiconducting $SrTiO_3$, Phys. Rev. Letters *14*, No. 9, 305-307 (Mar. 1, 1965).

Scott, R. B., Introduction, Book, Technology and Uses of Liquid Hydrogen, chapt. 1, pp. 1-8 (Pergamon Press Ltd., London, England, 1964).

Scott, R. B., Liquefied gases, handling of, Encyclopaedic Dictionary of Physics, 4, 329-330 (Pergamon Press Inc., New York, N. Y., 1961).

Scott, R. B., Liquid air, Encyclopaedic Dictionary of Physics, 4,330 (Pergamon Press Inc., New York, N. Y., 1961).

Scott, R. B., Low-temperature apparatus, constructional materials for, Encyclopaedic Dictionary of Physics, 4, 357-358 (Pergamon Press Inc., New York, N. Y., 1961).

Spector, N., Configurations $4f^26s$ and $4f^26p$ in doubly ionized Pr, J. Opt. Soc. Am. *54*, No. 11, 1359-1362 (Nov. 1964).

Spector, N., 4fnl configurations of doubly ionized cerium (Ce III), J. Opt. Soc. Am. *55*, No. 5, 492-501 (May 1965).

Spector, N., New odd low levels of neutral erbium (Er I), J. Opt. Soc. Am. *55*, No. 5, 576-577 (May 1965).

Spencer, L. V., Note on the theory of cavity ionization chambers, Radiation Res. *25*, No. 2, 352-358 (June 1965).

Steinert, L. A., Electromagnetic properties of a quantized relativistic electron-position gas, Il Nuovo Cimento, Serie X *36*, 935-953 (Apr. 1965).

Stern, K. H., Conductance of glass immersed in molten salts, J. Electrochem. Soc. *112*, No. 2, 208-211 (Feb. 1965).

Sugar, J., Description and analysis of the third spectrum of cerium (Ce III), J. Opt. Soc. Am. *55*, No. 1, 33-58 (Jan. 1965).

Sugar, J., Energy levels of Pr^{3+} in the vapor state, Phys. Rev. Letters *14*, No. 18, 731-732 (May 1965).

Swanson, N., Observed line shapes of collective excitations in Al, Be, and Ge, J. Opt. Soc. Am. *54*, No. 9, 1130-1133 (Sept. 1964).

Takayanagi, K., Geltman, S., Excitation of molecular Rotation by slow electrons, Physics Letters *13*, No. 2, 135-137 (Nov. 15, 1964); Phys. Rev. *138*, No. 4A, A1003-A1010 (May 17, 1965).

Takuma, H., Jennings, D. A., Stimulated Brillouin scattering in the off-axis resonator, Appl. Phys. Letters *5*, No. 12, 239-241 (Dec. 1964).

Thomas, D. B., Studies on the tungsten-rhenium thermocouple to 2000 °C, Proc. 18th Annual ISA Conf. and Exhibit, Sept. 9-12, 1963, Chicago, Ill., Preprint 57.3.63, pp. 67.3.63-1—57.3.63-9 (1963).

Thomas, R. N., Comment on the difference between a non-LTE and a pure absorption, model for the line-blanketing effect, Astrophys. J. *141*, No. 1, 333-335 (Jan. 1, 1965).

Thomas, R. N., Microscopic-astrophysics and the development of astrophysical laboratories, Bull. Assoc. Develop. Intern. Observatoire de Nice, No. 1, pp. 7-16 (1964).

Wacks, M. E., Franck-Condon factors for the ionization of CO, NO, and O_2, J. Chem. Phys. *41*, No. 4, 930-936 (Aug. 1964).

Wagner, R., Miller, P. D., Tamura, T., Marshak, H., The interaction of 350 keV polarized neutrons with oriented Ho^{165} nuclei, Physics Letters *10*, No. 3, 316-318 (June 15, 1964).

Wait, J. R., Radiation from sources immersed in compressible plasma media, Can. J. Phys. *42*, 1760-1780 (Sept. 1964).

Wait, J. R., Resonances of a spherical void in a compressible isotropic plasma, J. Geophys. Res. *69*, No. 19, 4189-4191 (Oct. 1, 1964).

Walker, D., an experimental study of the backscattering of 5.3 meV alpha particles from platinum and monel metal, Intern. J. Appl. Radiation Isotopes *16*, 183-189 (1965).

Warwick, C. S., Longitude distribution of proton flares, Astrophys. J. *141*, No. 2, 500-504 (Feb. 15, 1965).

Wasilik, J. H., Wheat, M. L., Elastic constants of cubic lead fluoride at room temperature, J. Appl. Phys. *36*, No. 3, Pt. 1, 791-793 (Mar. 1965).

Wassink, H. W., Estin, A. J., Investigation of plasma boundaries with electromagnetic surface waves, J. Appl. Phys. *35*, No. 10, 2795-2800 (Oct. 1964).

Waterhouse, R. V., Cook, R. K., Interference patterns in reverberent sound fields, II, J. Acoust. Soc. Am. *37*, No. 3, 424-428 (Mar. 1965).

Weinstock, J., Generalized master equation for quantum-mechanical systems to all orders in the density, Phys. Rev. *136*, 2d Series, No. 4A, A879-A888 (Nov. 1964).

Weinstock, J., Microscopic fluctuations and diffusion coefficients of a non-equilibrium plasma in a magnetic field, Phys. Fluids *8*, No. 3, 479-481 (Mar. 1965).

Weinstock, J., On the binary collision expansion of the classical N-body Green's function, Phys. Rev. *126*, No. 1, 341-344 (Apr. 1, 1962).

Westwater, E. R., A method for determination of the tropospheric temperature structure from ground-based measurement of oxygen emission, Proc. 3d Symp. Remote Sensing of Environment, Infrared Phys. Lab., Inst. Sci. Tech., University of Michigan, Ann Arbor, Mich., Feb. 1965, pp. 245-256 (Mar. 1965).

White, J. A., stability of traveling waves in lasers, Phys. Rev. *137*, No. 6A, A1651-A1654 (Mar. 1965).

Wieder, B., Microwave propagation in an overdose bounded magnetic-plasma, Phys. Fluids *7*, No. 7, 964-972 (July 1964).

Womack, C. M., Jr., Silverman, J. N., Atomic scattering factors for the lithium and beryllium isoelectronic sequences from accurate analytic Hartree-Fock wave functions, Z. Kryst. *118*, No. 5-6, 422-433 (Sept. 1963).

Wood, L. A., Unorthodoxy in science, J. Wash. Acad. Sci. *51*, 30 (Mar. 1961).

Wood, L. A., Utility of the Tait equation relating volume and pressure in the study of transitions in polymers, J. Polymer Sci. *B2*, No. 7, 703-707 (July 1964).

Wyckoff, J. M., Koch, H. W., Ziegler, B., Uhlig, R., Total photonuclear cross sections for low atomic number elements, Phys. Rev. *137*, No. 3B, B576-B594 (Feb. 1965).

Yolken, H. T., Kruger, J., Optical constants of iron in the visible region, J. Opt. Soc. Am. *55*, No. 7, 843-844 (June 1965).

Young, R. D., Schubert, D. C., Condensation of tungsten on tungsten in atomic detail: Monte Carlo and statistical calculations vs. experiment, J. Chem, Phys. *42*, No. 11, 3943-3950 (June 1965).

Zeitler, E., Olsen, H., Screening effects in elastic electron scattering, Phys. Rev. *136*, No. 6A, A1546-A1552 (Dec. 1964).

Zwanzig, R., On the validity of the Einstein-Smoluchowski theory of light scattering, J. Am. Chem. Soc. *86*, 3489-3493 (Mar. 30, 1964).

Radio Science

Andrews, D. H., LF-VLF frequency and time services of the National Bureau of Standards, (Proc. 19th Annual ISA Conf. and Exhibit, New York, N. Y., Oct. 12-15, 1964), ISA Preprint 21.3-2-64 (1964).

Bean, B. R., Attenuation of radio waves in the troposphere, Book, Advances in Radio Research 1, 121-155 (Academic Press, Inc., New York, N. Y., 1964).

Bean, B. R., Westwater, E. R., Abbott, R. L., Potential use of passive probing of atmospheric structure by thermal emissions at radio frequencies, Proc. 1963 Intern. Symp. Humidity and Moisture, Washington, D. C.), Book, Humidity and Moisture. Measurement and Control in Science and Industry. Vol. *2*. Applications, sec. VII, Paper 71, pp. 595-608 (Reinhold Publ. Corp., New York, N. Y., 1965).

Calvert, W., Knecht, R. W., VanZandt, T. E., Ionosphere explorer I satellite: first observations from the fixed-frequency topside sounder satellite, Science *146*, No. 3642, 391-395 (Oct. 16, 1964).

Chivers, H. J. A., Conjugate point observations at a variety of high geomagnetic latitudes, AGARDograph *78*, Artic Communications, chapt. 2, pp. 27-28 (Pergamon Press, Inc., London, England, 1964).

Chivers, H. J. A., Hargreaves, J. K., Ionospheric absorption in conjugate regions and possible oscillation of the exosphere, Nature *202*, No. 4935, 891-893 (May 30, 1964).

Cohen, R., Farley, D. T., Jr., Comments on the paper "An experimental investigation of backscattering of radio waves from the equatorial elecjet," by R. L. Closs, Proc. Phys. Soc. *84*, pt. 4, No. 540, 619-620 (J. W. Arrowsmith Ltd., London, England, June 1964).

Crombie, D. D., Rath, H. L. Reversal of the diurnal phase variations of GBR (16 kilocycles per second) observed over a path of 720 kilometers, J. Geophys. Res. *69*, No. 23, 5023-5027 (Dec. 1, 1964).

Davies, K., Ionospheric propagation at high frequencies, 4UITU Calling 2, 112-113 (1965).

Davies, K., Prediction of ionospheric characterisitcs at CRPL for skywave radio propagation at high frequencies, Telecommunications J. *31*, No. 12, 339-350 (Dec. 1964).

Davies, K., The use of topside sounders in ionospheric research, ITU Telecommunications J. pp. 1-8 (Mar. 1965).

Davies, K., The uses of oblique ionograms in frequency utilization, Telecommunications J. *31*, No. 10, 281-287 (Oct. 1964).

Davies, K., Baker, D. M., Ionospheric effects observed around the time of the Alaskan earthquake of March 28, 1964, J. Geophys. Res. *70*, No. 9, 2251-2253 (May 1, 1965).

Dougherty, H. T., Fading on microwave line-of-sight paths, Proc. 3d Tropospheric Refraction Effects Meeting 1, 125-135 (Nov. 1964).

Dutton, E. J., Bean, B. R., Westwater, E. R., Brightness temperature of the atmosphere using a bi-exponential model in the 6-45 GHz frequency

range, Proc. 1964 World Conf. Meteorology and 11th Weather Radar Conf., pp. 212-215 (Sept. 1964).

Fejer, J. A., Calvert, W., Resonance effects of electrostatic oscillations in the ionosphere, J. Geophys. Res. *69*, 5049-5062 (Dec. 1964).

Ferguson, E. E., Fehsenfeld, F. C., Dunkin, D. B., Schmeltekopf, A. L., Schiff, H. I., Laboratory studies of helium ion loss processes of interest in the ionosphere, Planetary Space Sci. *12*, 1169-1171 (Dec. 1964).

FitzGerrell, R. G., Radiation efficiency of half-wave dipole antennas, IEEE Trans. Ant. Prop. *AP-13*, No. 2, 326-327 (Mar. 1965).

Gallet, R. M., Natural electromagnetic phenomena below 30 kc/s, NATA Advance Study Institute, Bad Hamberg, 1963, pp. 167-204 (Plenum Press Inc., New York, N. Y., 1964).

Hargreaves, J. K., Chivers, H. J. A., Fluctuations in ionospheric absorption events at conjugate stations, Nature *203*, No. 4948, 963-964 (Aug. 29, 1964).

Hargreaves, J. K., Chivers, H. J. A., Petlock, J. D., A Study of auroral absorption events at the South Pole. 1. Characteristics of the events, J. Geophys. Res. *69*, No. 23, 5001-5007 (Dec. 1964).

Haurwitz, M. W., Solar flares with associated active dark filaments and their relation to 2800-Mc/s radio bursts, Astrophys. J *140*, No. 3, 1236-1246 (Oct. 1, 1964).

Herbstreit, J. W., Editor, Propagation and technical factors in radio spectrum utilization, RADIO SPECTRUM UTILIZATION, A report of the Joint Technical Advisory Committee of the Institute of Electrical and Electronics Engineers, Inc. and the Electronic Industries Association, chapt. III, pp. 30-208 (1964).

Herbstreit, J. W., Radio meteorology, Science *147*, No. 3653, 76-78 (Jan. 1, 1965).

Hildner, E., Receiver noise factor, Proc. Intern. Telemetry Conf., Washington, D. C., May 16-20, 1964, 1, 326-333 (May 1965).

Jean, A. G., Wait, J. R., The use of electromagnetic signals emitted from nuclear explosions to study of long-range VLF propogation, J. Geophys. Res. *70*, No. 5, 1258-1261 (Mar. 1, 1965).

Johler, J. R., Harper, J. D., Jr., On the effect of solar disturbances on the low-radiofrequency ionosphere reflection process, (North Atlantic Treaty Organization. Advisory Group for Aeronautical Research and Development. Avionics Panel. 6th Symp. Ionospheric Research Committee, AGARD, Naples, Italy, 1961). Book, The Effect of Disturbances of Solar Origin on Communications, ed. G. J. Gassman, pp. 303-304 (Pergamon Press, Inc., New York, N. Y., 1963).

Jones, W. G., Gallet, R. M., Representation of diurnal and geographic variations of ionospheric data by numerical methods. II. Control of stability, Telecommunications J. pp. 1-12 (Jan. 1965).

Klemperer, W. K., Ochs, G. R., Radio astronomy observations with

8.4 x $10^4 m^2$ 50 Mc/s antenna of the Jicamarca radar in Peru, Astron. J. *70*, N. 1327, 141-142 (Mar. 1965).

Knecht, R. W., The distribution of electrons in the lower and middle ionosphere, Book, Progress in Radio Science 1960-1963. Vol. *III*. the Ionosphere, pp. 14-45 (Elsevier Publ. Co., Amsterdam, The Netherlands, 1965).

Larson, W. E., Microwave and high-frequency calibration services of the National Bureau of Standards, IEEE Trans. Microwave Theory and Tech. *MTT-12*, No. 4, 480-482 (July 1964).

Little, C. G., National Bureau of Standards Central Radio Propagation Laboratory, Boulder, Astron. J. *69*, No. 9, 698-700 (Nov. 1964.)

Little, C. G., Schiffmacher, E. R., Chivers, H. J. A., Sullivan, K. W., Cosmic noise absorption events at geomagnetically conjugate stations, J. Geophys. Res. *70*, No. 3, 639-648 (Feb. 1, 1965).

Megill, L. R., Cahn, J. H., The calculation of electron energy distribution functions in the ionosphere, J. Geophys. Res. *69*, No. 23, 5041-5048 (Dec. 1, 1964).

Norton, R. B., VanZandt, T. E., The daytime equatorial F-layer, J. Atmospheric and Terrest. Phys. *26*, No. 11, 1047-1054 (Nov. 1964).

Reid, G. C., The contribution of nonthermal electrons to auroral absorption of radio waves, J. Geophys. Res. *69*, No. 15, 3296-3298 (Aug. 1964).

Rice, P. L., Herbstreit, J. W., Tropospheric propagation, Advan. Electron. Electron Phys. *20*, 199-259 (1964).

Roach, F. E., The light of the night sky: astronomical interplanetary and and geophysical, Space Sci. Rev. *3*, 512-540 (Nov. 1964).

Samson, C. A., A comparison of mountain slope and radiosonde observations, Mo. Weather Rev. *93*, No. 5, 327-330 (May 1965).

Shapley, A. H., The ionosphere; new guide, how to listen to the world, World Publ. *11*, 15-18 (Hellerup, Denmark, Mar. 1965).

Shimazaki, T., Dependence of the critical frequency of the ionospheric E-layer on solar zenith angle and the annual variation in E-layer ionization, Nature *205*, No. 4974, 889-891 (Feb. 27, 1965).

Thompson, M. C., Jr., ESD Maui, Hawaii, measurements, Proc. 3d Tropospheric Refraction Effects Meeting *1*, 89-93 (Nov. 1964).

Thompson, M. C., Jr., Grant, W. B., Noise tests of an airborne microwave refractometer system, Rev. Sci. Instr. *36*, No. 6, 758-759 (June 1965).

Wait, J. R., Cavity resonances for a spherical earth and a concentric shell, J. Atmospheric Terrest. Phys. *27*, 81-89 (1965).

Wait, J. R., Coherence theories of tropospheric radio propagation, IEEE Trans. Ant. Prop. *AP-12*, No. 5, 649-651 (Sept. 1964).

Wait, J. R., Justification for neglecting the compressibility of the ionosphere in VLF radio propagation, IEEE Trans. Ant. Prop. *AP-13*, 480-481 (May 1965).

Wait, J. R., Nature of the electromagnetic field reflected from a coastline, Electronics Letters *1*, 65 (May 1965).

Wait, J. R., Jackson, C. M., Influence of the refracitve index profile in VHF reflection from a tropospheric layer, IEEE Trans. Ant. Prop. *AP-12*, No. 4, 512-513 (July 1964).

Wright, J. W., Golomb, D., Rosenberg, N. W., Barnes, J. A., Formation of an electron depleted region in the ionosphere by chemical releases, (Proc. 4th Intern. Space Science Symp., Warsaw, Poland, June 4-10, 1963), Book, Space Research IV, 389-398 (North-Holland Publ. Co., Amsterdam, The Netherlands, 1964).

PATENTS

The following U.S. Patents have been granted to NBS inventors; the patents are assigned (or licensed as indicated) to the United States of America, as represented by the Secretary of the department noted in parentheses:

Orem, Theodore H., No. 3,139,653, July 7, 1964. Apparatus for the Growth of Preferentially Oriented Single Crystals of Metals. (Commerce)

Brenner, Abner; Reid, Walter E. Jr., and Connor, Jean H., No. 3,139,658, July 7, 1964. Production of Tungsten Objects. (NAVY)

Edwards, James W. and Hashman, Joseph S., No. 3,140,990, July 14, 1964. Method of Preparation of Ozone. (ARMY)

Harman, George G. Jr., No. 3,141,238, July 21, 1964. Method of Low Temperature Bonding for Subsequent High Temperature Use. (Commerce)

Couch, Dwight E.; Shapiro, Harold; and Brenner, Abner, No. 3,141,744, July 21, 1964. Wear-Resistant Nickel-Aluminum Coatings. (NAVY)

Henig, Seymour, No. 3,144,948, August 18, 1964. Collocating Machine Using a Time-Position Code. (Commerce)

Berlinsky, Anthony A.; Brennan, Martin J.; and Stockton, Charles H., No. 3,145,920, August 25, 1964. Floating-Point Keypunch Machine. (Commerce)

Pummer, Walter J. and Wall, Leo A., No. 3,150,163, September 22, 1964. Pentafluorobenzonitrile and Method of Making the Same. (NAVY)

Rosenberg, Samuel J. and Royston, Thomas P. Jr., No. 3,156,558, November 10, 1964. High-Density, Nonmagnetic Stainless Steel. (Commerce)

Vetter, Maurice J., No. 3,158,825, November 24, 1964. Movable Resonant Cavity Tuning Probe in Dielectric Sleeve Having Nonuniform Outer Surface. (Commerce)

Harman, George G. Jr.; and Raybold, Richard L., No. 3,160,764, December 8, 1964. Pulse Shaper Employing Charge-Storing Semiconductor Device. (Commerce)

Ordway, Fred D. Jr., No. 3,164,782, January 5, 1965. Gas-Filled Envelope for Solid Laser Tube Having Internal Electrodes. (Licensed to the United States of America as represented by the Secretary of Commerce.)

Engen, Glenn F., No. 3,166,725, January 19, 1965. Broadband Tuning Transformer Permitting Independent Matching at Adjacent Frequencies. (Commerce)

Berlinsky, Anthony A., and Brennan, Martin J., No. 3,167,244, January 26, 1965. Automatic or Manual Multiple Programmer. (Commerce)

Doherty, Robert H. and Davis, Thomas L., No. 3,167,770, January 26, 1965. Time-Multiplex System for the Distribution of Serial Pulse Time Codes with Microsecond Synchronization. (AIR FORCE)

Hoekstra, Harold D., No. 3,174,710, March 23, 1965. Take-Off Safety Indicator. (Licensed to the United States of America as represented by the Secretary of Commerce.)

Guildner, Leslie A. and Stimson, Harold F., No. 3,177,017, April 6, 1965. Ball and Socket Pipe Joint. (Commerce)

Montgomery, George Franklin, No. 3,177,421, April 6, 1965. Rectified Alternating-Current Converter. (Commerce)

Bowen, Rafael L., No. 3,179,623, April 20, 1965. Method of Preparing a Monomer Having Phenoxy and Methacrylate Groups Linked by Hydroxy Glyceryl Groups. (Commerce)

Castle, Alfred B., No. 3,183,512, May 11, 1965. Mechanical Graphic Recording Omni-Directional Accelerometer. (NAVY)

Thompson, Moody C. Jr., No. 3,188,634, June 8, 1965. Distance Measuring System with Automatic Index Compensation. (Commerce)

Metzger, William H., No. 3,189,990, June 22, 1965. Method of Preparing Small Diameter Tubes And the Like. (Commerce)

Wall, Leo A. and Pummer, Walter J., No. 3,192,190, June 29, 1965. Octafluorovinylphenyl Ether and Its Polymers. (NAVY)

Allred, Charles M., No. 3,192,372, June 29, 1965. Signal-Level Comparing System. (Commerce)

Bender, Peter L. and Beaty, Earl C., No. 3,192,472, June 29, 1965. Alkali Vapor Frequency Standard Utilizing Optical Pumping. (Commerce)

THE GENERAL CONFERENCE ON WEIGHTS AND MEASURES

The Twelfth General Conference on Weights and Measures, held at the International Bureau of Weights and Measures, Paris, France, from October 6 to 13, 1964, was attended by representatives of 37 nations. These gatherings have been historic occasions since their beginning in 1875 under the Treaty of the Meter. The Conference focuses attempts to enhance the universality of science by fostering the growth of a common language among nations of diverse outlooks and backgrounds.

Actions taken by the Conference include:

—provisionally redefining the second, the international unit of time. Contrasted to the previous astronomical definition, the second is now also measured in terms of an invariant transition of the cesium atom. The accuracy obtainable is 1 part in 10^9, an increase of 200 times.

—approving twelve secondary wavelengths for the international standards of length.

A. Wavelengths of Krypton 86
   6,458.0720 10^{-10} meter
   6,422.8006 10^{-10} meter
   5,651.1286 10^{-10} meter
   4,503.6162 10^{-10} meter

B. Wavelengths of mercury 198
   5,792.2683 10^{-10} meter
   5,771.1983 10^{-10} meter
   5,462.2705 10^{-10} meter
   4,359.5624 10^{-10} meter

C. Wavelengths of cadmium 114
   6,440.2480 10^{-10} meter
   5,087.2379 10^{-10} meter
   4,801.2521 10^{-10} meter
   4,679.4581 10^{-10} meter

—accepting a new definition for volumetric measurements. The liter, defined as the volume occupied by one kilogram of water, was also to be equal in volume to a cubic decimeter. Yet, an error of 28 millionths exists when compared to the cubic decimeter. The Conference therefore abrogated the old definition and made the liter merely a special name for the cubic decimeter. The resolution, though, pointed out that the word "liter" should not be used to express the results of high precision volume measurements.

—agreeing to recognize formally the curie as the unit of activity of a radioactive substance. The curie, already used in a great many countries, is measured by units of the second to the minus one power (s^{-1}). Therefore the distintegration value of one curie ($3.7\ 10^{10}\ s^{-1}$) was retained and the symbol "Ci" was formally established.

—attempting to provide an increase in the annual operating budget. A few delegations (notably the Soviet block) had received instructions not to approve such a proposal. Because the terms of the Treaty of the Meter require unanimity on budget increases the objective was not immediately met.

—appropriating $300,000 to complete the equipment needs of a new laboratory which will promote the international standardizaiton of measurements of ionizing radiations. The new radiation measurements laboratory was dedicated the week before the Conference officially opened.

U. S. DEPARTMENT OF COMMERCE