Annual Report 1955

National Bureau of Standards

U. S. Department of Commerce

UNITED STATES DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
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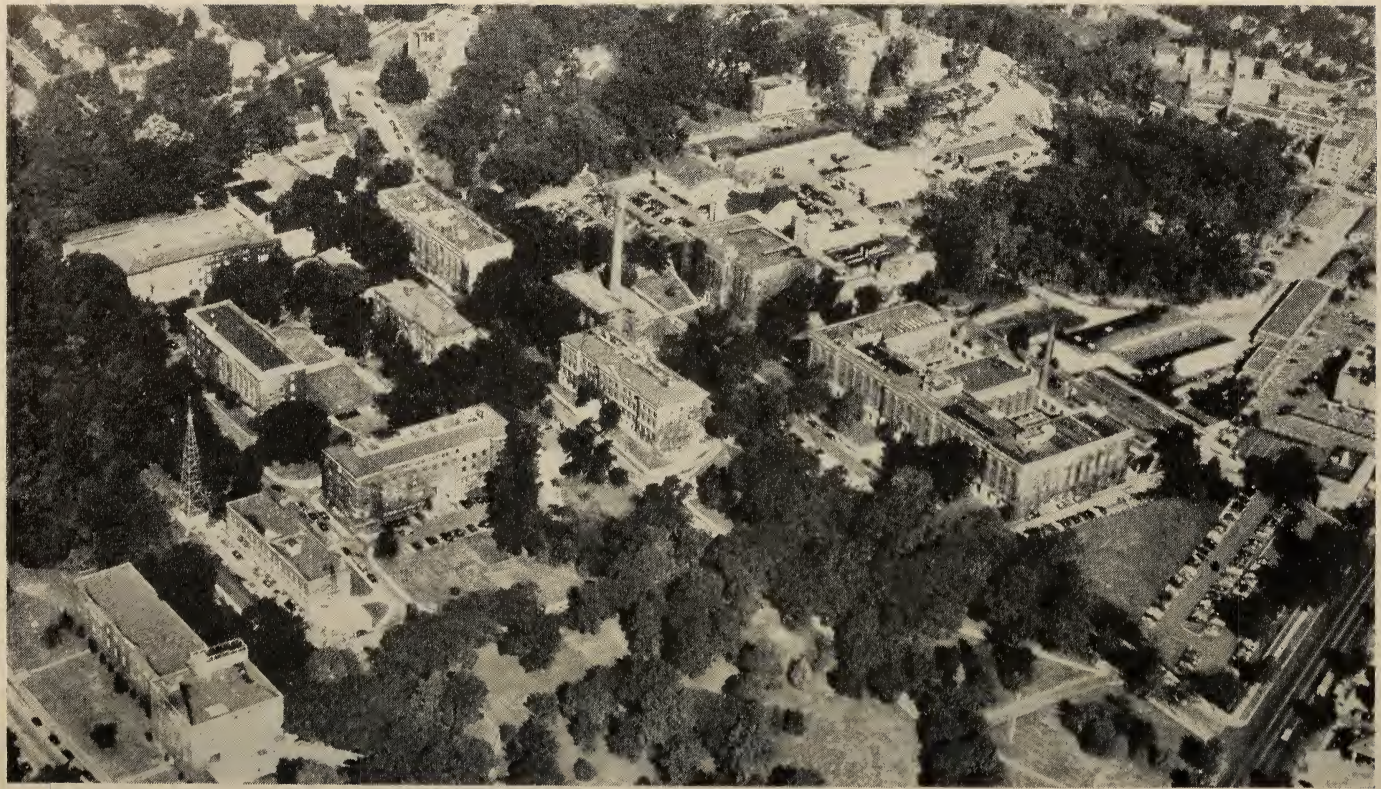

The National Bureau of Standards, Washington, D. C.

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1. General Review

1.1. Introduction

During the past year, the major effort of the National Bureau of Standards has been devoted to the strengthening of its basic programs. With the assistance of scientific advisory committees, the Bureau is seeking to develop a balanced technical program by increasing the level of research, especially basic research, in those fields for which the Bureau has an assigned responsibility.

An effective standards research program must at all times remain at the forefront of science. It must continually push to the frontiers in order to provide the new standards needed by scientists in their studies of new materials and newly understood phenomena. Standards are important to scientific inquiry. They are the results of meticulous investigation themselves. They are intimately associated with the basic units of measurement or comparison by which experiments may be properly described and verified. Research associated with the development of standards helps to unravel some of the puzzling results obtained with new experiments and leads scientists and engineers to the best avenues for the solution of their special technical problems. Thus, it provides clues for effective applied research and helps to eliminate false starts in development work.

By virtue of its responsibility for the custody, maintenance, and establishment of the Nation's primary standards of physical measurement, the National Bureau of Standards serves Government, science, and industry. The Bureau is the source for physical standards used in mass production and in the development of interchangeable parts—so vital to our modern economy. For industry and science, the Bureau also performs critical calibrations of working standards and distributes standard samples for use in production and research. For Government, the Bureau develops methods for the acceptance testing of materials in procurement and helps to devise codes and specifications. In addition, the scientific staff of the Bureau provides technical advice to various scientific and Government groups and undertakes a large variety of studies to meet the special needs of other Government agencies.

Obviously, the work of the National Bureau of Standards is quite broad. The scope of this responsibility is such that the Bureau

must continually adjust its programs to meet the most pressing needs of the time. During the past three years the Bureau has sought to attain an effective balanced level of research support for the basic programs. This the Bureau is working toward.

1.2. Technical Activities

Standards and Measurements. As in previous years, a large part of the technical program was concerned with scientific standards and methods of precise measurement. A number of international comparisons of fundamental standards were carried out. For example, the national primary X-ray standard was compared with the British standard, and the two United States primary radium standards were compared with those of Canada and the United Kingdom. The Bureau also cooperated with the International Bureau of Weights and Measures at Sèvres, France, in an international intercomparison of standard gage blocks, used to insure uniform dimensions in mass production. Several improvements in equipment and measurement techniques led to increased accuracy of electrical measurements, particularly at audiofrequencies. Among these were improved guarding and shielding for resistance and capacitance standards and development of a bridge circuit for measuring core loss in steel alloys. A technique was devised for studying the performance of the highly sensitive microbalances used in such fields as atomic energy, where minute samples must be weighed with high accuracy. Two devices were developed that precisely measure radiation in terms of the heating effect it produces. One of these, a radiation-balance microcalorimeter, will aid materially in meeting the increased demand for calibration of radioactive sources. The other, an X-ray calorimeter, will serve as a basic standard for measurement of the high-energy X-rays now being used in medical treatment and industrial radiography. To meet the increasing demand for standard samples of radioactivity, a radiochemistry laboratory was established. The new laboratory will prepare and distribute approximately 57 different radioactive nuclides and ores to hospitals, research laboratories, and industrial plants.

Recent advances in electronics have emphasized the need for adequate standards and measurement techniques in the relatively unexplored microwave region of the radio spectrum. Develop-

ments in this extreme high-frequency range included a self-balancing bolometer bridge which brings increased speed and accuracy to microwave power measurements. Another instrument was devised which makes possible coaxial impedance measurements to high accuracy over a wide range of microwave frequencies. Progress was also made in developing reliable voltage-transfer standards for frequencies up to 600 megacycles per second.

With the development of jet and rocket propulsion, vibrations in high-speed aircraft and guided missiles must now be measured over wider ranges of frequency and amplitude than ever before. As partial fulfillment of this need, a high-resolution system was designed and built for calibrating vibration pickups over the broad frequency band from 0 to 50,000 cycles per second. Vibration standards were developed, and a limited calibration service for vibration pickups measuring displacement, velocity, or acceleration was established.

During the year the Bureau redetermined the velocity of light in two independent measurements by quite different methods. The two values are in close agreement and thus provide confirmation for the higher values of electromagnetic wave velocity that have been consistently obtained by microwave measurements since World War II. In one method the velocity of light was determined from measurement of the molecular constants of carbon monoxide by infrared spectroscopy. The other determination made use of phase-shift measurements on very-high-frequency radio waves to obtain their velocity of propagation. Before World War II the value 299,776±4 kilometers per second was generally accepted as an average of the findings of the various laboratories. However, since the war higher values have been obtained by most investigators (average value, 299,793±1 km/sec). The results obtained by the Bureau give 299,792±6 km/sec by the molecular constants method and 299,795.1±3.1 km/sec by the radio interferometer.

Several measuring instruments were devised for specific purposes. For example, an instrument, using microwave principles, was developed for rapid, accurate measurement of atmospheric water vapor, particularly in the upper air. It will provide aerological data for operation of high-performance aircraft. In connection with a study of spectacle lenses for the Veterans Administration,

the Bureau developed an instrument that accurately measures both central and marginal powers of a spectacle lens. Previously there was no completely satisfactory method for measuring the accuracy of a spectacle lens at points other than the optical center. Although the NBS instrument is basically a research tool, its essential principles have been utilized to design marginal-power attachments for the standard vertex-power instrument used by practicing opticians.

Properties of Materials. In studies of the basic properties of materials, increased emphasis was placed on those inorganic materials that are stable at very high temperatures. Data on such materials are required for further advances in atomic power plants, high-speed missiles, and jet aircraft, but information on their high-temperature behavior has been lacking. In one project, cermets—heat-resistant ceramic-metal combinations—were studied in connection with their use in jet engines and rockets. The need for nuclear reactor design data prompted an investigation of the high-temperature reactions of uranium dioxide with other heat-resistant compounds. High-temperature concretes were studied to obtain materials for jet aircraft aprons that can withstand exposure to high, variable temperatures. As part of a cooperative interlaboratory study of the extractive metallurgy of titanium, the Bureau prepared selected titanium compounds of high purity. Included were titanium tetrachloride of 99.999-percent purity and 99.998-percent titanium tetrabromide. Other work in the high-temperature field concerned ceramic coatings for protection of high-temperature alloys or for use as high-temperature insulation, diffusion of gases in glasses, phase equilibria of refractory materials, and thermal decomposition mechanisms of inorganic materials.

In the field of high polymers, pressure porosimeter and electron microscope studies provided new insight into the structure and behavior of leather. This work revealed the presence of large numbers of extremely small pores—less than a millionth of an inch in radius—in both leather and its parent substance, collagen. The quantitative information obtained on pore-size distribution within the individual collagen fibrils should aid the leather technologist in understanding the swelling and shrinkage accompanying water-leather interactions. It is also expected to shed additional light on the ability of leather to transmit or absorb water vapor, tannins, or impregnants.

Electronic Computing. Large-scale processing of numerical data has become a major management undertaking in Federal agencies Not only are data processing problems encountered on a massive scale in government, but frequently they are of such special nature as to require unique design and research services. To provide an advisory center for Government agencies on electronic computing and data processing techniques, a data processing systems laboratory was established as a separate division of the Bureau. Combining NBS programs in analog and digital computers, the new division carries on research, development, and systems design and analysis in these fields. The new division working with the Applied Mathematics Division places the Bureau in a stronger position to advise on the use of high-speed computing techniques in many new areas of potential application—such as massive paperwork operations, automatic control systems, and simulation of physical systems.

During 1955 the Bureau's high-speed electronic digital computer, SEAC, continued in round-the-clock operation except for a 2-month period required to move it to a new permanent location on the Bureau grounds. Problems were solved in Government procurement and industrial mobilization as well as in aerodynamics, atomic energy, meteorology, thermometry, optics, nuclear physics, thermodynamics, sound, and navigation.

Research on individual computer components led to the development of a new type of diode amplifier that promises to play an important part in the future design of high-speed computers. This compact, rugged device uses germanium or silicon crystals instead of vacuum tubes. Because of its economy and speed of operation, it appears to offer a means for increasing the practical operating speed of present-day electronic digital computers.

In computer components work sponsored by the Naval Research Laboratory, a gas-diode memory circuit was developed for use in a data correlator and classifier. This circuit should find application wherever computed data must be presented for rapid visual analysis. In another project sponsored by the Air Force, packaged circuitry was designed which combines increased logical capabilities with greatly decreased power consumption. These computer packages should make feasible the building of larger and more powerful computing machines without the need for excessively large power supplies and air conditioning equipment.

Electronic Technology. A study undertaken for the Navy Bureau of Aeronautics showed the feasibility of standardizing many of the electronic circuits used in Navy aeronautical equipment. Known as the NBS-BuAer preferred circuits program, this continuing investigation seeks to determine those well-known circuit configurations that are common to a wide variety of electronic devices but which now differ unnecessarily in detail. A number of preferred circuits have been selected and prepared for joint NBS-Navy publication as a manual for design engineers.

Although use of the circuits is entirely optional, their application should save critical engineering man-hours, reduce production lead time, and accelerate production. Preferred circuits should also provide the military services with means for simplifying maintenance training, for designing simple "throwaway" units, for achieving improved operational reliability, and for establishing design standard levels.

Another industrially significant program concerned the automatic production of electronics. Practical methods for modular design and mechanized production of electronics have resulted from a long-range program sponsored at NBS by the Navy Bureau of Aeronautics. First announced in 1953, this new approach to electronic mechanization makes use of stacked ceramic wafers, each bearing printed or applied resistors, conductors, capacitors, and other parts. Some 4 to 6 wafers make up a module, corresponding to a stage of an electronic device. The uniformity and simplicity of the parts make the modular system particularly suited to mechanized production.

In the past 2 years the modular design and mechanized production concepts have stimulated extensive industrial interest and have resulted in similar developments in industry. To further industrial preparedness, the Navy is encouraging the use of modular concepts in the production of several special naval equipments. Thus, during 1955 the NBS modular electronics program was concerned largely with indoctrination and training of manufacturers and of industrial and military users of modular designs and techniques. Toward this end, an agreement was made for the Aerovox Corporation to operate the Bureau's pilot line for experimental mechanized production of electronic equipment. This agreement should help broaden the Nation's experience and knowledge re-

garding use of modular design concepts in military equipment. NBS research in modular design was mainly directed toward improvements in specific modular components and fabrication techniques. For example, new resistor formulations and new techniques for applying resistors and capacitors to the ceramic wafers were developed.

Calibration, Testing, and Standard Samples. One of the important services of the Bureau to science and industry is the comparison of working standards with the national standards of measurement. Such calibration services are vital to industrial production and progress, for all working standards in this country depend upon calibration in terms of the national standards maintained by the Bureau. The Bureau is also responsible for testing many of the materials—usually raw materials like cement—that are purchased by Federal agencies.

During 1955, approximately 174,000 items were calibrated or tested. Typical of the calibration activity were the following: 694 standard cells, 839 radium sources, 491 sources of radioactive cobalt, 750 items of radiological equipment, 757 hydrometers, 994 water current meters, 33,110 clinical thermometers, 2,400 dilution pipets. Testing for the Government included the sample-testing of 3,000,000 lamps and 15,000,000 barrels of cement.

Approximately 32,500 standard samples of chemicals, metals, and alloys were issued to industrial and research laboratories. Standard samples are materials that are certified for chemical composition or for some physical or chemical property, such as heat of combustion, melting point, or index of refraction. They provide precise bases of comparison so that, for example, the manufacturer of a chemical can control its purity by comparing his product with the standard sample. Standard samples make possible uniform measurements of heat and temperature, define the colors of paints, and calibrate the instruments that control the composition of synthetic rubbers and motor fuels. The list of standard samples issued by NBS now includes more than 500 materials.

Cooperative and Consulting Services. The Bureau is called upon to provide technical and advisory services to almost every agency of the Federal Government and to many State and municipal governments. An example of this service is the development and

establishment of Federal Specifications. These specifications result in purchase economies by establishing criteria which govern quality and by providing opportunity for all businesses to compete for Federal trade through the bid system. The Bureau also cooperates extensively with technical and trade associations both in this country and abroad, on problems of concern to the Government and the Nation, particularly those relating to the determination and establishment of scientific quantities and standards. In addition, requests for technical information or advice are received daily from other Federal agencies, State and local governments, universities, industrial plants, and laboratories.

During 1955 services of an advisory or consulting nature were rendered to a large number of government agencies. Typical services included advice to the Post Office Department on automatic electronic equipment for processing mail; assistance to the Virginia State Highway Department in calibrating equipment for testing highway signs; advice to the Civil Aeronautics Administration regarding the fire hazards of methyl alcohol solutions; study of the causes of plaster failure in an Alaskan hospital for the Department of the Interior; consultative service on the elevators in the U. S. Capitol; advice to the Federal Trade Commission in the preparation of an amendment to the Flammable Fabrics Act; suggestions to the National Zoological Park on flooring for animal cages; assistance to the National Institutes of Health in acoustical design of interview rooms; and cooperation with local authorities in California and the Department of Health, Education, and Welfare on the smog problem.

The Bureau participated in the work of hundreds of technical committees, societies, associations, and commissions organized to bring new advances of science into the technology of industry, to standardize materials and products for greater economy and improved quality, and to establish uniform scientific standards throughout the world. Bureau staff members held committee memberships in more than 140 national and international groups such as the American Society for Testing Materials, American Standards Association, American Society of Mechanical Engineers, American Chemical Society, and the International Committee on Weights and Measures. An important area of international cooperation concerned the International Geophysical Year of

1957–58, during which scientists of 40 nations will make simultaneous worldwide observations of physical phenomena related to the Earth. Bureau staff members were active in both national and international planning for the IGY and also rendered consultative services in connection with the design of observational equipment.

1.3. Administrative Activities

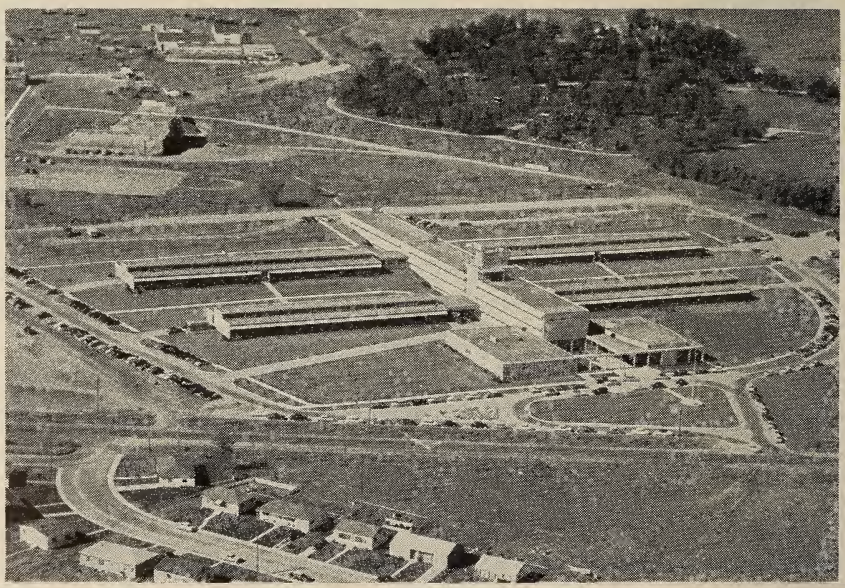
The Bureau's activities are of two major budgetary classes: First, the basic programs which are supported by direct appropriations from the Congress; second, various projects undertaken for other Government agencies with funds transferred from these agencies.

During 1955, the total funds obligated for both areas of activity, including construction and facilities were $19,986,431. Of this total, about 33 percent, or $6,575,331, came from direct Congressional appropriation for the basic program, while the remaining 67 percent, or $13,411,100, represented programs conducted for other Government agencies. The bulk of the transferred funds (all but $1,483,100) were provided by the Department of Defense and the Atomic Energy Commission.

An objective of the Bureau management, acting in consultation with its various advisory groups, is to increase the ratio of the basic program to the total program. This can be accomplished through increased fiscal support for the basic program and by more selective screening of the projects in the transferred fund program. Preference is given to transferred fund projects which are most closely related to activities in the basic program.

During the past year, 12 technical committees were serving the Bureau's scientific program (appendix, page 155). Composed of prominent scientists and industrial representatives, these committees, which supplement the Bureau's statutory Visiting Committee (appendix, page 155), are a valuable source of consultation and stimulation and serve to bring to the Bureau the views and needs of the Nation's scientists and technologists.

On September 14, 1954, President Dwight D. Eisenhower formally dedicated the NBS Boulder (Colorado) Laboratories. The ceremony marked the completion and occupancy of the radio laboratory building of the Central Radio Propagation Laboratory which carries out the Bureau programs relating to radio standards



President Dwight D. Eisenhower formally dedicated the NBS Boulder Laboratories on September 14. The ceremony marked the completion and occupancy of the radio laboratory building by the Central Radio Propagation Laboratory, one of the two major NBS activities making up the Boulder Laboratories. In foreground of the air view of the Boulder Laboratories is the Central Radio Propagation Laboratory, housing the three radio divisions. The Cryogenic Engineering Laboratory is located directly back of the Radio Laboratory.

and radio propagation. Other events of the dedication program included scientific conferences in the fields of research carried out at Boulder. The Cryogenics Engineering Laboratory, previously established on the Boulder site by the Bureau and the Atomic Energy Commission, became an integral part of the Boulder Laboratories. The Cryogenics Engineering Conference was the first national conference devoted entirely to engineering phases of low-temperature research.

During the past year the Bureau held its first major Open House in 17 years. More than 600 leading scientists and officials of Government, industry, and universities participated in the program. The Open House, which covered the broad scope of the Bureau's basic activities and their relationship to technological progress, was designed to make more generally known the services which the Bureau provides. The success of this Open House has led to plans for making this type of presentation on a regular basis. During the year, the Bureau re-established its tour program for the general public, supplementing the existing program for scientific, professional, and other groups having a special interest in NBS activities.

At the end of the reporting period, total employment at the Bureau was 2,864. Most of the staff was stationed at the Bureau's laboratories in Washington, D. C. About 500 were located at the NBS Boulder Laboratories, and at 20 field stations in the United States and abroad.

1.4. Publications

The results of the Bureau's technical program are in general embodied in its reports and publications. Even when the work is developmental in nature—for example, the development of a specific device—a report will represent the culmination of the activity, and it is this report which will often prove of most value to Government, science, and industry. The reports and publications of the Bureau are therefore suggestive of the scope of its activities. During the year these totaled over 1,389, exclusive of calibration and test reports and of general administrative documents. Some 825 classified and unclassified reports were issued to other Government agencies, particularly the Department of Defense, while over 440 papers and documents were published formally. Of the

formal publications, some 124 consisted of scientific and technical papers, 89 of which were published in the *Journal of Research of the National Bureau of Standards* (a monthly periodical) and the remainder in the journals of various professional, engineering, and trade organizations. In addition, approximately 65 summary reports were published in the Bureau's monthly *Technical News Bulletin*. The third monthly periodical of the Bureau, *Basic Radio Propagation Predictions*, presented each month, for a 1-month period 3 months in advance, radio-propagation data needed in determining the best frequencies to use in long-range radio communications.

Thirty-four papers were published in the Bureau's nonperiodical series of publications: 8 in the Applied Mathematics Series, 4 in the Handbook series, 15 in the Circular series, 4 in the Building Materials and Structures Report series, and 3 in the Miscellaneous Publication series.

A list of publications issued during the fiscal year is given in the appendix, section 5.5 (page 158).

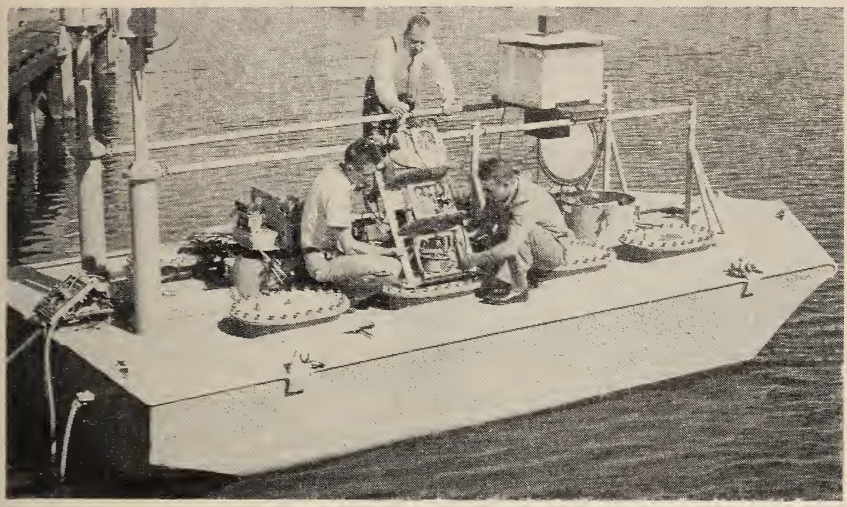
2. Research and Development Program

The Bureau's technical program is carried out through organizational units called Divisions. These are shown in appendix 5.1. The review of the research and development programs is presented in this section under headings corresponding generally to these organizational units.

2.1. Electricity and Electronics

The work in electricity is primarily concerned with the development, improvement, and dissemination of the standards of measurement for electrical quantities and the studies of properties of materials that are important in electricity and magnetism. The object is to provide electrical standards that are as far as possible constant with time, uniform throughout the nation, and consistent with the more fundamental mechanical units. The work includes the disseminating of standards for resistance, inductance, capacitance, voltage, current, power, energy, magnetizing force, and magnetic induction.

The electronics activities include the standardizing of test methods for electronic components, studying materials and proc-



This floating weather station automatically reports meteorological data by radio at regular intervals. It can be left unattended for 6-month periods (p. 16).

esses for component fabrication, establishing optimum designs of electronic equipment for maximum life and reliability, and cooperating with other Government agencies and industrial groups in formulating codes and specifications. In areas in which the Bureau is uniquely qualified electronic development programs are undertaken to meet the special requirements of the Bureau and other Government agencies.

Fundamental Electrical Units. As a check on the fundamental electrical standards, several preliminary determinations of the absolute value of the ampere were made with the Pellat current balance. The values obtained show that the ampere as currently maintained by NBS standards is in satisfactorily close agreement (within 10 parts per million) with the theoretically defined absolute unit. During the past year standard resistors and saturated standard cells were exchanged and their values compared with those of other nations at the International Bureau of Weights and Measures at Sèvres, France. Standard cells were also exchanged with the Physikalisch-Technische Bundesanstalt of Western Germany.

The U. S. national standard for the volt has been maintained for some years by a primary group of 23 saturated cells. As a further step in assuring continued reliability of the standard, this number was increased to 48 this past year by including an additional group of cells which have shown unusual stability over a period of 5 years.

Electrochemistry. Voltaic cell combinations of electrodes and electrolytes are becoming increasingly important as reliable constant-voltage sources for aircraft and other technological applications. Under way are studies of Ag/Ag_2O, NaOH, and HgO/Hg cells under carefully controlled conditions of purity and measurements. Results indicate that after construction of the cell, the potential first increases and then decreases several hundredths of a volt. These changes represent a significant discrepancy from the heat data calculations, and show a need for repeating the earlier fundamental measurements on which the electrochemical constants are based.

The increased interest in storage batteries for special applications has focused attention on types other than the common lead-acid cell in general automotive use. Studies are under way on modifications of such secondary batteries as the alkaline nickel and iron electrode type, the nickel and cadmium type, and the recently suggested zinc and silver-oxide type.

Improvements in Measuring Techniques. Recent improvements in equipment and in measurement techniques have led to increased accuracy of electrical measurements, particularly at audiofrequencies. Among these improvements are: (1) improved shielding in air capacitors so that they are less affected by stray capacitance in the course of 400-cps measurements for determinations of the ratio and phase angle of computer-type transformers; (2) the introduction of guarding and shielding for precise determination of phase defect of four-terminal resistance standards at audiofrequencies; (3) development of a bridge circuit for the measurement of core loss in silicon steel and other steel alloys up to much higher inductions than previously possible; and (4) the application of both a modified 60-cps bridge circuit and the Bureau's precise transfer wattmeter to obtain concordant results when measuring the residual phase defect of a large air-core-power reactor. This reactor will give a basis for similar measurements by industrial laboratories on power transformers of the largest sizes. A preliminary model of an electrothermic wattmeter has also been constructed that has an accuracy of about 0.03 percent in the audio range.

A more rapid method announced last year for precisely measuring the rate of a-c watt-hour meters is now in regular use by the

Bureau. The method minimizes the use of an electrodynamic wattmeter and avoids the laborious process of holding the a-c power constant while the meter registration is accumulating. In lieu of regular use of the wattmeter for all tests, measurements may now be made by a comparison process that employs a group of carefully selected watt-hour meters. One of the meters is adapted for use as a standard while the others serve as comparison standards. Rate comparisons are performed by comparing the number of revolutions of the disk of the meter under study with that of the standard. The standard meter must, of course, occasionally have its rate determined by the older wattmeter method.

Resistor Noise. Under the sponsorship of the Navy Bureau of Aeronautics systematic studies have been continued on the electrical noise generated in the composition resistors widely used in electronic gear. Electrical noise, i. e., spontaneously generated spurious electrical signals, may appear as audible noise in apparatus whose output is sound, but even where this is not the case the presence of electrical noise in resistors limits their usefulness for many applications. The work has required the development of new types of measuring equipment for determining the inherent noise characteristics of resistors, and the performance of a variety of tests on existing types of filamentary and other resistors, to develop an acceptable basis for comparing the resistors. Results of the investigation include readily reproducible methods of measurement, and will provide a basis for orderly practices for the procurement of resistors by military specifications.

Electron Tubes. Electrical conduction by thermal electrons in the pores of oxide-coated cathodes plays an important role in cathode characteristics. To study this effect, electron tubes having oxide-coated cathodes with different degrees of coating porosity were constructed and investigated. Other experiments show that tube life is closely related to the rate of sublimation of cathodic materials. A very sensitive microbalance has been installed for the measurement in vacuo of such sublimation rates.

As a tool for studies of these kinds, a cathode emission tracer that provides a rapid, convenient method for measuring and evaluating the performance of thermionic cathodes was developed. The instrument automatically displays on the screen of a cathode-ray oscilloscope a calibrated plot of the emission characteristics of the cathode under study.

Research on Electric Spark Discharge. Using chopped voltage-wave techniques to produce very brief (i. e., less than one-millionth of a second) electrical discharges between a sphere and a plane, oscillograms of the spark current have been obtained so that current measurements can be associated with the photographs of the initial stages of the discharge. The beam-intensified cathode ray oscilloscope developed earlier at NBS makes possible this detailed study of the mechanism of electric breakdown in air.

Pole-top Failure. With the support of the Rural Electrification Administration the Bureau has investigated lightning failures of equipment mounted at the top of poles used for electrical distribution circuits. Tests with very large artificial surges of voltage and current revealed that the most common types of field failures could be duplicated in the laboratory. On the basis of these tests the positions of some of the conducting elements on the pole were changed and gaps were relocated. Repeated laboratory surge tests demonstrated that with the new pole-top arrangement injury from lightning would not result. This work has resulted in new specifications for the layout of the pole-top hardware and for grounding conductor locations. The new specifications will apply to existing and proposed installations on more than 5 million poles.

Design of Mutual Inductance Transducers. The mutual inductance transducer, developed earlier at the Bureau, has found wide application in electronic distance-measuring instruments. The transducer detects extremely minute changes in the position of a nearby conducting plate and can be made to record such changes with an accuracy of 5 percent or better. Until recently, design analysis of the transducer has been restricted to its immediate use in a particular instrument. Because of the need for general design criteria for use in future applications, the Bureau made a detailed study of the device's operating principles with major emphasis on transducers using highly conducting reference plates. The results include a number of design recommendations for obtaining optimum combinations of sensitivity, stability, and linearity over the range in which the instrument is to be used.

Marine Weather Station. Preliminary tests of a prototype automatic marine weather station, developed for the Navy Bureau of Aeronautics, were completed in Chesapeake Bay. The unit is incorporated into a buoy that can be anchored in remote locations.

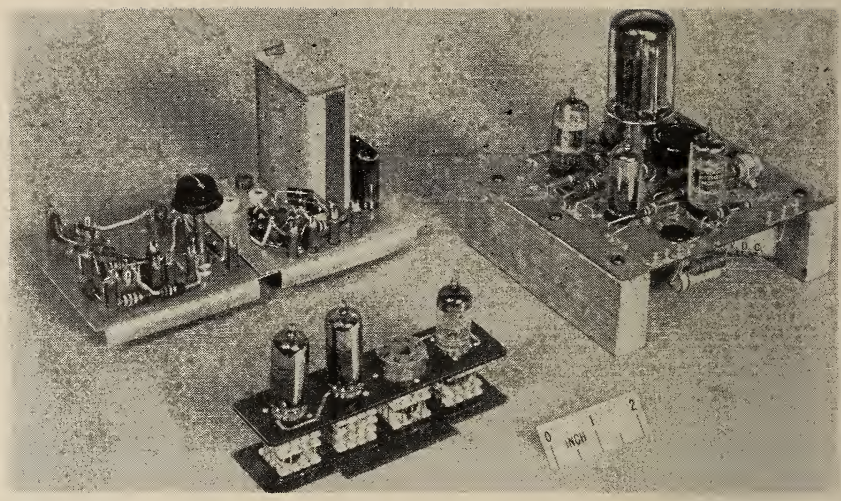
It provides for unattended operation over long periods of time, and reports meteorological data by radio link at regular intervals. Also, eight hurricane detection buoys, with appropriate sensing and radio transmitting equipment, were designed and constructed.

Special Electronic Devices. Several electronic devices were made available for specialized application within the Bureau or by other Government agencies. One of these is an 80-kilocycle amplifier and synchronous detector for use in fundamental studies of the microwave absorption lines of gases. Another device is detection equipment for an electron-photon interaction study where it is necessary to discriminate currents of 10^{-13} amp at 450 cps.

In the development of a compact wide-range receiver for the Rome Air Development Center, one problem arose which could be solved only by the design of a 24-section filter. This filter was constructed using miniaturization techniques and incorporates quite simple but effective tuning adjustments.

A current problem of concern to the U. S. Weather Bureau is accessibility to permanent meteorological records. The volume of such records in the form of punched cards has become a serious problem. The storage problem can be alleviated by storing microfilm records instead of the bulkier cards, but no automatic reading device for records in this form has hitherto been available. Such equipment is now in process of development at NBS for the Weather Bureau. The practicability of the proposed operating principles has been demonstrated.

Preferred Circuits. Studies leading to the standardization of electronic circuits have been continued for the Navy Bureau of Aeronautics. In the absence of such standardization, detailed circuits designed to perform identical functions in a variety of complex electronic devices, may differ widely in the kind of parts, their numerical values and circuit arrangements. Where the component circuits have been standardized, great savings in engineering design time and great reductions in the diversity of electronic parts to be stocked have resulted. Gains in performance and reliability are also possible if suitable care is taken in the initial selection of a "preferred" circuit. The program was organized to select such preferred circuits from the large numbers of established designs. A number of preferred circuits have been selected and prepared for joint NBS-Navy publication under the title "Preferred



The NBS-BuAer preferred circuits program is designed to aid electronic equipment manufacturers and military users. Preferred circuits can be applied to both conventional and modular construction techniques (p. 17).

Circuits Manual, Navy Aeronautical Electronic Equipment." Use of the circuits is entirely optional.

Mechanized Production of Electronics. Under the sponsorship of the Navy Bureau of Aeronautics, the Bureau has continued certain phases of its program of modular design and mechanized production of electronics. The NBS modular design and mechanized production concepts, developed as a military preparedness measure and originally announced in 1953, have stimulated extensive interest and similar developments in industry. The main emphasis of the Bureau's current program is to indoctrinate and provide a suitable training program for manufacturers as well as industrial and military users of modular designs and techniques. This is in keeping with the Navy's preparedness policy of encouraging the use of modular-design concepts in the production of several special naval equipments. Toward this end a facilities use agreement was recently made with the Aerovox Corporation which will operate the NBS pilot line for mechanized production of electronic equipment. The agreement is designed to broaden the Nation's base in experience and know how for the use of modular design concepts in military equipment. Several manufacturers are now producing or are preparing to produce the modular design essentially as originally developed.

A step in the making of tape capacitors for the mechanized production of electronics program (p. 18).

During the past year research efforts were directed toward improvements in specific modular components and fabrication techniques. The quality of the tape resistor is being improved through (1) use of a recently developed curing oven that has extremely accurate temperature control, (2) development of new resistor formulations, and (3) new techniques of spraying and attaching resistors and capacitors to ceramic wafers. Results to date indicate that it is possible to make by mechanical means high-quality resistance and capacitance units that are more stable and accurate over a wider range of operating conditions than heretofore attainable. Under study are methods for incorporating the manufacture of the cracked carbon and boro-carbon resistors into the regular production line.

2.2. Optics and Metrology

The Bureau's work in optics and metrology was principally concerned with problems of measurement, instrumentation, and standardization. Fields of activity included photometry, colorimetry, optical instruments, photographic technology, interferom-

etry, thermal expansion, and calibration of line and end standards. In addition, specific development programs were carried out for other Government agencies. Typical projects dealt with intercomparison of length and optical standards, optical properties of spectacle lenses, aircraft and airport lighting, indices of refraction of synthetic crystals for infrared applications, measurement of atmospheric transmission and its application to airplane landings, and application of high-speed computers to lens design.

Intercomparison of Standards. The National Bureau of Standards cooperated with the International Bureau of Weights and Measures and the other national standardizing laboratories in an international intercomparison of standard gage blocks. Gage blocks approximately 2, 3, and 4 inches (50, 75, and 100 mm) long were submitted to the International Bureau of Weights and Measures at Sèvres, France, after their lengths had been carefully measured by the participating laboratories. Results have not been completely reported, but indications are that for all countries approximately two-thirds of the measurements reported to date agree within two-millionths of an inch.

Line standards, such as the meter bar, and end standards, such as gage blocks, are ordinarily measured by different procedures. During the past year, NBS inaugurated a program for intercomparison of its line and end standards. Preliminary results indicate that the two sets of standards are consistent.

During the past year, NBS calibrated 32 electric lamps, in 4 groups of 8 each, for intensity at 2,042° K, intensity and luminous flux at 2,353° K, and luminous flux at 2,788° K. These three temperatures are, respectively, the temperature of a complete radiator at the freezing point of platinum (the international standard of luminous intensity), the approximate temperature of the filament of a vacuum tungsten lamp, and the approximate temperature of the filament of a gas-filled tungsten lamp. Four from each group of eight lamps were taken to the International Bureau of Weights and Measures to be calibrated against its standards and also to be compared with the standards of other national standardizing laboratories.

Determination of Color Differences. Accurate matching of colors is becoming increasingly important to modern industry.

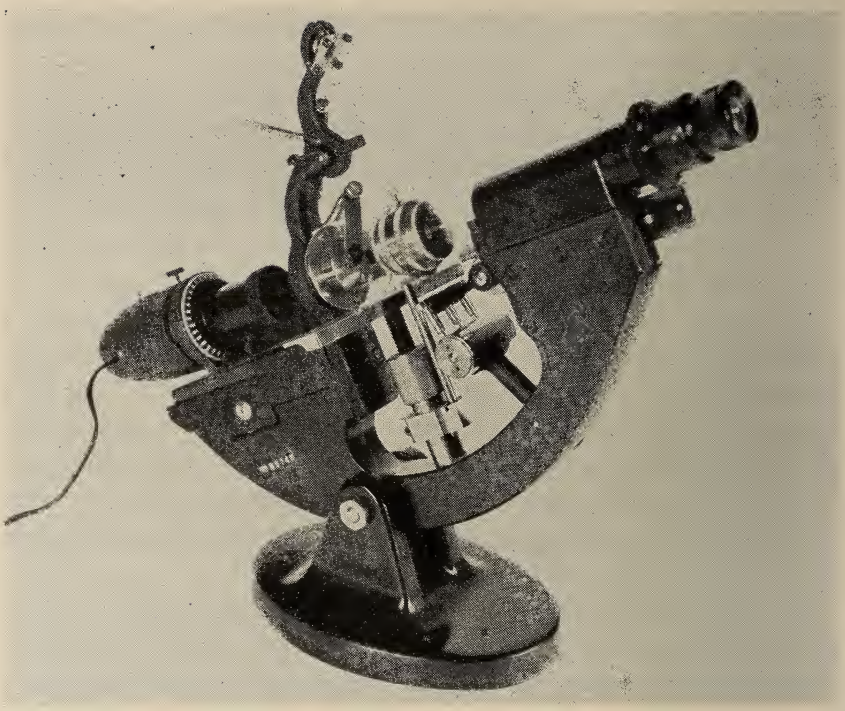
Household appliances such as stoves, refrigerators, washing machines, and clothes dryers may be assembled from parts produced on different production lines and finished with different materials. A noticeable color difference between parts may be objectionable to the customer and may hurt the sale of the product. Likewise, for many other uses, such as advertising signs, trademarks, traffic lights, and railroad signals, color is rigidly specified and closely controlled.

For many years manufacturers and purchasers of colored materials have employed inspectors to determine whether or not two samples are sufficiently similar in color to be called a "match". Frequently inspectors cannot agree, and in recent decades instruments have been developed to measure color and color differences precisely. But the extent to which instrumental values of color differences agree with estimates of human observers is a question that has never been satisfactorily resolved.

To obtain data which may lead to a solution of this problem, the Bureau, in cooperation with the Porcelain Enamel Institute, embarked some years ago on a long-range research program. Although much experimental work remains to be done, preliminary phases of the investigation have provided significant information on the evaluation of color differences. This initial stage of the program has been carried out by personnel of NBS and of Hunterlab, with the cooperation of a number of industrial laboratories.

While the extent to which instrumental measurements of color difference correlate with visual estimates has not been completely determined, useful conclusions can be drawn from the results obtained thus far. In general, it appears that color-difference meters properly operated are likely to be more reliable than the estimates of a single observer or even a small group of observers. Correlation of instrumental measurements with visual estimates will probably be satisfactory in most cases but should be verified for each color where such correlation is important. The numerical size of an instrumentally measured color difference will depend on the instrument and the color-difference equation used.

Glass Color Standards. Many commercial products—such as foods and vegetable and mineral oils—are graded on the basis of color. To maintain consistency of grading in different parts of the country, standard sets of colored glasses are used. These

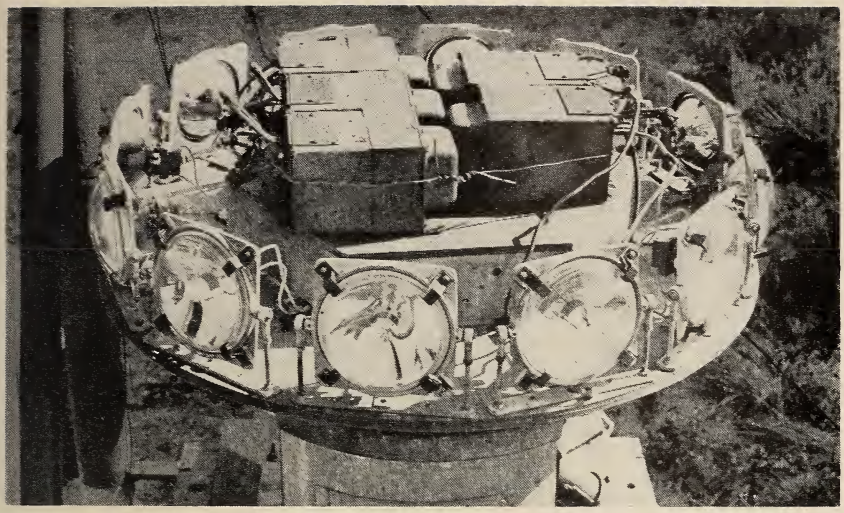


NBS attachments for measuring marginal power of spectacle lenses are shown in place on a standard power measuring instrument used by practicing optometrists.

standard glasses can be combined to produce a very large number of different standard colors which are matched with the product to be graded.

After some 4,000 of these glasses had been submitted to the Bureau for calibration, a statistical study was made of the data. The study shows (1) the ideal system of colors with which the glasses should comply if the colors presented by the combination of glasses are to be correct, and (2) the deviations which may be expected. The results of this work are made available to users of the glass standards by a calibration service which gives users the differences between the nominal and actual color.

Spectacle Lenses. The Bureau completed an investigation of spectacle lenses sponsored by the Veterans' Administration. The project involved performance studies of corrected spectacle lenses, which are designed to give approximately the same visual correction through the central and peripheral parts of the lens. A special instrument was designed for making the required measurements.



Experimental model of approach beacon system for jet aircraft in marginal weather.

This instrument accurately measures the power of a lens at the periphery as well as at the center. The data thus obtained were used to prepare specifications indicating the performance that is generally realized by commercial lenses. Formulas were derived for computing the astigmatism along any principal ray for a lens, such as a spectacle lens, composed of spherical and toric surfaces.

Aviation Lighting. At the request of the Air Force, a comprehensive study was made of the operational requirements of airfield lighting systems for jet aircraft, and a system meeting these needs was designed. A system of approach beacons for use in marginal weather was designed and field-tested.

The Bureau collaborated with the Rohm & Haas Company and the Civil Aeronautics Administration in developing a green plastic for use in place of glass in aviation lighting equipment. The resulting material is not only less expensive than glass but has better colorimetric characteristics and is much lighter. The reduction in weight is of great advantage to airway mechanics who frequently must carry the 2-foot beacon covers on foot up steep mountain slopes.

An eye-level warning light for aircraft instrument panels was developed for the Navy Bureau of Aeronautics. The light is small enough to be mounted on the cowling above a cockpit instrument panel, close to the pilot's normal line of sight without

material interference with his vision. The device warns the pilot by appropriate illuminated legends when any part of the aircraft essential to flight or landing is not operating properly.

Refractometry of Synthetic Crystals. During World War II, methods were developed for producing large, transparent synthetic crystals, suitable for lens construction, of such materials as calcium fluoride, lithium fluoride, silver chloride, and cesium iodide. Many of these crystals are transparent to the infrared and are therefore of great importance in connection with the increasing interest in this spectral region. However, before they can be generally useful in lens systems, their indices of refraction must be measured throughout the spectral region within which they transmit light.

During the past year the Bureau measured indices of refraction and their change with temperature for sodium chloride, cesium iodide, and arsenic sulphide (As_2S_3) in the ultraviolet, visible, and infrared portions of the spectrum. The index of refraction was also measured for four infrared glasses, and an interferometric method was applied to measure the index of refraction of Canada balsam. In connection with this work, an interferometric method was developed for determining the uniformity of the index of refraction within large disks of optical glass.

2.3. Heat and Power

To provide a fundamental basis for precise measurements of heat and power, the Bureau maintains temperature scales covering most of the range from the lowest obtainable temperature to the highest temperature of incandescent bodies and flames. The Bureau is also responsible for determining and maintaining standards of viscosity, heat capacity, and heat of combustion; it maintains the primary standards for determination of the octane number of automotive and aviation fuels. Research is conducted to increase the accuracy of these standards and to develop improved measuring instruments and apparatus.

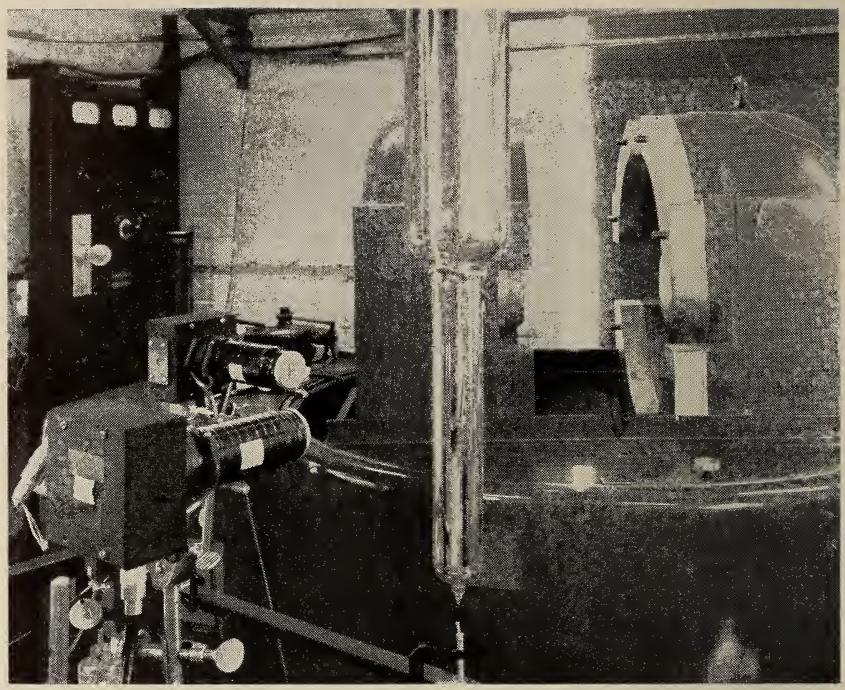
From the standards of temperature, the work in heat and power broadens to include the determination of quantities of heat by calorimetry at temperatures extending over a large part of the scale. Concurrent theoretical programs relate thermal properties to molecular structure and permit the calculation and compilation of tables of thermal properties over an even wider temperature

range. Particular emphasis is placed on investigations of electrical, magnetic, and thermal properties of matter at extremely low temperatures. In cooperation with the research programs of medical agencies, the Bureau applies thermodynamic techniques to the measurement of biologically important materials. Rheological studies, dealing with the flow characteristics of lubricants and of rubber solutions, are also conducted. From these fields of activity, the work in heat and power extends to research on the mechanism of combustion in engines, bearing and lubrication studies, high pressure pneumatics, and applied thermodynamic investigations of such heat engines as compressors and internal combustion engines.

Temperature Standards. Recent years have brought an increasing need for more accurate measures of temperature on the fundamental Thermodynamic Scale. To meet this need, the Bureau began a 5-year program of gas thermometry covering temperatures from somewhat above the ice point up to 800° C. Objectives of the program include the accurate determination of the thermodynamic temperature of the sulphur point and measurement of differences between the Thermodynamic Scale and the International Temperature Scale. The latter scale is a practical scale which is commonly used in laboratory measurements.

Other research seeks to develop and improve temperature scales in the very low and very high ranges. During the past 2 years the inaccuracies in the presently accepted helium vapor-pressure scale of temperature between 1° and 4° K (−272° to −269° C) have become recognized as a serious problem. The Bureau has been using its magnetic thermometer to investigate this region. Results to date are in excellent agreement with those of other laboratories below 2.17° K, but discrepancies exist above this. point. Efforts are being made to identify possible sources of error.

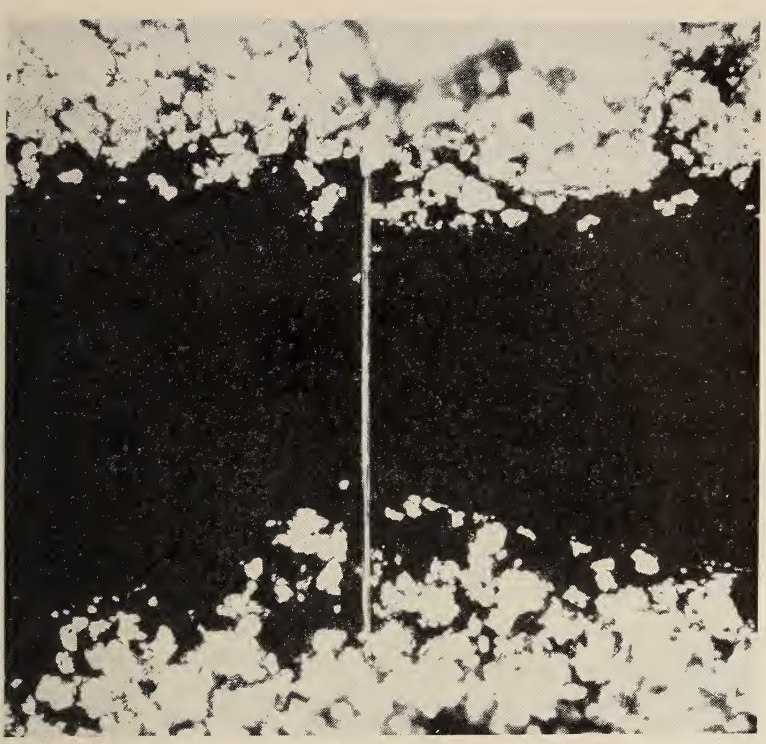
Below 1° K, gamma irradiation from cobalt-60 sources was established as a project facility for low-temperature calorimetry, and new measurements were made upon the paramagnetic salt, chromic methylammonium alum, down to the region of 0.01° K. The major aims of this work are to improve measurement techniques and to resolve major discrepancies in order to establish an accurate temperature scale in the neighborhood of absolute zero.



A new technique for studying the processes of nuclear disintegration is provided by alinement of radioactive nuclei. The experiments are conducted at temperatures near absolute zero using this equipment (p. 27).

In the high-temperature range, advances were made in a spectroscopic investigation of flames and hot gases. This program is sponsored by the Wright Air Development Center. Its long-range objective is to develop methods of measuring and interpreting temperatures in gaseous systems. The radiation from such systems is studied in detail as a function of various parameters such as temperature and pressure. Important phases of the work include analyzing newly observed bands and improving the analysis of known bands. In the infrared region, intensities and line half-widths of carbon monoxide were investigated to permit more accurate evaluation of flame temperatures. A method for measuring population "temperatures" in absorption was developed. This method, which uses the logarithm of the inverse of the minimum transmission, rather than percent absorption, is especially valuable in treating cases showing very strong self-absorption.

Low-Temperature Research. At liquid-helium temperatures metals such as lead and tin completely lose their electrical resistance. The Bureau has been studying this phenomenon, known as superconductivity, under the sponsorship of the Air Research



Magnified (1,000 times), a tin "whisker" 1 micron in diameter is shown mounted between silver paste electrodes for superconducting and phase transition studies at liquid helium temperatures.

and Development Command. During the past year the superconductivity program dealt largely with an unusual class of tin crystals called "whiskers." The interest in tin whiskers stems primarily from their size—about 1 micron in diameter. As the surface-to-volume ratio of a superconductive wire becomes large, as in the case of tin whiskers, size effects occur. A study of these effects provides information about the surface tension between superconducting and normal domains and about the penetration of a magnetic field at the surface of a superconductor. Recent results indicate that domain segmentation is not possible in tin whiskers under certain conditions which ordinarily favor such a structure. This has been explained in terms of a prohibitively high interdomain surface energy in filaments of this size. The Bureau is now seeking a more precise expression of these results and is investigating the effects of magnetic field penetration on the phase transition in tin whiskers.

In 1954, the Bureau achieved alinement of radioactive nuclei in

a low-temperature investigation sponsored by the Office of Naval Research. These results were obtained in a study of gamma-ray emission from 30-day cerium-141. During 1955 further experiments of this type were carried out with two isotopes: 11-day neodymium-147 and 140-day cerium-139. Work was also begun on a new method of polarizing nuclei (Overhauser effect), by which it should be possible to work in a more convenient temperature range, and also to orient a larger number of different nuclei. The method depends on the saturation of electron paramagnetic resonance signals.

Interesting phenomena were observed when gaseous oxygen and nitrogen were subjected to a high-frequency electrodeless discharge at reduced pressure and then cooled rapidly to the temperature of liquid helium. It appears that these phenomena are caused by free atoms and radicals, such as atomic oxygen, atomic hydrogen, and hydroxyl (OH), which do not exist under usual conditions. The solid condensed from nitrogen at 4.2° K emits a bright green glow with occasional blue flashes. The spectra from these glows have been tentatively interpreted as due to interaction of the solid lattice with atomic and molecular nitrogen. Oxygen products condensed at 4.2° K appear as a transparent, glasslike substance. When the temperature is raised, the original deposit evaporates, and solid violet material is condensed on the surface. The violet substance has been identified as ozone.

Properties of Air and Related Substances. A comprehensive investigation of air and its principal constituents, conducted for the National Advisory Committee for Aeronautics, the Air Force, the Navy, and the Atomic Energy Commission, produced extensive compilations of data as well as a variety of experimental and theoretical procedures. The need for data required extension of temperature and pressure ranges. Thus, to help solve problems of condensation in hypersonic wind tunnels, measurements were made on phase equilibria in oxygen-nitrogen mixtures at temperatures as low as 65° K, on the heats of vaporization and surface tension of oxygen-nitrogen mixtures, and on the condensation line of air. To provide high-pressure data for aircraft pneumatic systems and other applications, data of state were measured for air over a wide range of pressures from room temperature down to 125° K. Apparatus was built for very precise thermal-conductivity measurements on gases under pressure. It is expected that this

apparatus will supply data sufficiently precise for theoretical prediction of the pressure dependence of the transport properties at moderate pressures. Measurements were completed on the thermal conductivity of nitrogen to 100 atmospheres and 500° C.

Various research and technical applications now require adequate values of the properties of air and other gases at temperatures up to 15,000° K. Work in this area required extension of the methods of statistical mechanics. The ideal-gas thermodynamic properties of atoms and ions and of diatomic molecules were calculated to very high temperatures.

The Bureau compiled and published the thermodynamic and transport properties of air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam. Another extensive calculation of tables was completed covering the ideal gas thermodynamic functions and equilibrium constants for isotopic exchange and substitution reactions for over a hundred diatomic hydrides, deuterides, and tritides.

Thermodynamic Properties of Metals and Salts. In recent years the importance of metals, alloys, and salts has been greatly extended by the rapid technological growth in atomic energy and aerodynamics. In designing for optimum efficiency in power generation and high-speed flight, many metals and salts are now extensively used in liquid form for heat transfer. The success of many high-temperature processes depends on the ability of these materials to resist chemical decomposition or volatilization. There is thus a need for more accurate thermodynamic data on metals and salts.

In cooperation with the Atomic Energy Commission, the Department of Defense, and the National Advisory Committee for Aeronautics, the Bureau has for several years been endeavoring to meet this need. In recent years it measured accurately the heat capacities up to high temperatures of 18 metals and alloys and of 14 salts, together with melting points and heats of fusion and transition. From the heat capacity measurements, other important thermodynamic properties, such as entropy and free energy, were calculated. New apparatus is now being constructed to extend the range of measurements from 900° up to 1,500° C.

Mechanical Degradation of Polymers. Significant information on the mechanical degradation of polymers was obtained by studying

the decrease in molecular weight of polyisobutenes when their concentrated solutions were sheared through a capillary in the NBS-McKee consistometer. In previous investigations mechanical degradation has been inseparable from pyrolytic and oxidative degradation. The NBS study eliminated the effects of these latter types of degradation. The distinguishing characteristic of mechanical degradation is that a polymer molecule must exceed some minimum size before it can be broken by this process under given shearing conditions.

Molecular weight changes occur as a result of shearing during the processing of many polymeric products such as elastomers, plastics, and fibers. Mechanical degradation is also an important consideration in the use of polymers as lubricating oil additives to improve viscosity index and to lower pour point. Study of the kinetics and energetics of the process promises to provide valuable information about the entanglement of macromolecules in polymeric systems.

Combustion in Engines. Continued investigation of the causes of engine detonation, or knock, gave additional information on this phenomenon. With paraffin hydrocarbon fuels, the onset of detonation was found to take place at a definite temperature regardless of the structure of the hydrocarbon molecule. This temperature, near 1,150° F, is obtained by a combination of heat of compression and heat from cool-flame reactions occurring just prior to detonation. If the increase in temperature due to cool-flame reaction is small, as with higher-octane hydrocarbons, then the heat from compression may be increased before the "detonation temperature" is reached. Thus a high-octane fuel may be burned in a higher-compression engine. Conversely, low-octane fuels, which undergo rather extensive cool-flame reactions, may not be compressed as much before detonation occurs.

Isotopic carbon-13 atoms were used to trace carbon-carbon bonds in combustion of a hydrocarbon. Contrary to some current theories on formation of diatomic carbon molecules (C_2) in flames, C_2 apparently results from a process in which the carbon bonds of the fuel are broken early in the flame reaction and reformed randomly to give C_2. The same technique was used to show that the soot formed originates by a nonselective process involving equally all the carbon atoms of the fuel molecule.

2.4. Atomic and Radiation Physics

Fundamental atomic and nuclear studies are important to other research laboratories, medical institutions, industry, the military services, and other Government agencies. The Bureau's program in atomic and radiation physics is concerned primarily with studies of (1) particles such as atoms, nuclei, neutrons, and electrons; (2) properties of radiation, particularly gamma and X-rays and ultraviolet and infrared light; and (3) the interactions between such radiations and particles. Emphasis is placed on the fundamental research and development necessary to meet the increasing demand for new standards, more accurate values of atomic and nuclear constants, reliable data on the properties of high-energy radiations, new and improved methods of measurement, and the calibration of radiation sources and radiation detection instruments.

Velocity of Light Redetermined. The Bureau determined the velocity of light from measurement of the molecular constants of carbon monoxide by infrared spectroscopy. This work provides confirmation for the higher values of electromagnetic wave velocity that have been consistently obtained by microwave measurements since World War II.

The velocity of electromagnetic waves has been a subject of investigation for many years. In the period preceding World War II, the value 299,776±4 kilometers per second was generally accepted as an average of the findings of the various laboratories. However, since the war higher values have been obtained by most investigators, largely through measurement of the velocity of propagation of microwaves. Consideration of this more recent work has led to an average value of 299,793±1 km/sec. The Bureau obtained a value of 299,792±6 km/sec by the molecular constants method. This value is in close agreement with another value obtained independently at NBS by a radio-interferometer method (page 107).

The molecular constants method was originally suggested by Dr. A. E. Douglas of Ottawa, Canada. As applied at NBS it involved measurement of the frequencies not only of lines in the infrared absorption spectrum of carbon monoxide but also of infrared emission spectral lines obtained when CO is produced in the flame of a burning gas. Spectral lines corresponding to the rotational states only of the excited CO molecule were already available

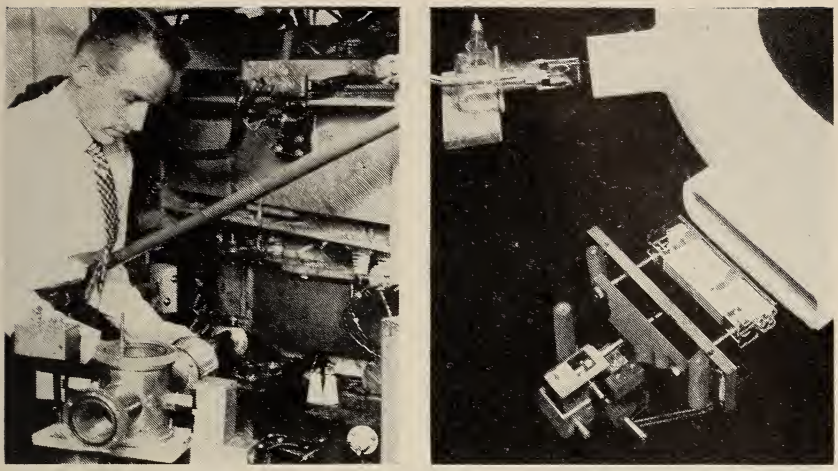
from microwave spectroscopy. The Bureau measured other lines corresponding to both vibrational and rotational states by infrared spectroscopy. The experimentally determined frequencies of the spectral lines were then used to calculate values of the molecular constants of CO which occur in theoretical formulas for the frequencies. The same molecular constants were obtained in both the infrared and microwave equations, but they were in different units: the microwave constants were in megacycles per second while the infrared constants were in reciprocal centimeters. Thus, the velocity of light could be calculated by taking the ratios of corresponding molecular constants.

The precision of this determination was due in large part to the selection of the CO spectrum for investigation. This spectrum has many spectral lines (both absorption and emission), from which molecular constants can be obtained. Also, the use of flame spectra made for greater precision by providing relatively large values of the rotational quantum number J, which occurs in higher powers in the infrared equations.

Radiation Balance. A radiation-balance microcalorimeter has been developed which precisely determines the emission rate of low-activity radioactive sources. The instrument does this by measuring the minute amounts of heat energy that accompany radioactive emission. The device is extremely compact and requires a relatively short time to complete a determination. It can be used to determine the intensity of a single source or to compare two sources of nearly equivalent energy emission. The balance is expected to aid materially in meeting the increased demand for certification of radioactive sources.

X-ray Calorimeter. The interpretation of experimental data obtained with high energy X-rays generally depends upon an accurate knowledge of the beam intensity. For research above 2 million volts, measurement methods developed for medium energies are difficult to perform and often inaccurate. To meet this need, the Bureau has developed a calorimeter for use as a primary standard in the measurement of high energy X-ray beam intensities.

The calorimeter consists essentially of a lead cylinder of a size suitable for absorbing most of the X-ray beam. The temperature rise in the lead cylinder due to the absorbed X-rays is compared



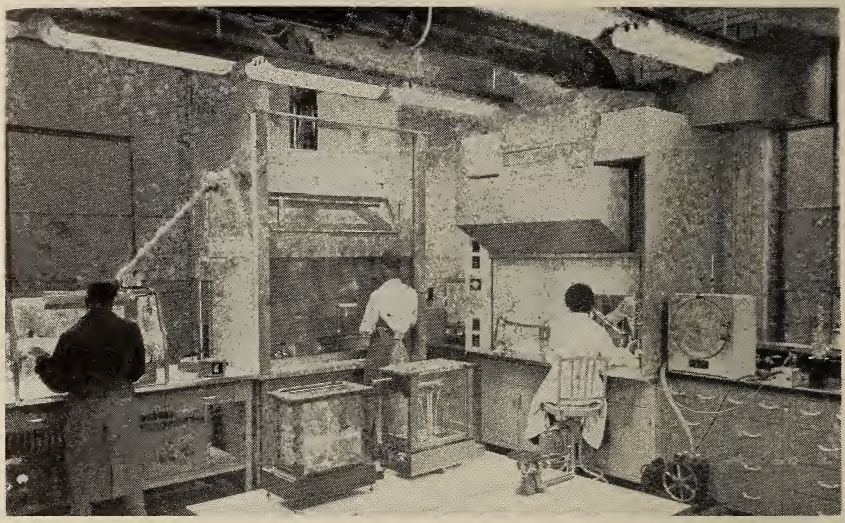
By removing electrons from the Bureau's 30-million-volt betatron in a beam, it is possible to study the direct interaction of electrons with matter at a position remote from the betatron but near the electron target (p. 33). The port, being adjusted at left, serves as the outlet for electron beams. The magnetic extractor developed to make experiment possible is at right.

with the temperature rise produced by a measurable quantity of electrical energy dissipated in the cylinder. The measurement therefore supplies a direct comparison between X-ray energy and electrical energy with an accuracy of a few percent.

Electron Beam Extractor. In order to extend the usefulness of the betatron, several attempts have been made to remove the electrons from the betatron in a beam. A magnetic extractor, recently developed by the Bureau now makes it possible to obtain an external beam of electrons. Using this, the direct electron interaction with matter at a position outside the betatron can be studied.

The extractor employs a specially constructed coil that is inserted into the vacuum chamber in a position to which the electrons can be deflected. A pulsed current through this coil produces a local magnetic field of 5,500 gauss, which is sufficient to cancel the main magnetic guiding field in that region. The electrons, upon reaching this region, travel in an approximately straight path and thereby escape from the guiding field of the magnet. The electron beam has been successfully extracted from the betatron at energies up to 24 Mev and with peak currents of the order of 5×10^{-10} amp.

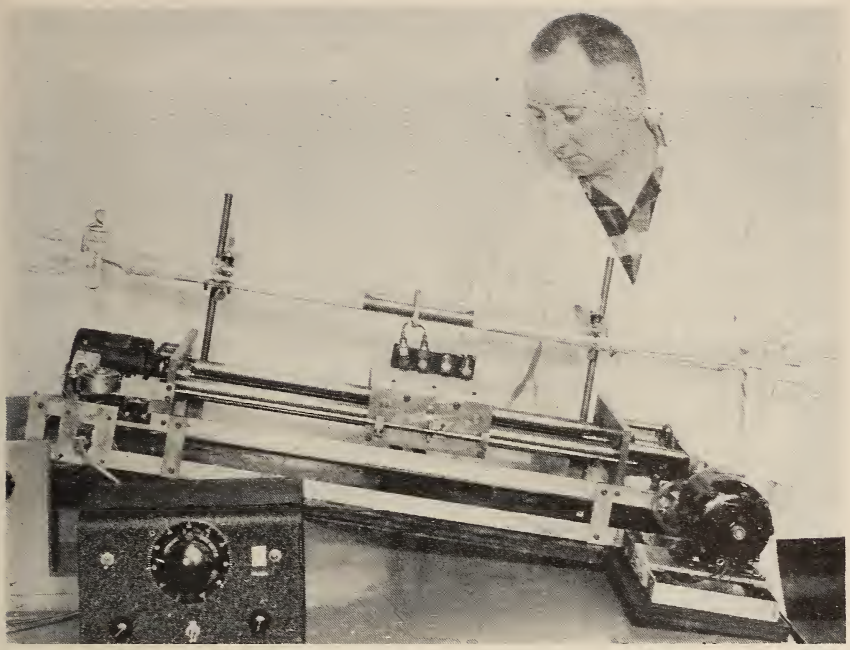
New Radiochemistry Laboratory. New uses for radioactive isotopes in physics, industry, and medical research and therapy have increased tremendously the demand for NBS standard samples of



Interior of "hot lab" in the radiochemistry laboratory. Here solutions of radioactive materials are prepared for use as standard samples (p. 33).

radioactivity. To accommodate this increased demand, the Bureau has established a radiochemistry laboratory. The program of this laboratory involves the preparation, maintenance, and distribution of approximately 57 different radioactive nuclides and ores, including carbon-14, sodium-22, phosphorus-32, and iodine-131. Nuclides are distributed as solutions in small glass vials and are specified at preparation time in terms of disintegrations per second per milliliter. The resources of the new laboratory are expected to expedite greatly the Bureau's program of radioactive sample distribution.

Attenuation of Gamma Rays at Oblique Incidence. An investigation has been conducted of the attenuation of gamma radiation incident obliquely on barriers of lead, concrete, and concrete-equivalent materials. Results of the study, which was sponsored by the Atomic Energy Commission, indicate that considerable error may be involved in some estimates of protective barrier thickness necessary to produce a specified attenuation. Estimates based on attenuation data for normally incident radiation were found to be several half-value layers low for obliquely incident radiation of the same energy. Thus it is obvious that the additional factor of incidence angle must be considered in any plan for construction of radiation protection barriers.



The automatic zone melter recently constructed at the Bureau provides a simple, inexpensive device for obtaining extremely high purity in semiconducting materials. It will also blend evenly, specific amounts of two metals to obtain a desired alloy.

The NBS study was initiated primarily to determine the dependence of the "obliquity effect" on variations in (1) incident photon energy, (2) angle of incidence, and (3) barrier material for an initially parallel beam of radiation. Gamma radiation from cobalt-60, cesium-137, and gold-198 was used at incidence angles of 0°, 30°, 50°, 60°, and 70°.

Zone Melting Apparatus. An automatic laboratory-type zone melter constructed at the Bureau combines versatility and dependability with unusual simplicity and ease of operation. The device is now being used in the Bureau's solid state physics laboratory to obtain extremely high purity in semiconducting materials and to produce a series of intermetallic compounds between the metal antimony and the metals indium, gallium, or aluminum.

The zone melting process has been used to purify metals for several years and is now a familiar industrial and scientific tool. By this process it is possible in some cases to obtain such a high degree of purity that the remaining impurities are undetectable by present analytical methods. It is also possible to blend in evenly a specific amount of another metal to obtain a desired alloy.

International Intercomparison of Radiation Standards. In 1953 the NBS primary X-ray standard was transported to the National Physical Laboratory in England for comparison with the British primary X-ray standard. At that time two important discrepancies were disclosed, and both of these problems have since been under intensive study. The National Physical Laboratory has now redesigned its standard, and this year it was brought to this country. Comparison with the NBS standard showed an agreement of from 0.3 to 0.4 percent in the 60 to 250 kv range. This international measurement in roentgens gave much better results than the 1953 measurements, when differences of 3 to 7 percent were obtained.

Recently the British primary radium standard and the Canadian national radium standard were brought to this country for comparison with the two United States primary radium standards kept at the Bureau. The intercomparisons were conducted over a period of 12 days and were made as exhaustive as possible, using the NBS standard electroscope, a Peltier-effect radiation balance, and Geiger and scintillation counters. The results closely confirm the ratios of the weights of the British and the two United States standards. However, a new weight, differing from its previous value by approximately 0.5 percent, was derived for the Canadian standard. Further work is expected on the intercomparison program with Great Britain, Canada, and other interested countries. On the basis of the intercomparisons, plans have been made to establish international standards of a number of nuclides, beginning with phosphorus-32 and cobalt-60.

Negative Ion Research. The growth of the gaseous electronics industry and the understanding of the nature of the earth's upper atmosphere depend on knowing the properties and the behavior of negatively charged atoms. In the upper atmosphere these atoms, called negative ions, may influence radio communications by changing the strength of the reflected signals from the ionosphere layers. Although important to the physics of ionized gases, these negative ions are very fragile, and hence very difficult to handle experimentally. Since the theoretical elucidation of their properties is equally intractable, very little is known about even the most important properties of atomic negative ions.

A significant break in this field of research has resulted from the development at the Bureau of experimental apparatus for the direct measurement of two of the ions' most important properties: their binding energy and light absorption. Beams of negative ions in very high vacuum are illuminated with very intense light. This light detaches a minute current of free electrons, which is measured. Negative ions of hydrogen and oxygen have been studied. It was discovered that the generally accepted value of binding energy of the atomic oxygen ion is in serious error. The new NBS value may provide the solution to a long standing controversy concerning the basic thermodynamic properties of nitrogen.

2.5. Chemistry

A wide range of fundamental and applied research in physical, analytical, organic, and inorganic chemistry makes it possible for the Bureau to supply essential facts and data required by other Government laboratories, industry, and science. Chemistry laboratories are devoted to a variety of subjects including organic protective coatings, colloids, adsorbents, carbohydrates, metals and alloys, electrodeposited coatings, gases, *p*H standards, hydrocarbons, dielectrics, and pure substances. The techniques used include analytical separations by ion exchange, radioactive labeling of organic and inorganic compounds, emission and infrared spectroscopy, flame photometry, electrodeposition from fused salts and from nonaqueous solvents, electrophoresis, and purification by growth of single crystals. Industrial quality control and fundamental research activities throughout the nation create a heavy demand for NBS standard samples, most of which originate in this division.

Colloidal Dispersions. Some of the most interesting and important types of collodial particles are formed in solution by the reversible association of large numbers of small molecules or ions. Termed association colloids, they are exemplified by such diverse substances as detergents, dyes, and hydrous oxide precipitates. The colloidal aggregates formed in detergent solutions are called micelles. Their structure is being investigated to throw further light on the mechanism of detergency.

Typical representatives of the three main types of detergents—sodium dodecyl sulfate (anionic), dodecylamine hydrochloride (cationic), and a polyoxethylene condensate of ditertiary butyl

phenol (non-ionic)—are being studied through measurements of viscosity, light scattering, and electrophoresis. Viscosity and light scattering studies provide knowledge of the size, shape, and solvation of the micelles. From electrophoresis measurements the electrical charge on the micelles can be evaluated. This, in in turn, permits a more rigorous reinterpretation of the data on micelle size and shape. Besides contributing to a better understanding of association colloids, this work has resulted in a number of improved experimental devices and techniques applicable to other problems.

Titanium Compounds. In order to provide identical materials to the many research programs concerning the fundamental properties of the element titanium, selected compounds of high purity were prepared. For example, titanium tetrachloride of 99.999 percent purity and titanium tetrabromide of 99.998 percent purity were furnished in a cooperative program of basic research on the extractive metallurgy of titanium, sponsored by the Office of Naval Research. Descriptions of methods for purifying and for testing the purity of the products by cryoscopic, infrared, and spectrochemical means were published.

In another program involving the study of barium titanate ceramic dielectrics, sponsored by the Diamond Ordnance Fuze Laboratories of the Army, barium titanyl oxalate having a ratio of barium oxide to titanium dioxide of 1.0000 was prepared. Ignition of this compound produces pure barium titanate of theoretical composition. Titanium dioxide of high purity, as well as barium carbonate, were also prepared. With these three compounds, the critical composition of important ceramic dielectrics can be accurately controlled.

Labeled Sugars. Radioactive sugars and related compounds, with their precisely placed carbon-14 atoms, provide a means for solving many problems in biology, medicine, bacteriology, and the physical sciences. In fact, they have proved so useful that there has been an increasing demand for more and differently labeled sugars, to attack new and specialized problems, especially those in cancer research. Workers in biological research alone used 276 of the samples during the current year. Because of the high cost of C^{14}-labeled reagents, more efficient methods of synthesis have been devised under AEC sponsorship that have increased the

Complex jet-engine alloys can be analyzed accurately by using ion-exchange columns to separate metallic constituents (p. 39). This procedure permits the quantitative determination of nickel, manganese, cobalt, and iron in the presence of niobium, molybdenum, tantalum, tungsten, silicon, and copper.

yield of D-glucose-1-C^{14} from 10 to 50 percent; of D-glucose-6-C^{14} from 15 to 50 percent; of D-arabinose-1-C^{14} from 3 to 37 percent; and of glycitols from 65 to 95 percent. Although the work on these labeled carbohydrates has a practical objective, fundamental studies of the reactions and their mechanisms have contributed much to our knowledge of the structure of organic compounds.

To meet the important need for these compounds, the Bureau will continue to prepare and distribute them to research workers at cost, until such time as they are available from private industry.

Research in Analytical Chemistry. New techniques, better methods, and improved instruments help greatly to meet the demands for higher accuracy now required by research laboratories and for more complete quality control by industry. A research staff is therefore required to keep abreast of new developments and to anticipate new needs because the materials to be analyzed often contain combinations of the less common elements that have

Inert atmosphere chamber used in studying electrodeposition of metals from nonaqueous media. The chamber permits filtration, distillation, transfer, and weighing of reactants or products without contamination from water or carbon dioxide.

received little attention. Methods for analyzing industrially important alloys have received much attention; ion-exchange methods have been developed for separating the constituents of heat-resisting jet engine alloys and for separating the rare earths from one another; flame photometric methods are now being used for the rarer alkali metals, such as lithium, in clays and ceramic products; methods are now available for the difficult separation and determination of chlorides, bromides, and iodides; microchemical methods have been developed for the analysis of complex polymers containing fluorine, chlorine, and bromine; and spectroscopic methods have been developed for the analysis of complex dental alloys, zinc alloys, and high-speed tool steels. The latter methods are very rapid and are therefore of special importance in the manufacture of commercial articles where control of composition is a deciding factor.

Electrodeposition of Metals from Organic Solutions and Fused Salts. Many elements have physical and chemical properties that would make them extremely useful as protective or ornamental coatings on other metals. However, some of the more promising

ones, such as beryllium, aluminum, titanium, zirconium, cannot be electrodeposited from water solutions. Exploratory work has indicated that deposits of some of these can be obtained electrolytically from nonaqueous solutions. Methods have been developed for depositing beryllium and alloys of boron with beryllium and magnesium from organic solutions. Work on electrodeposition is jointly sponsored by the Department of the Navy, the Department of the Army, the Department of the Air Force, and the Atomic Energy Commission. Improvements have been made in plating aluminum from organic solvents, and aluminum alloys containing titanium and zirconium have been obtained. Although these processes are not of immediate commercial application, they represent advances that will undoubtedly find special use in future technology.

During a general investigation of deposition of metals from fused salt baths it was shown that pure molybdenum may be recovered from most scrap molybdenum alloys.

Advances in Physical Chemistry. The silver chloride electrode is one of the most useful reference electrodes for electrochemical measurements in analytical and physical chemistry. An extended series of long-needed measurements that provide its standard electrode potential from 0° to 100° C has been completed. An advance in the theoretical understanding of the static dielectric constant of polar liquids was made by a mathematical analysis of the influence of molecular shape on dielectric constants. Absorption of microwave radiation was detected in the nonpolar gas, carbon dioxide. This discovery is of scientific interest, particularly in the field of molecular structure.

The thermochemical measurement of the heats of formation of chemical substances is the primary method for precisely measuring the binding energy in molecules. These data are essential in studying variation of energy content with structure, such as occurs in isomeric substances and in a homologous series of organic compounds, and in calculating heat balances and reaction equilibrium constants required by engineers for the design and construction of chemical process plants. In a project sponsored by the Navy Bureau of Aeronautics, the Office of Naval Research, and the Atomic Energy Commission, the heats of formation of several isomeric heptenes were measured to secure information on the

steric effects in hydrocarbon molecules. Measurement of the heats of formation of titanium tetrachloride and tetrabromide has provided important information on the thermodynamic properties of titanium-halogen systems, which are the present basis in the production of titanium, a metal that is assuming an important role in industry.

Evaluation of Scientific Data. An important function of the Bureau is the assembly, tabulation, and critical evaluation of data in those areas in which science looks to the Bureau for critically evaluated information in convenient and usable form. Careful scrutiny of the chemical literature often supplemented by painstaking recalculation of reported values, is required to provide reliable data. In cooperation with and with the financial support of the National Research Council, basic data on infrared spectra relating to about 15,000 compounds are being distributed to more than 200 cooperating laboratories. Infrared spectra have much the same value in the identification of chemical substances as fingerprints have in identifying persons. Such data are of great importance in making analyses, in purifying materials, and often in establishing the nature and properties of new substances. In the field of catalysis and adsorbents an annotated bibliography has been prepared in cooperation with the Bone Char Research Project under the title "Bibliography of Solid Adsorbents, 1943–53." This 1,500-page volume, in press as NBS Circular 566, contains nearly 14,000 scientific abstracts. Similarly, critical compilations of dielectric and thermochemical data have been made available.

Special Investigations and Devices. An investigation of the accuracy and standardizing procedures for instruments that record the heating values of natural and liquefied petroleum gases has been completed. With the cooperation of the industries that supply these gases, this work will contribute to the accuracy of measurement of one of the more important commodities of commerce.

Developments and use of many chemical compounds have been retarded because of their reaction with air. Potentially useful materials that are dangerous or that are altered rapidly in contact with the atmosphere have remained unexplored and unused. Devices for separation, purification, transfer, and storage of poisonous, noxious, or unstable compounds have been developed through processes that include purification in isolated systems,

crystallization or distillation at temperatures far below normal, and separations based on liquid-solid equilibrium in closed glass vessels or in metallic systems if the reacting materials are corrosive to glass.

A device developed for the Army Signal Corps occupying only 13 cubic inches and operating on a 115-volt power supply maintains small apparatus at very constant temperatures for an indefinite time, estimated to be at least 5 years. It depends on the solid to liquid reversible phase changes of stable, extremely pure chemical compounds. In operation, it quickly attains a temperature of about 87.5° C with fluctuations not exceeding 0.001° C.

2.6. Mechanics

The Bureau's work in the field of mechanics is concerned with developing, improving, and maintaining standards for measuring mechanical quantities over a wide range. These quantities include *sound level power* ranging from the threshold of hearing to the sound experienced near jet aircraft; *static pressures* from those present at altitudes up to 500,000 ft above sea level to those encountered in ordnance work and high pressure industrial processes; *relative humidity* in the temperature range down to −50° F; *volume capacity* from 0.02 cm^3 to 2,500 gal; *flow* from very low to very high rates in water, gases, and hydrocarbon fuels; *weights* from 1/10000000 to 10,000 lb; *forces* from 1 to 3,000,000 lb; and *vibration amplitudes* over the frequency range from 10 to 30,000 cps.

Improvements in present mechanical standards and the development of new standards require determinations of numerous constants and properties of materials, such as density, elasticity, and tensile strength. Furthermore, basic research is required along a broad front dealing with the mechanics of gases, liquids, and solids. Work is under way on the transmission of sound through air and other gases down to very low pressures, and for frequencies from the lower limit of the audible range, about 10 cps, to ultrasonic frequencies measured in millions of cycles per second. Important advances have been made during the year in understanding the origin of boundary layer turbulence, which is an important problem in high speed aircraft, in combustion, and wherever gases or fluids flow along a solid surface. Greater emphasis has been placed on a study of shock and vibration. The effects of repeated

loads and temperatures have been studied as important factors in determining strength of materials and structures.

The basic research program has led to important applications such as measurement of physical properties of sea water at great depths with ultrasonic waves and the determination of humidity at high altitudes with thin humidity-sensitive coatings.

Measurement of Hearing. A puzzling difference between the standard sound pressures for the threshold of hearing used in this country and in England has been investigated. Preliminary measurements made cooperatively by the National Physical Laboratory in England and the Bureau show that the English standard sound pressures at threshold are about 10 decibels less than the American standard. A more thorough investigation of this difference is under way, sponsored by the Army Surgeon General's Office, with plans to make measurements on about 100 persons. An important element in this research program, being carried on at the Audiology Center of Walter Reed Army Hospital, is the absolute measurement of sound pressures at threshold in the ear canal. Measurements of the acoustical impedance of bones of the head for about the same number of persons is expected to provide for the first time a standard for bone conduction audiometry. This audiometric technique is of basic importance in a physician's diagnosis of hearing loss. Such diagnoses have been hampered for some years by the lack of a suitable standard.

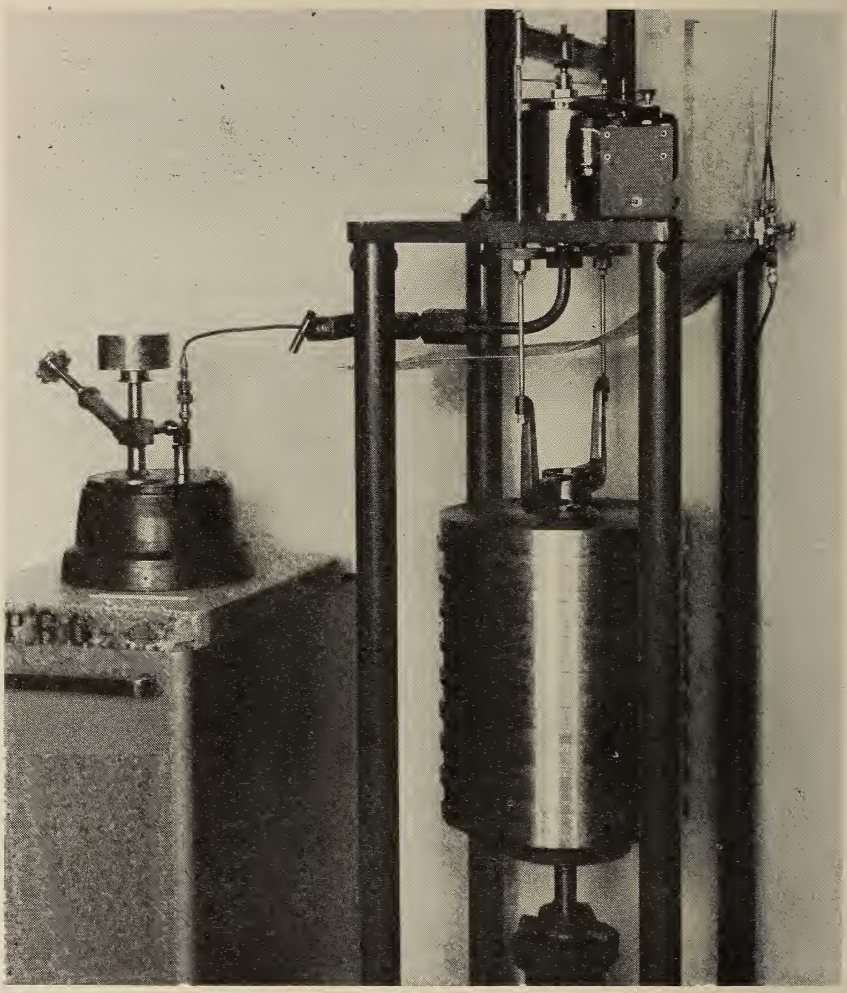
Jet Noise. Noise produced by aircraft jet engines has become a major problem. The noise can be sufficiently powerful to cause permanent damage to the hearing of a person near a jet engine. NACA sponsored researches into the physics of the noise generation, and investigations into methods for reducing it, are being pursued in several laboratories. At the Bureau a technique has been developed for measuring accurately the total sound power produced by a jet of gas issuing into air. The technique is being applied to model jets, and to models of nozzles designed for reducing jet noise.

Architectural Acoustics. The measurement of the physical properties of acoustical materials has presented for many years a problem that has not yet been completely solved. This problem is of considerable economic importance; millions of dollars worth of acoustical materials are manufactured and installed every year.

The essence of the technical problem is that measurements by various laboratories of the sound absorption by acoustical materials do not agree exactly. The lack of agreement apparently arises from the inability to achieve a random sound field for absorption measurements. Several physical criteria have been adduced by NBS staff members for ensuring such a field during absorption measurements. It has been found that a sound field that is random as far as direction of propagation is concerned, nevertheless exhibits statistical correlation between the sound pressures at any two points. A measurement of this correlation for a given sound field enables one to decide whether or not the sound field is sufficiently random. This should lead to a standard method for measuring the sound absorbent properties of the acoustical materials used in architecture.

Measurement on Material Substances with Sound. Sound waves are used to measure the physical properties of various substances. One important application is to researches in the sea. Underwater propagation measurements are frequently made with an acoustic interferometer. Under the sponsorship of the Office of Naval Research, a nonreflecting interferometer has been developed in which the sound wave incident upon a transducer is totally absorbed by the electric circuit of the transducer when suitably adjusted. This makes it possible to obtain a more direct and more accurate measurement of sound velocity and attenuation in fluids.

Analysis of Sound. The resolution of a sound wave into its component frequencies is one of the important basic techniques for determining what should be done about reducing noise, or how a communication system should be designed. Laboratory investigations of the analysis of sound are frequently hampered by the physical limitations of the available instruments for making such resolutions. For example, an analyzer might be able to single out a particular component in a complex mixture of different frequencies, but might require an excessively long time. An investigation of methods for making frequency analyses with physical instruments, sponsored by the Air Force, Navy, and the Atomic Energy Commission, has disclosed that the accuracy which might be possible in frequency determination, the time required to determine a particular frequency, and the noise inherent in the physical instrument, are not independent. The exact relationship developed



Controlled clearance piston gage (right), the new standard for pressures from 50 to 200,000 psi, is used to calibrate a small piston gage (left).

shows how the experimenter can trade accuracy of frequency determination for speed of analysis despite the presence of the inevitable noise which every physical instrument has.

Measurement of High Pressures. Modern industrial processes and military weapons are more and more frequently using pressures above 100,000 pounds per square inch. These high pressures must be measured under transient or rapidly changing conditions as well as under very high static pressures. The results of the NBS program in high-pressure measurement are applicable to both types of measurement, and work sponsored by the Aberdeen Prov-

ing Ground is aimed particularly at the problem of providing adequate standards for calibrating instruments used in such measurements. During the year attention has been given to improving the NBS controlled-clearance piston gages to increase precision of measurements at very high pressures. Improvements were made in the auxiliary equipment necessary in this work, including the further improvement of electrically insulating seals to permit multiple electrical connections to be made to the interior of high-pressure vessels. The development of an essentially leak-tight movable seal, having relatively low friction, for use in equipment generating very high pressures was also accomplished.

Aerological and Flight Test Instruments. The field of aerological instrumentation has assumed increased importance, particularly in connection with the operation of high-performance aircraft. In this work accurate and rapid measurement of water-vapor content of the atmosphere, including that of the upper air, is required. Under the sponsorship of the Department of Defense and the Atomic Energy Commission, an improved instrument using microwave principles has been developed for such measurements. This instrument depends upon the varying dielectric constant of the atmosphere as water-vapor content varies, and provides a sensitive and accurate measure of humidity. In military aircraft flight testing, increasing attention is being given to telemetering techniques for overcoming the limitations of conventional testing methods. Under the sponsorship of the Office of Naval Research, the Air Force, and the Atomic Energy Commission, improved methods of measuring the characteristics of certain telemetering instruments have been devised, and work has continued in improving flight test instruments to enable them to meet increasingly severe requirements in testing modern aircraft.

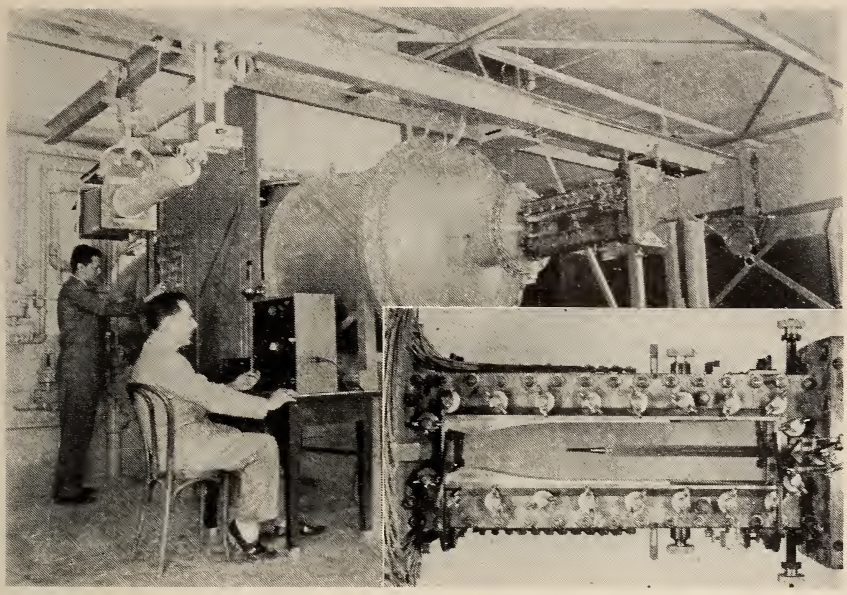
Water-Wave Research. The physical laws governing growth and decay of water waves, the relation of their amplitude and other characteristics to the wind producing them, and the forces exerted by such waves on engineering structures have long been of importance to naval architects in designing ships, and to engineers in designing shore and harbor structures. Because of the importance of these problems a continuing program of water-wave research has been under way for some years at NBS, supported principally by the Office of Naval Research.

Two phases of this investigation, involving an experimental study of the growth of wind waves in a channel and a theoretical study of the wind tides on idealized reservoirs of rectangular shape have recently been completed. These studies have particular application to the design of engineering structures along the shoreline of lakes located on comparatively flat terrain where the wind forces may be large and where relatively small tides may inundate large areas of adjoining land. The results of these studies illuminate certain aspects of energy transfer from air currents to water waves and tides and provide means for estimating the magnitude of wind-generated waves and tides.

Density Current Research. Salt-water intrusion into the coastal rivers and navigation canals of the country has in recent years seriously threatened the water supplies of cities, industries, and farms located along these rivers. Because of the importance of this problem, the Army Corps of Engineers has supported an extensive research program on density-current flow at the Bureau during the past 6 years. This program has consisted of two principal phases: (1) the density-current flow from a canal lock connecting on one side to a saline body of water and on the other side to a fresh-water channel, and (2) the density-current flow from an ocean into a fresh-water channel.

The results of these investigations, reported to the Corps of Engineers, include the effect of density difference, river velocity, depth of channel, length of travel, salt-water barriers, etc., on the velocity, depth, mixing, interfacial stresses, and other characteristics of the density-current flow.

Boundary Layer Transition. An important problem arising from motion of a body through air or water is the nature of the flow in a thin layer over the surface, called the boundary layer. In general, the fluid in a boundary layer flows smoothly and orderly (laminar) for some distance along the surface and then breaks into the chaotic motions of turbulent flow. Between the two types of flow there is a transition region in which flow is alternately laminar and turbulent. Referred to as boundary-layer transition, this phenomenon is of great practical importance. For example, the speed and range of both aircraft and missiles are strongly influenced by the extent to which their surfaces are covered by turbulent flow. Recently the Bureau concluded one phase of a continuing experi-



The NBS supersonic wind tunnel produces wind velocities up to twice the speed of sound. ***Insert:*** **Closeup of test chamber with hot-wire anemometer probe in place (p. 48).**

mental investigation sponsored by the National Advisory Committee for Aeronautics on the fundamental processes of boundary-layer transition. With the hot-wire anemometer as the principal measuring instrument, studies were made in the boundary layer with air flowing along a flat plate. The nature of the transition region has been clearly defined. It was shown that transition is a process in which turbulent spots first form, then grow as they move downstream. The rate of propagation, shape, and other significant features of such turbulent spots have been studied. These results have provided new insight and have given added impetus to basic investigations on the mechanics of transition.

Surface Roughness. An important aspect of the transition of laminar to turbulent flow along the surface of bodies moving through air or water is the effect of surface roughness. Under the sponsorship of the National Advisory Committee for Aeronautics, the effect of 2- and 3-dimensional roughness elements on boundary layer transition in air flowing past a flat plate was investigated. It was found that there is a marked difference in behavior between 2-dimensional and 3-dimensional roughness. Three-dimensional roughness has less effect on transition than does the 2-dimensional

but is extremely sensitive to changes in wind speed or position in the surface. The data obtained show that rougher surfaces induce earlier transition. Also, surface roughness must be considered in any attempt to control boundary layer transition by using suction.

Vibration Standards for the Calibration of Pickups. Thousands of vibration pickups are used by governmental and industrial laboratories for testing missiles, aircraft, ships, surface vehicles, and other types of equipment. Major engineering decisions are based upon measurements made with vibration pickups, particularly the endurance of aircraft and other structures. The successful performance of these structures and the lives of operating personnel depend upon the accuracy of observations made with the pickups and therefore on their calibration. To meet this need, vibration standards have been developed and NBS now offers a limited calibration service for vibration pickups measuring displacement, velocity, or acceleration.

The vibration standard consists of an electrodynamic vibration exciter and a velocity sensing coil calibrated by the reciprocity method. This calibration requires measurements of mass, frequency, and electrical quantities only, and therefore avoids the difficulty of measuring accurately the small displacements of high-frequency vibrations. Between 30 and 900 cps the calibration factor of the standard was found to be constant within 1 percent. At higher frequencies the calibration factor is known with somewhat less accuracy because of undesirable resonances. These resonances change the electromechanical characteristics of the standard and result in less stability than is present at the lower frequencies. The method for calibrating pickups involves the application of a known level of vibration amplitude to the pickup and the measurement, with a potentiometer circuit, of the ratio of the pickup output voltage to the output voltage of the velocity sensing coil.

If desired, both the magnitude and phase of the calibration factor can be determined. Pickups calibrated for amplitude only would be suitable for making many vibration measurements in structures. Pickups calibrated for both amplitude and phase would be suitable as secondary reference standards for governmental and industrial laboratories, or for vibration measurement on structures where great precision is needed.

Thermal Stresses. With the advent of high-speed flight, a need has arisen for a reliable method of predicting stresses and deflections in aircraft structures caused by transient temperature gradients from aerodynamic and jet-engine heating. The solution of the problem is a dual one requiring first the computation of the transient temperature distribution, and secondly the computation of thermal stresses and deflections corresponding to the temperature distribution. A study sponsored by the Office of Naval Research was undertaken to develop procedures for predicting thermal stresses and deflections and to check these procedures by tests on simple structures.

A numerical method for computing on SEAC the two-dimensional transient conductive heat flow in an I-beam has been generalized to include prediction of temperature distribution in beams of various cross-sectional shapes, and the effects of radiant as well as conductive heat transfer.

Analyses were made of simple beams heated from one side only. Consideration of a large number of cases led to the conclusion that large variations in temperature distribution and heating rate may have only moderate effects on thermal stresses and curvatures.

Radiant heat transfer between parallel plates of inconel and aluminum was investigated for a wide range of temperatures and temperature differences. It was found that using a simple gray body assumption instead of the actual emissivity of the material to compute the heat transfer rate resulted in errors from 2 to 29 percent. It was shown that in the absence of convective heating, radiant heat transfer predominates over conductive heat transfer for inconel structures and is significant for aluminum structures at elevated temperatures.

Fatigue Strength of Aircraft Structures. Owing to a steady increase in maneuvering loads of high-performance military aircraft, the problem of fatigue failures has become critical. Design data on fatigue strength of aircraft structures are urgently needed. In response to this need the Navy Bureau of Aeronautics has requested that fatigue tests be made to provide data on typical structural components, especially in the high-load range.

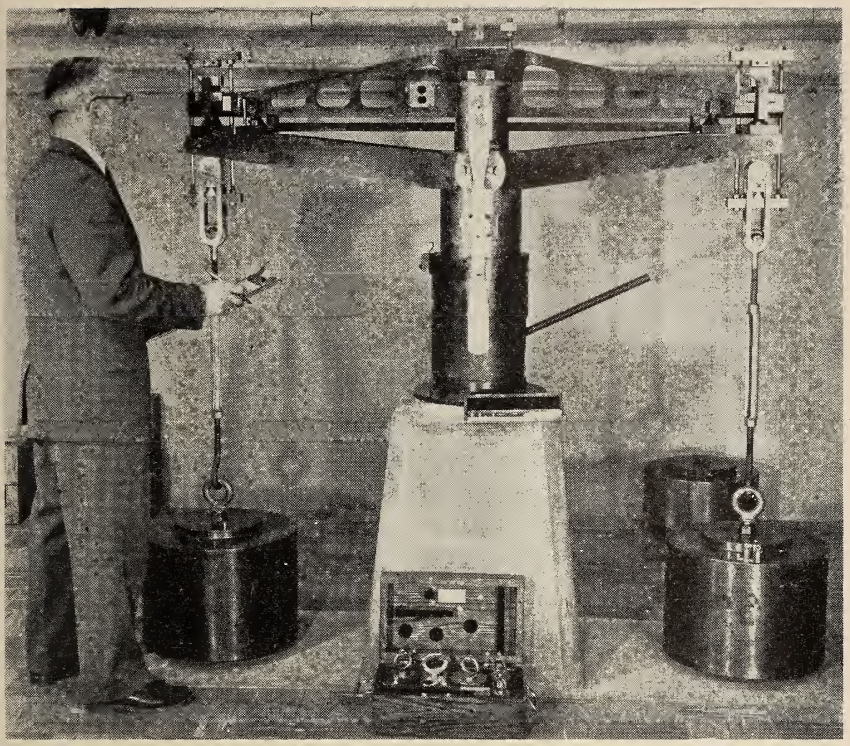
Most aircraft structures are so complicated that predicting their performance under repeated loads from available data on fatigue strength of materials is quite difficult, if not impossible. The

general use of limit loads as criteria for airplane design makes them a desirable basis for making a plot of stress versus number of cycles to failure. A test program was initiated to determine the variation of life with percentage of limit load for 2 types of wing beams under 2 different loading conditions. Fatigue results of the various tests were in good agreement.

In order to provide additional data, tests sponsored by the Navy Bureau of Aeronautics were conducted on 75S–T6 aluminum alloy specimens machined from hand-forged bars of 75S aluminum alloy. The stress concentrations used for this work were rectangular lugs protruding from the minimum cross section of the specimens. The tests were designed to show the effects of variations in the fillet radius at the base of the lug, the lug height, width, and the mean stress. The maximum stress was chosen to emphasize fatigue failure occurring in 10,000 cycles or less. The test results showed that fatigue strength decreases with decreasing fillet radius and increasing lug width. Substantial variation in lug height had no effect on the fatigue strength. Very high stresses reduced the effect of the stress concentrations. This is believed due to the increased plastic flow at the stress concentration.

Airplane Design. In determining whether the structure of an airplane can support the loads that will be imposed upon it during its lifetime, its structure is analytically evaluated for flight, landing, and takeoff conditions and the prototype undergoes a series of tests to evaluate its strength. Usually, only those conditions believed to be most severe are investigated in the analytical evaluation because of the limited time available. By using high-speed digital computing machines, it has become possible to study a wider variety of conditions and to determine the relative importance of the different parameters in the configuration of the airplane as it flies, takes off, or lands.

With the plan of investigating a wider range of parameters than had previously been included in the analysis, a study was undertaken for the Navy Bureau of Aeronautics to determine the loads on the landing gears of an airplane when it made arrested landings on an aircraft carrier. By varying each of the landing conditions in turn while keeping others constant, initial landing conditions resulting in maximum loads on the landing gears were found. This study indicated which of the initial conditions should govern the



Thousand-pound balance developed for use by State weights and measures groups. Apparatus conveniently weighs a 1,000-lb weight with an accuracy of about one part in a million.

design of the landing gears and also over what range the pilot could safely vary his sinking speed, engaging speed, wing lift, and pitching velocity as he brings his plane in for a carrier landing.

Faced with the problem of providing room for fuel tanks or other stores in the airplane wing, or decreasing the over-all weight of the airplane, a designer might eliminate some of the wing ribs or reduce their stiffness. To answer the question of whether either of these alternatives may lead to serious vibration in flight, the vibration modes of several wings were determined. A delta wing was chosen as basic. The vibration frequencies and modes were computed for the basic wing and for several modifications of the basic wing. Results showed that the frequencies and mode shapes of modified wings differed little from those of the basic wing and, therefore, that the modifications would not appreciably affect vibration characteristics of the delta wing.

One Thousand-Pound Balance. A balance that can weigh a 1,000-lb weight with an accuracy of about one part in 1,000,000 was

constructed. The balance was designed with special pickup attachments to make it convenient in laboratories handling large weights. Although the balance was developed especially for use by State Weights and Measures groups, it will be of interest to many industrial laboratories. Working drawings of the balance have been made available to balance and scale manufacturers.

Densities of Alcohol-Water Mixtures. It is known that alcohol-water mixtures provide additional thrust for jet aircraft takeoffs. Both ethyl alcohol and methyl alcohol are used. The proportions of alcohol to water for maximum thrust increase are limited to rather narrow ranges, different for each of the two alcohols. The approximate proportions are to be checked in the field with a hydrometer. To provide a basis for these field checks, the Air Force has sponsored a series of density determinations to derive a relation between specific gravity, temperature, and concentration of the mixture. The first density determinations were made on methyl alcohol-water mixtures.

Combustion in High-Velocity Air. Preliminary studies under sponsorship of the Navy Bureau of Aeronautics on gaseous oxygen injection in ramjets and reheaters showed enough promise to warrant further study in reheaters only. A development and testing program sponsored by the Wright Air Development Center on ceramics and metal ceramics for jet engine components has been completed and specimens have been prepared for WADC to test in full-scale engines.

Fuel Accessories for Aircraft. Having aided the military services adopt standard fluids for testing and setting reciprocating engine carburetors and gas-turbine fuel-control units, the Bureau has begun to specify fuel control settings for test equipment of the Navy. Test equipment at approximately half of Navy's overhaul stations has been adjusted by NBS personnel so that test results agree with those obtained at the Bureau. These correlation programs are continuing. During the year calibration facilities for fuel flowmeters were set up with an accuracy of 0.2 percent over the flow range from 4 to 100,000 lb/hr. Eight master regulator units have been built for use at Navy stations to check the reliability of their carburetor flow benches. This work has been sponsored by the Navy Bureau of Aeronautics.

2.7. Organic and Fibrous Materials

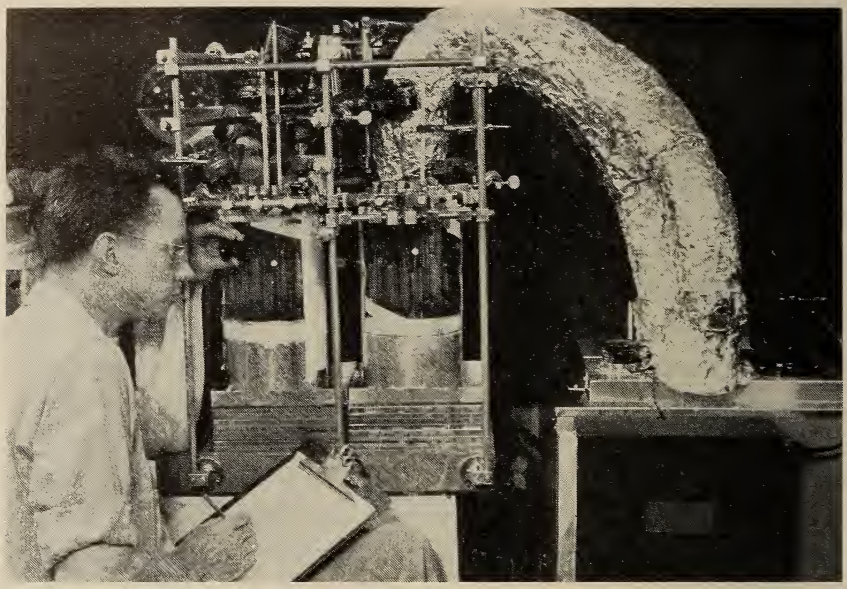
The Bureau undertakes a wide range of basic and applied research on natural and synthetic polymeric materials, including rubber, textiles, paper, leather, and plastics. All of these materials are composed of very long, chainlike molecules formed by the process of polymerization. Many of their useful properties depend upon the size, shape, distribution, and flexibility of the molecules and interaction with other molecules. The mechanisms involved in forming polymers, their constitution, structure, and properties are being investigated to advance fundamental knowledge of these industrially important materials.

Basic research during the year included studies of crystallization and melting phenomena in polymers, the propagation of stresses and strains in fibers, the structure of polymers, stability of polymeric materials in relation to their chemical structure, dielectric relaxation times, and molecular properties of polymers used as blood plasma expanders.

Representative applied research projects were concerned with rain erosion of aircraft surfaces, laboratory methods for estimating permanence of record papers, the development of polymers for high temperature use, a method for measuring infrared absorption of insoluble materials, a method for measuring the temperature of air in a tire while the tire is operating, and improvements in dental materials and processes. Several statistical procedures of value to the polymer technologist were also developed and published.

Crystallization Phenomena in Polymers. In a program sponsored by the Office of Naval Research, the thermodynamics of natural rubber and guttapercha crystallization were investigated, the existence of equilibrium melting temperatures was established, and the thermodynamic parameters governing the crystallization were determined. The high melting point and other unusual crystallization features of stark rubber, a variety of natural rubber, were found to result from the preferred orientation of its crystallites. The orientation was described by a pole figure analysis using X-ray diffraction techniques. Based upon these results, methods were developed for preparing stark rubber in the laboratory.

In view of the use of butadiene as one of the major constituents in GR–S synthetic rubber, the melting behavior of polybutadienes prepared at different temperatures was studied. The melting tem-



Apparatus used at NBS to obtain a more complete understanding of stark rubber (p. 55).

peratures were found to be appreciably higher than expected and to depend on the proportion of the polymer in the *trans* 1,4 configuration.

Behavior of "Pure Gum" Rubber Vulcanizates in Tension. Finding a single parameter to define the stress-strain properties of a given rubber would help in studying vulcanization kinetics. Such a parameter has been sought in work sponsored at the Bureau by the Office of Synthetic Rubber of the Reconstruction Finance Corporation. The most obvious choice is Young's modulus, the slope of the stress-strain curve at the origin. Indeed, for pure gum rubber vulcanizates in tension for a fixed time, it has been found possible to express the ratio of stress to Young's modulus in terms of a specific function of the elongation. The elongation function can be applied to natural rubber and to the common synthetic rubbers GR–S, GR–I, and Neoprene, but not to vulcanizates of these rubbers containing carbon black. The same function was found applicable to various fixed times of creep between 1 and 10,000 minutes, and the amount of creep, in the absence of degradation, was found to be approximately linear with the logarithm of the time. In order to avoid effects associated with crystallization, elongations were limited to values less than

200 percent. Using this normalized function, one can obtain a value of Young's modulus for any specified time of creep from a single observation of stress and strain.

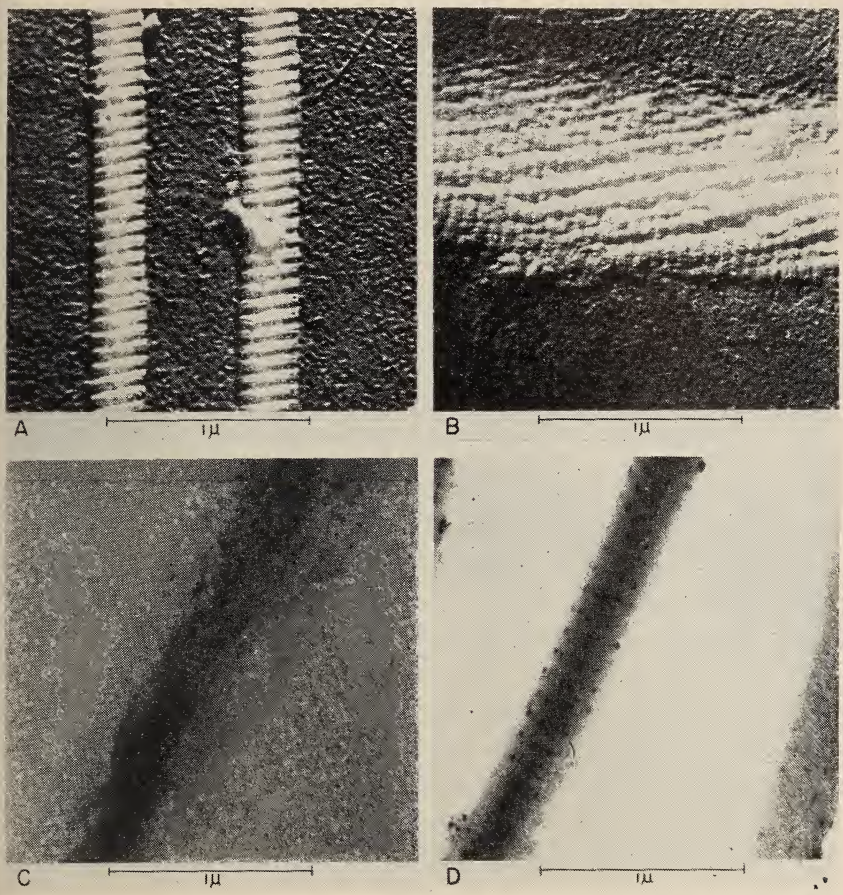
Effect of Atmospheric Contaminants on Textiles. The effect of dinitrogen tetroxide, an atmospheric contaminant, on textiles was studied with the aid of equipment specially developed for the purpose. In this equipment the textile is exposed to a stream of air of specified temperature, relative humidity, and concentration of contaminant. Dinitrogen tetroxide in concentrations of the order present in smog and in certain industrial areas causes deterioration of cellulosic textiles. Fabrics made of cellulose fiber, cotton, ramie, and commercially deacetylated acetate were found to be equal in resistance to air containing dinitrogen tetroxide. However, they were less resistant than viscose rayon fabric. Both partial cyanoethylation and partial acetylation increased the resistance of cotton fabrics to dinitrogen tetroxide.

Effects of Light on Coated Groundwood Papers. It has been found in recent research that clay coatings on papers containing groundwood fibers afford partial protection against deterioration by light. The fact that exposure to light changes the color of groundwood paper can be readily observed by placing a partially covered sheet of newsprint in sunlight for a few hours and then comparing the colors of the exposed and covered portions. Because coated groundwood printing papers are being used in growing quantities, it is of interest to the Government as well as to other users of paper to know how much protection against light is given by the coating. Both clay-coated groundwood papers and some from which the coating had been removed were irradiated by a carbon-arc lamp with a cupric chloride filter so as to simulate skylight filtered through window glass. Uncoated groundwood, chemical wood, and rag papers were similarly irradiated for comparison. The effect was measured by changes in alpha-cellulose content and reflectance of blue light. Results showed that the coating offers partial protection against light; the coated groundwood papers showed greater deterioration than those not containing groundwood, but much less than uncoated groundwood papers or those from which the coating had been removed. Laboratory aging tests using heat alone showed that groundwood papers are quite stable under applied heat.

Accelerated Aging of Record Papers. A quick and reliable laboratory method for estimating relative permanence of record papers is important for large users of such papers, both to determine the quality of record papers they buy and to assess the probable value of new types of papers. Accelerated aging of paper by heating for 72 hours at 100° C has been used as a test for many years. In 1928 the Bureau tested a series of commercial writing papers before and after aging under these conditions, and stored specimens of the paper for future testing. Chemical tests were made after 4, 8, and 22 years of natural aging, and physical tests after 4, 8, and 26 years. A fair correlation between accelerated and natural aging was found for changes in alpha cellulose, copper number, total acidity, and folding endurance. Results of chemical tests on rag papers showed very little change in 22 years, whereas the folding endurance decreased to half its original value. Therefore a distinction must be made between the permanence of the cellulose fibers and that of the properties of the paper sheet.

Amino Acid Analysis of Collagen. In recent years increased emphasis has been placed on the fundamental structure of fibrous proteins, such as collagen. In addition to the importance of collagen in leathermaking, recognition of the important role it serves in the various connective tissues of the body has greatly intensified the interest of medical science. Electron microscope, low- and high-angle X-ray diffraction, and similar measurements have resulted in a number of proposed structural formulas for collagen. Ultimate proof of the structure still resides, however, in amino acid analysis.

Progress in unraveling the structure of collagen has been retarded in the past by the time-consuming, laborious methods of amino acid analysis. For this reason, efforts at the Bureau have been directed toward a more rapid means of determining the amino acid content of collagen. A two-dimensional paper chromatographic technique has been developed which will permit an accurate analysis of 17 of the 18 amino acids found in collagen in 4 days. A complete amino acid analysis of purified collagen by this rapid procedure confirmed values generally accepted for the protein. This is one of the few analyses in which all the amino acids have been estimated from the same initial collagen sample.



These electron micrographs, revealing the presence of large numbers of extremely small pores, may provide new insight into the structure and behavior of leather. Micrographs show disrupted collagen fibrils of kangaroo tail tendon dispersed in water.

This technique should encourage more studies on the amino acid contents of proteins. As a means of following the course of a chemical reaction, it should produce more precise information on degradation of proteins. A study has been completed on the reaction between nitrous acid and collagen in which the paper chromatographic method was used as an analytical tool for analysis of the products.

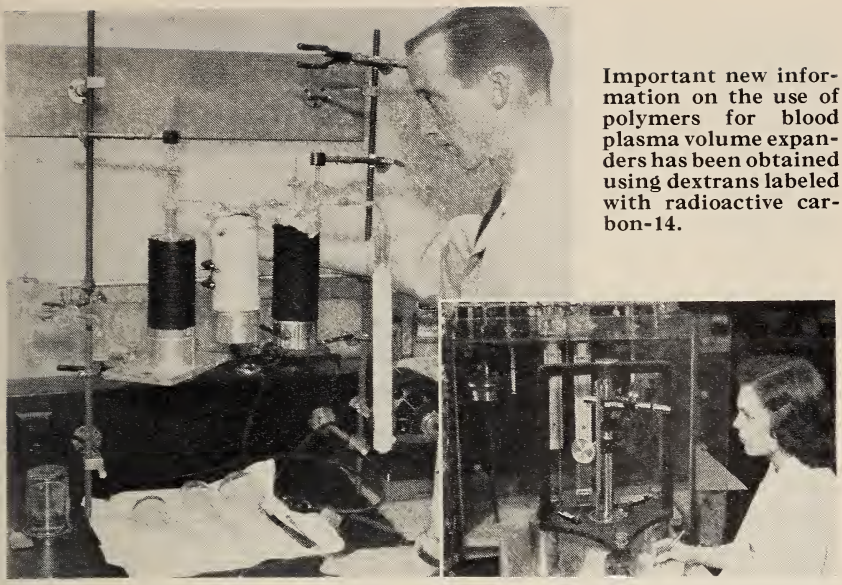
Micropore Structure of Leather. Many of the unique properties of collagen and the tanned product, leather, are believed to result directly from the character of the collagen that is formed in nature as a fibrous network. For example, the remarkable resistance of leather to flexural fatigue may be attributed to the ability of the

individual fibers to reorient under stress. Similarly, the permeability of leather to water vapor, which makes it well suited to use in footwear, is related to the presence of pores.

Pressure porosimeter and electron microscope studies completed during the year are expected to provide new insight into the structure and behavior of leather. This work revealed the presence of large numbers of extremely small pores—less than a millionth of an inch in radius—in both leather and its parent substance, collagen. The quantitative information obtained on pore-sizes distribution within the individual collagen fibrils will aid the leather technologist in understanding the swelling and shrinkage accompanying water-leather interactions. It is also shedding additional light on the ability of leather to transmit or absorb water vapor, tannins, or impregnants.

Temperature of Tires. The temperature of a tire while operating is an important factor affecting the rate of deterioration. Although many measurements of temperature have been made, there is no published information on the reliability of such measurements. This past year a study was completed on the temperatures encountered at different locations within the inner tube while the tire is operating. The study resulted in a reliable procedure for obtaining the average temperature of the air within a tire. This work was sponsored by the Office of Synthetic Rubber of the Reconstruction Finance Corporation.

High-Temperature Polymers. A great need exists in the military services for materials having low dielectric loss and at the same time a high thermal stability. Often such materials must be subjected to temperatures as high as 525° C or even higher. Under sponsorship of the Army Ordnance Corps, the Bureau is attempting to develop such a material by two different methods of attack. The first is to synthesize polymers having certain structures that are likely to resist thermal decomposition at these higher temperatures. In the second method attempts are being made to improve the thermal stability of existing materials. To this end samples of polytetrafluorethylene have been subjected to high temperatures under various gases. It has been found that some gases, e. g., nitrogen, have no effect on the rate of decomposition; others, such as water and oxygen, have an accelerating effect; while still others, such as chlorine, hydrogen, and fluorine,



Important new information on the use of polymers for blood plasma volume expanders has been obtained using dextrans labeled with radioactive carbon-14.

In this apparatus, tagged expanders are converted to carbon dioxide for measurement in an ionization chamber. *Insert:* Molecular weight data on blood plasma expanders are obtained by measuring their osmotic pressures.

markedly inhibit the rate of decomposition. When the most suitable gases for improving thermal stability are determined, they will be incorporated into the polymers as solid compounds that give off these gases at high temperatures.

Blood Plasma Expanders. In cooperation with the Office of the Surgeon General, Department of the Army, and the National Research Council, the Bureau continued its study of the molecular properties of polymers that are being used as blood plasma volume expanders. Clinical tests have shown that the most commonly used plasma substitute, dextran, has a tendency to cause an increased bleeding time in patients who have the material infused into their blood. The hypothesis has been advanced that this adverse effect may be caused by sorption of the dextran molecules to body tissues or to the surfaces of the blood-clotting agents (platelets) in the blood. A preliminary study of the sorption of dextran to collodion membranes was made using dextrans labeled with carbon-14. The amount of radioactivity remaining on the membranes after exposure to the dextran solutions is a measure of the degree of sorption. It was demonstrated that sorption actually did take place and also that the presence of surface-active

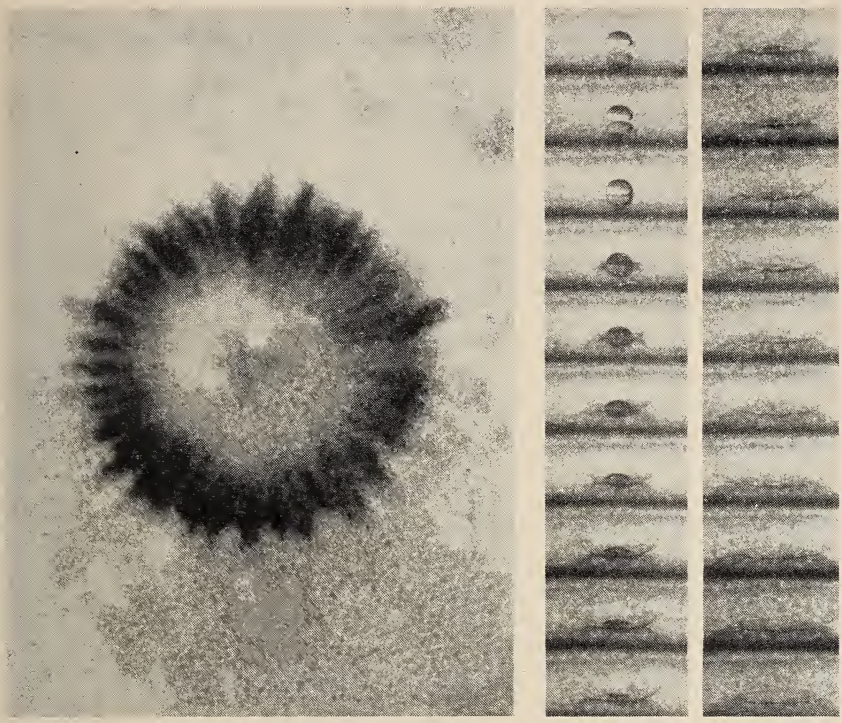
agents had an effect on the amount of dextran adsorbed. Later investigations, also employing the carbon^{14}-labeled dextrans, showed that sorption of dextran also takes place on platelets obtained from human blood. It has not yet been determined, however, that this adsorption is the cause of the excessive bleeding previously mentioned.

Dielectric Studies. Almost all polar organic substances, whether crystalline or liquid, exhibit evidence of a spectrum of dielectric relaxation times. A theory which begins with molecular considerations and leads to such a spectrum for polar organic crystals has been developed. Each of the dielectric relaxation times comprising the spectrum is the negative reciprocal of one of the eigenvalues of a simple matrix. The theory leads to predictions that are qualitatively correct, but a quantitative application has not yet been attempted.

Multiaxial Stretching of Plastic Glazing Material. Polymethyl methacrylate plastic sheet is used in canopies and windows for aircraft. When subjected to tensile stress for various periods of time, this material develops fine cracks, known as "crazing," and must then be replaced. The Bureau has been studying this problem for some time under the sponsorship of the National Advisory Committee for Aeronautics. In 1952 it was shown that by multiaxially stretching polymethyl methacrylate sheet, the resistance to crazing is greatly increased. In addition, a laminar structure is produced which results in greatly increased strength.

Several new or modified transparent plastics offering increased heat resistance have recently been produced. These materials include modified polymethyl methacrylate and polymethyl alpha-chloro-acrylate. The effects of multiaxial stretching on the properties of these plastics has been investigated. This work showed that the craze resistance of these materials is also greatly increased by stretching, with a similar laminar structure resulting. Thus these new transparent plastics offer great promise for use in stretched form for aircraft glazing, with increased heat resistance over the plastic glazing now in use.

Infrared Spectra of Insoluble Organic Materials. The infrared spectra of insoluble materials can be obtained by embedding the materials in a potassium bromide pellet which serves as the analytical specimen. This potassium bromide pellet technique is suitable



Photographic studies are providing a better understanding of the mechanism of rain erosion of aircraft surfaces (p. 63). *Left:* Starch-iodide trace of radial flow of waterdrop. *Right:* High-speed moving pictures of the collision and flow of a water drop.

for materials that have a very fine particle size, i. e., 1 to 5 microns in diameter. Some materials cannot, however, be powdered to this size, and others cannot be pulverized without deterioration of the material. By embedding materials to be studied in a matrix having a refractive index comparable to that of the material under examination, it was shown that particles as large as 110 microns in diameter can be measured. Most polymeric substances have a refractive index between 1.47 and 1.6 $n_D^{20°}$. Potassium chloride, sodium chloride, potassium bromide, and potassium iodide represent a series of matrices that can be used to cover this range. The infrared spectra of insoluble resins, paper, and textile fibers have been obtained by this technique.

Mechanism of Rain Erosion. One of the problems accompanying the development of high-speed aircraft is erosion of the surfaces of the leading edge and of the radar housings, which results from flying through rain. Work toward an understanding of the

mechanism of this type of erosion was initiated at NBS in 1952 by the Navy Bureau of Aeronautics and has since been sponsored by Wright Air Development Center.

Basic information on the effect of a collision of a solid with a more or less spherical mass of liquid has been obtained. The waterdrop is the tool in this erosion process. At high striking velocities, a waterdrop acts as though it were a hard sphere, but unlike a sphere of hard material, it undergoes a radial flow of very high velocity. The damage done to a given material by collision with a waterdrop at high speed is caused by impact pressure and by the shearing action of the radial flow of the drop or the torque that this flow exerts against protruding irregularities of the surface. Response of a material to stresses, that collision with a waterdrop imposes, depends on its own characteristic properties. Hence, there are as many erosion mechanisms as there are broad groups of properties in structural materials.

Panographic Dental X-ray Machine. The Bureau cooperated with the Air Force Dental Service in the design and construction of a panographic X-ray machine that rapidly takes an X-ray picture of the entire dental arch. This machine will permit a considerable saving in time over present techniques in which up to 14 small films are used for a full-mouth survey.

In the panographic machine, the film is placed outside the mouth and is exposed by passing a narrow beam of X-rays through the patient's head from the rear. Movement of the X-ray source and the film is so coordinated that only those structures of the dental arch desired in the finished film are projected, while other overlying structures are not. Preliminary experimental exposures have been made on human skulls and a limited number of live subjects. Results indicate that the method may be capable of producing panoramic full-mouth exposures in about 40 seconds, exclusive of processing time.

It is expected that much time and effort may be saved in making mass radiographic surveys by this method, and at the same time, more comprehensive and inclusive radiographs will be produced, giving more information than conventional full-mouth radiographic surveys. In addition to its usefulness to the armed services, the equipment has potential application in many other fields where large numbers of people are examined for dental defects.

Gallium Alloys. Gallium alloys were investigated as tooth-filling materials in a program of dental research conducted by the Bureau in cooperation with the American Dental Association, the armed services, and the Veterans Administration. Because gallium melts at 29.8° C, it can be mixed with powdered metals or alloys by essentially the same techniques as are used to mix mercury with silver alloys to form the amalgams commonly used for restoring teeth. Gallium's ability to wet many materials, including tooth structures, should give good adaptation when a gallium alloy is condensed into a cavity.

Results indicated that face-centered cubic metals such as gold, nickel, copper, and some intermetallic compounds of copper and tin when mixed with gallium do produce alloys which harden at room or mouth temperature. Data obtained on a gallium-nickel-silicon alloy do not show the decrease in strength found in amalgam alloys heated to the elevated temperatures normally encountered in the mouth. Also, the gallium alloys appear to have better tarnish resistance than does dental amalgam. One disadvantage of the gallium alloys is their relatively high setting expansion (50 microns per centimeter or greater). Data obtained indicate that it may be possible, however, to reduce this expansion somewhat by adding small amounts of cobalt, silicon, or other elements. Some of the gallium alloys appear to have properties equal or superior to dental amalgam, but clinical evaluation will be necessary before any of them can be recommended for dental use.

2.8. Metallurgy

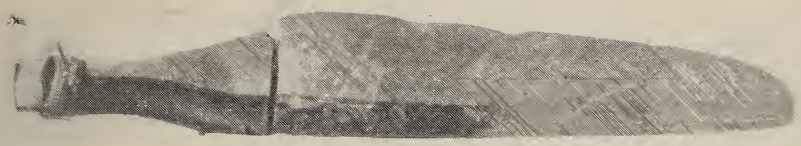
The Bureau's work in physical metallurgy is concerned with the melting, fabrication, and heat treatment of metals and alloys; and with determinations of metal structure, properties, and behavior under normal and unusual conditions of service. In general, this program is directed toward increasing both theoretical and practical knowledge in order that new or improved metals and alloys may be developed for better, safer, and longer performance in present uses and to meet requirements of new applications.

Constitution Diagrams. Accurate and detailed diagrams that show the melting points, structural changes occurring at various temperatures, intermetallic compounds, and solubility relationships are of vital importance in understanding the behavior and making the best use of metallic alloys. The use of iron-chromium-

nickel-molybdenum stainless steels in turbine buckets, aircraft parts, and automobile engine valves is limited, probably because of structural changes induced by the very high temperatures in which such parts operate. To obtain more information on this subject approximately 100 alloys were prepared and portions of each were exposed for long times to temperatures between 1,500° and 2,200° F. Metallographic and X-ray diffraction studies of these specimens permitted the construction of diagrams that show the temperature range of existence and solubility relationships of various phases, including two new intermetallic compounds. These are similar to the previously identified brittle sigma phase. The diagrams show the operating conditions that should be avoided to prevent forming these undesirable constituents.

Work on the binary diagrams of magnesium with lanthanide (rare earth) metals was begun under the sponsorship of Wright Air Development Center. Additions of mixed lanthanide elements improve the strength and stiffness of magnesium at high temperatures for applications in modern high-speed aircraft. Development of accurate binary diagrams should help to explain this effect and should indicate the possibilities of further improvement. The establishment of binary diagrams of interest to the Atomic Energy Commission was continued.

Properties and Behavior of Alloys. The effect of a few thousandths of 1 percent of boron, in promoting the hardenability of steel that is quenched after heat treatment, has been established, but the accompanying effect of boron on other properties of the steel is not well known. The popular low-alloy chromium-nickel-manganese steels of the 81xx series can be heat treated to desirable hardness and strengths, particularly when boron is added, but this improvement in some properties may be accompanied by a decrease either in ductility or in resistance to impact. Under the sponsorship of Watertown Arsenal, an investigation of the effect of boron additions on the impact properties of slack-quenched-and-tempered steels is in progress. Experimental steels were made and heat treated, and the testing program is under way. Another phase of the problem was initiated late in the year, at the request of Wright Air Development Center, to investigate the effect of boron additions, alone and with other elements, on the susceptibility of 8140 steel to temper embrittlement.

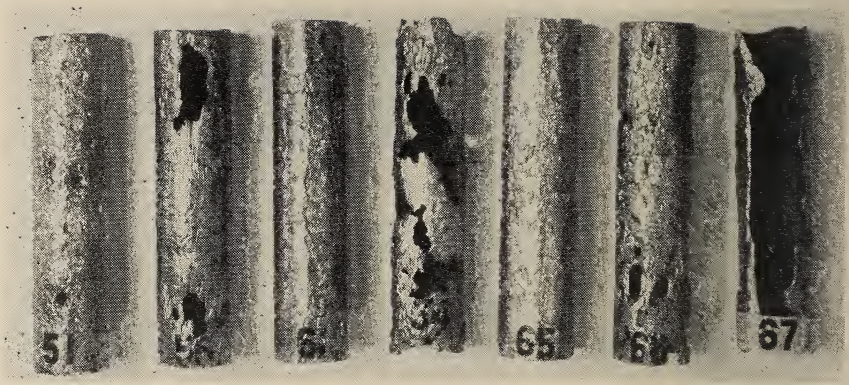


A fatigue crack starting on the inside of the hollow steel blade caused the failure of this aircraft propeller. NBS examination showed that the crack resulted from a gouge made by a mandrel during the blade's fabrication (p. 69).

Tensile strengths of 300,000 pounds per square inch have been obtained by appropriate heat-treatment of low-alloy steels, for example, type 4340, but optimum use of these high strengths in structures cannot be made until means can be found to improve ductility. Under the sponsorship of the Navy Bureau of Aeronautics, experimental steels of slightly modified 4340 composition were prepared, heat treated to 300,000 psi tensile strength, and were subjected to tests. The best of the experimental steels, which will be studied further, has about 10 percent elongation at room temperature, and about 15 foot-pounds impact strength at −50° C.

Mechanism of the Deformation of Metals. Metals under applied stress may be subject to elastic or plastic deformation, or both. Elastic deformation occurs under short-time application of relatively light loads, and the metal recovers completely when the load is removed. Plastic deformation involves permanent changes in the metal and occurs under heavier loads and longer times of load application or at higher temperatures. In an attempt to determine the mechanism of such deformation, particularly in the transition range where plastic deformation begins, polycrystalline rods and coarsely crystalline specimens are being studied by X-ray diffraction and metallographic techniques. The purpose is to identify the effects of intergranular stresses, dislocations, grain boundary migrations, and misorientations in lattice structure. Studies show that changes in Young's modulus under applied stress are different in different directions in both polycrystalline rods and in individual crystals.

In a continuing investigation of the flow and fracture of nickel-copper alloys at elevated temperatures, a study of the creep characteristics of nickel was completed and published. Determinations were made of the short-time tensile and creep behavior of 70:30 and 30:70 nickel-copper alloys at elevated temperatures.



Results of an NBS study shows how some soils damaged unprotected steel pipe specimens during 14 years' exposure. Underground and other types of corrosion cost the United States billions of dollars annually (p. 70).

Another aspect of metal deformation and fracture in service is the loss of ductility of many types of steel at low temperatures. Such brittle fracture in normally ductile steel has received particular attention in connection with cracks and failures in all-welded ships, but has also been found in other types of structures. The Bureau's study of plates from ships that had suffered actual cracks or fractures in service was concluded during the year. Effects of variations in composition within the limits of specification requirements had previously been established and it had been shown that the tendency for cracks to form and propagate could be predicted from determinations of the transition temperature in impact or tensile tests. There was evidence, however, that the final answers would require more complete and detailed information about the production of individual plates than was available from the service failures. To fill this need a project was begun under joint sponsorship of the Ship Structure Committee and American Iron and Steel Institute to study material from current production of ship plate. Plans were made on a statistical basis for selecting plates and specimens to show variations within a single plate, in plates from different portions of the same or different ingots from the same heat, or from different heats. Some of the materials selected at the mills have been received and the experimental program is under way.

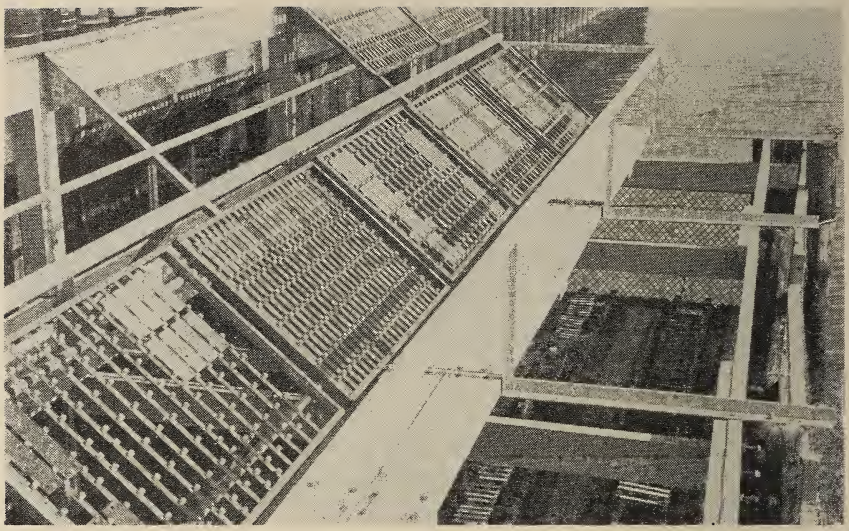
Many years of experience in determining the causes of failures of metals and alloys in service, particularly in transportation equip-

ment, were summarized in an NBS publication, Circular 550. A revision of this publication was prepared, by request, for inclusion in the forthcoming outside publication, *Engineering Materials Handbook*.

Titanium. The high strength-weight characteristics of the "wonder metal," titanium, have not been fully used because of uncertainty about its performance in other respects. Work at the Bureau sponsored in part by Wright Air Development Center showed that the tensile and impact properties of commercially pure titanium at temperatures from +300° to −196° C, were sensitive to the presence of notches or imperfections in the surface, and that this notch-sensitivity increased as the temperature was lowered. Differences in the notch-sensitivity of different lots of commercially pure titanium were correlated with differences in the content of interstitial elements, particularly oxygen.

Fatigue of Metals. Under the sponsorship of the National Advisory Committee for Aeronautics, an investigation is in progress to determine the initial stages of fatigue cracking of aluminum alloys and to explain why the yield strength of one aluminum alloy (75S) is 25 percent greater than that of another (24S) even though the fatigue characteristics of the two alloys are almost identical. Large-grained aluminum alloys were subjected to uniaxial fatigue stresses, with photomicrographic recording to detect the first appearance of cracks in the surface. Most of the cracks started, not in grain boundaries, but within a grain on the slip plane that had the largest resolved shear stress. This shows that decreased resistance from plastic deformation within the grain is a more important factor than stress concentration from inhomogeneous deformation at the grain boundary.

The fatigue properties of steel wire and of steel-wire springs are being studied under the sponsorship of Springfield Arsenal. During the year, a comparison was made of the fatigue properties of wire drawn from steel of commercial origin and from steel that had been specially prepared by vacuum melting. It was found that the material reduction of inclusions and impurities in the vacuum-melted steel improved the fatigue properties slightly. To aid in studies of fatigue under torsional stresses, a testing machine small enough to be mounted on the stage of a microscope was constructed.



These exposure racks are used in corrosion-resistance studies for aluminum alloy specimens. Useful information concerning the effect of a marine atmosphere on such material has been obtained over a 20-year period (p. 71).

Corrosion. Corrosion of metals costs the United States economy billions of dollars annually. The Bureau's contribution to this problem consists principally of attempts to determine the fundamental causes of corrosion and includes sponsored studies of the corrosion resistance of specific alloys and types of alloys.

Continued studies of the corrosion of monocrystalline aluminum, in acids and alkalies, have shown that the rate and pattern of the corrosive attack differ with the crystallographic orientation of the exposed surface and with the corrodent. Some of the results are being prepared for publication and current activities are directed to a study of the initial corrosive reactions and the location of the first corrosive attack with reference to the crystallographic orientation and structural imperfections and irregularities.

The possibilities of electrical measurement for studying corrosion reactions in progress, and the clarification of the complicated circuitry, are being studied. Two publications were issued during the year, one on geometric factors in electrical measurements, the other on the measurement of corrosion rates by polarization characteristics.

The application of stress to a corroding metal increases the rate and sometimes changes the nature of the corroding attack, and frequently generates an attack that would not occur at all in the

absence of either stress or the corroding medium. Current studies include attempts to determine why the stress-corrosion of beta brass follows a transcrystalline path, whereas in alpha brass the cracks are intercrystalline, i. e., in the grain boundaries. In a study of the stress-corrosion of type 304 stainless steel, sponsored by the Welding Research Council, a satisfactorily reproducible, short-time procedure to produce stress-corrosion cracks has been developed and work was begun to determine the effect of structural characteristics and minor variations in composition on the stress corrosion of this material.

The continuing program of exposure tests in marine atmospheres, sponsored by the Bureau of Aeronautics, includes studies of various metals used in aircraft construction and of surface or protective coatings, heat treatment, and methods of fabrication and assembly. A 20-year study of the behavior of several types of aluminum alloys was completed and the results were published. Four new phases of the work were initiated during the year.

2.9. Mineral Products

The Bureau conducts both fundamental and applied research on a wide variety of inorganic materials. These materials are of interest in the ceramic sciences and in the nonmetallic mineral industries because of their use in the production of refractories, porcelains, pottery, cements, glazes, glasses, and enamels. The primary objective of this work is the accumulation of basic data on their properties and behavior in order that such materials may be better utilized. Particular emphasis is placed on broad areas of fundamental research which, because of their nature, are not likely to receive adequate attention in academic or industrial laboratories. Examples include investigation of phase equilibria of inorganic systems, accumulation of thermochemical data, determination of constitution and microstructure of crystalline and noncrystalline materials, preparation of standard X-ray diffraction patterns, and compilation of basic data on the physical and chemical properties of inorganic nonmetallic substances.

The demand for materials that are stable at the very high temperatures in atomic power plants, high-speed military missiles, and aircraft has led to an increased interest in the inorganic materials that are stable at temperatures well above the working range of

the most refractory of metals. Because of the serious lack of basic data on the properties and behavior of such materials at very high temperatures, the Bureau has placed increased emphasis on accumulation of data acquired for technological advances in these new fields. Recent investigations in this area have been concerned with study of the mechanisms of creep in single and polycrystalline materials at high temperatures, properties of uranium oxide systems at temperatures of 2,000° C and above, diffusion of gases in glasses, high-temperature protective coatings for metals, phase equilibrium studies of refractory materials, and mechanisms of thermal decomposition of inorganic materials.

Thermal Decomposition of Crystalline Materials. A continuing basic study of the thermal decomposition of crystalline solids has been for the past year primarily concerned with the carbonates because of their many industrial applications. The thermal decomposition of manganous and ferrous carbonates is complicated by the several valence changes which these metals undergo at elevated temperatures. The thermal curves of these materials are greatly modified by such conditions as rate of heating, size of sample, porosity of the sample holder, and the nature of the surrounding atmosphere. Because of these variations it has not been possible to obtain agreement on the steps through which these materials passed on heating. However, an investigation carried out at NBS combining the use of high-temperature X-ray diffraction, an automatic recording thermal balance, differential thermal curves, and controlled atmospheres, has determined precisely the equilibrium conditions at different temperatures in air, carbon dioxide, and inert gases. From this study it is possible to account for the wide variations in the data obtained by workers in the past and to predict the results that will be obtained under a variety of conditions.

Structure and Properties of Glass. The increasing use of glass as an engineering material requires an accurate knowledge of its intimate structure. Information on the changes in structure that occur with changes in composition, fabrication and heat treatment is also important. Basic studies of the physical, chemical, and mechanical properties of simple glasses of different compositions and structures have been continued. The elastic moduli of a series of glasses have been measured by a dynamic (resonance)

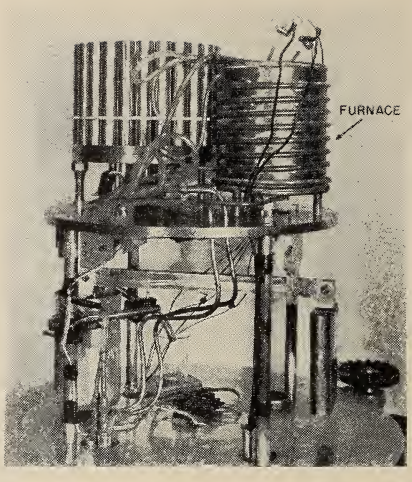
method at both room and elevated temperatures. The data obtained by these measurements have proven more sensitive as an indicator of equilibrium conditions in glass than either density or index of refraction. The information is particularly useful in the development of heat treatment procedures, of annealing schedules for glass, and of discovering glass compositions of very high moduli for the production of glass fibers.

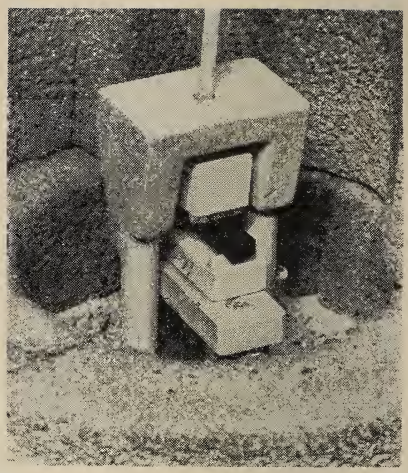
Studies of the viscosity, surface tension, compressibility, density, coefficient of expansion, and electrical conductivity of glasses were extended to include glasses of the binary alkaline earth borate systems and the same systems with the addition of 3 mole percent of potassium oxide. Data obtained in these investigations have been useful in bringing about a better understanding of structure of simple glasses of different compositions.

Ceramic Transducers. The Bureau has developed for the Office of Ordnance Research a number of piezoelectric ceramic compositions that are characterized by abrupt changes in their solid solution structures when their compositions are varied. Such ceramic transducers have high mechanical efficiency over a wide temperature range. One example is the mole composition 45 $PbTiO_3$:55 $PbZrO_3$. Other examples were discovered in the systems lead titanate-lead stannate, lead titanate-lead hafnate, and lead titanate-lead zirconate-lead stannate.

The chief figure of merit of a piezoelectric ceramic is the radial coupling coefficient. For the well-known ceramic piezoelectric barium titanate, the average coefficient is about 0.35 in the working range 20° to 80° C. This value can be compared with an average coefficient of 0.35 ± 0.5 over the temperature range 25° to 225° C for the mole composition 47.25 $PbTiO_3$:42.75 $PbZrO_3$:10.0$PbSnO_3$. Similarly, the coefficient ranges from 0.38 at 25° C to 0.31 at 250° C for specimens made from equal parts of lead titanate and lead hafnate.

Ceramics Containing Uranium Dioxide. A knowledge of the high-temperature reactions of uranium dioxide with other refractory materials is essential to nuclear reactor design at higher temperatures than those found in reactors now in operation. The high-temperature reactions of uranium dioxide with 15 metal oxides were surveyed for the Atomic Energy Commission. The information is based on data established at the Bureau and taken





Left: **Miniaturized furnace and automatic loading device for transverse testing of uranium oxide at elevated temperatures in controlled atmospheres. Four different size fractions of high-purity fused UO_2 have been measured at elevated temperatures in this furnace (p. 73).** ***Right:*** **Interior of furnace.**

from the literature. Uranium dioxide forms no compounds or solid solutions with either alumina, beryllia, or silica. Five of the binary systems studied show extensive or complete solid solution.

Physical properties of urania made from four different size fractions of high-purity fused UO_2 have been measured at both ordinary and elevated temperatures. Flexural strength ranged from 8,000 to 12,000 pounds per square inch at room temperature, and was appreciably higher at 1,000° C for specimens made from the two finer fractions. Results of the investigation show that urania for the fabrication of useful shapes should not be coarser than about 5 microns.

Mechanism of Deformation in Ceramics. Under the sponsorship of the Wright Air Development Center, the study of plastic deformation in ceramic-oxide single crystals has been extended to polycrystalline bodies. Creep rates of such polycrystalline materials as alumina at 1,000° to 1,200° C, and magnesia at 1,200° C, have been investigated. Both of these materials deform under constant load. The alumina shows strong creep recovery and as much as one-half the strain is recovered in 10 hours after the load is removed. However, magnesia shows very slight creep recovery. These results agree with previous findings that showed that alumina can slip only on one plane and magnesia can slip on many.

The Bureau has devised a new method for determining the creep yield tensile stress. In the new method, comparatively simple bending tests replace the former tensile tests on small specimens which are difficult to test in tension at high temperatures. However, time dependent plastic deformation affects the determination of creep yield stress and the mathematical treatment of the data presents a difficult problem. A method of stress analysis has been developed that corrects the results of bending tests to give the true value of creep yield stress in tension.

Electrical Conductance in Vitreous Ceramics. As one phase of a broad study of the viterous state, NBS has been investigating the basic mechanisms controlling electrical conduction in vitreous ceramic materials. The results have immediate practical significance because of the need for electrically insulating materials that can be used as coatings on wires and electronic instrument components at high temperatures. This task has included a study of electrical conductivity in ternary silicates and ternary lead germanates. An anaylsis of conductivity data obtained on these two ternary systems shows that the results can be interpreted in terms of the physicochemical properties of the constituent ions. The similarity in the conduction behavior of the two ternary systems is based on the structural similarity of the ions in the base compositions. The results of the investigation promise new formulations for glasses, glazes, and ceramic coatings to meet specific, specialized requirements.

Thermochemistry of Inorganic Materials. Pozzolans are materials that contain active silica and alumina. They are added to portland cement to enhance its properties. The calcium hydroxide released by the hydration of the cement reacts with the active silica or alumina of the pozzolan to alter the properties of the hydrated cement. As a part of the study of these reactions being carried out at the Bureau, measurements were made of the heat of reaction between calcium hydroxide and silica gel. Differential thermal analyses up to 1,000° C were made of these pastes. The analyses indicate that calcium hydroxide reacts completely with silica gel at room temperature up to a CaO/SiO_2 molar ratio of 1.5 and perhaps even to higher ratios over an extended time. The heat-of-reaction data show complete reaction up to a ratio of 1.0, above

which the heat of reaction per mole of SiO_2 assumed a new and smaller value. Heat-of-solution data were obtained for several crystalline hydrated silicates, which will be used in computing their heats of formation for comparison with the values obtained for the heat of reaction of calcium hydroxide with silica gel. The crystalline materials present the ultimate possible products of such reaction, and this comparison permits an estimate of the progress of the reaction toward completion.

Crystal Structure of the Phosphates. The inorganic solid phosphates are a very large and complicated group of compounds, many of which are of importance in such diverse fields as detergents and fertilizers and in the biology of bone and teeth. This group of compounds has many types of structures similar to the silicates. The first systematic study at NBS of the structure of the trivalent orthophosphates has been completed. Several of these compounds were found to occur in more than one atomic arrangement and the range of stability of various forms was also investigated. Work is nearing completion on the mixed orthophosphates.

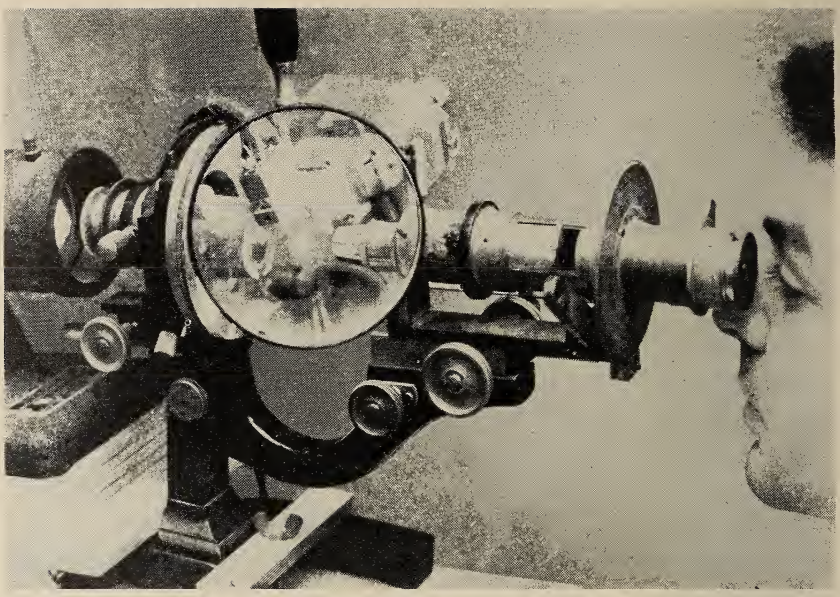
Standard X-ray Diffraction Patterns. Standard X-ray diffraction data is used widely in research and industry as a rapid and precise method of chemical analysis. The increased usefulness of the file depends on improving the accuracy of the data and increasing the number of compounds covered. The Bureau has been improving the file both by replacing conflicting data and by adding data on compounds not previously represented in the file. The program is sponsored by the Joint Committee for Chemical Analysis by X-ray Diffraction Methods, which is composed of members from the American Society for Testing Materials and the American Crystallographic Association. Up to the present, 227 NBS standard patterns have been produced and the data published. These replace 560 patterns of the original file and add 42 materials not previously represented.

Phase Studies of the System Lime-Silica-Water. The calcium silicate hydrates are of great importance to the building materials industry because they are the principal cementitious agents in portland cement concrete and in such pressure-cured units as sand-lime brick and autoclaved cement blocks. An investigation of phase equilibria has been completed for the system lime-silica-water at 180° C, the temperature commonly used in the manufacture of

autoclaved cement products. The study shows that two calcium silicate hydrates, closely related to the minerals xonotlite and hillebrandite, are stable at this temperature. The regions of stability of these compounds, and of quartz and calcium hydroxide, were established. A study of the solubility relationships of some of the naturally occurring calcium silicate hydrate minerals has been completed, and an investigation of the lime-silica-water system at 60° C is under way.

High-Temperature, Ceramic-Metal Strain Gages. Recently there has been an increasing need for a completely prefabricated strain gage that can be used to measure static strains in aircraft and other structures at temperatures considerably above the 300° F limit of conventional electrical-resistance strain gages. A program aimed at developing a ceramic type gage that can be used at much higher temperatures has been under way during the past year under the joint sponsorship of the Bureau of Aeronautics and the Wright Air Development Center. The experimental gage design showing most promise consists of two alloy filament wires of 0.001-in. diameter, spot welded to thin Inconel strips which in turn are attached to a backing of ceramic-coated asbestos paper. Such gages, when affixed to an aluminum alloy specimen with an air-hardening ceramic cement, have been found to measure strains as high as 1 percent at 800° F. When properly fabricated, the prototype gage has a low drift rate and a low temperature coefficient. Further work is in progress to improve the reproducibility of the gage factor and to extend the maximum operating temperature above the present limit of about 800° F.

Phase Equilibrium Studies on Portland Cement. A study of the phase equilibrium in portland cement clinker is being conducted in cooperation with the Portland Cement Association. During the past year the ternary system CaO-$12CaO.7Al_2O_3$-$2CaO.Fe_2O_3$ has been investigated. This system constitutes a boundary of the quaternary system where the iron-bearing solid-solution series is reported to occur. By the use of differential thermal analysis, X-ray powder diffraction analysis, and quenching techniques, it has been confirmed that a solid-solution series does exist between the compound $2CaO.Fe_2O_3$ and a composition in the vicinity of $6CaO.2Al_2O_3.Fe_2O_3$. The extent of the solid solution range on



A knowledge of the composition of the liquid reaction zone of a portland cement clinker at kiln temperatures was provided for the first time by the results of phase equilibrium studies at NBS (p. 77).

each side of a line $2CaO.Fe_2O_3$-$6CaO.2Al_2O_3.Fe_2O_3$ is also being investigated.

Previous work has shown that the alkalies Na_2O and K_2O may affect the constitution of clinker significantly, even though these oxides are ordinarily present in cement in amounts of less than 1 percent. This information led to an investigation of phase equilibria in the senary system K_2O-Na_2O-CaO-Al_2O_3-Fe_2O_3-SiO_2. This appears to be the first systematic study of phase relations in any six-component refractory oxide system. The investigation of this complex system was made possible by the use of the high-temperature centrifuge together with the more conventional methods. From this work, information has been obtained on the entire course of crystallization of one typical clinker composition and on part of a second. A knowledge of the composition of the liquid reaction zone of an actual clinker at kiln temperatures is provided for the first time by these results.

Effect of Ceramic Coatings on the Creep of Alloys. Ceramic coatings are being widely used on components of equipment operating at high temperature to provide protection against such detrimental effects as oxidation and carbon absorption. Recent work at NBS, sponsored by the Wright Air Development Center,

shows that under certain conditions ceramic coatings can also substantially reduce the creep rate of high-temperature alloys. The relationship between the chemical composition of the coating and that of the alloy appears to be an important factor in the effect of the coating on creep behavior. A barium silicate type coating, containing dispersed particles of cerium oxide for refractoriness, caused reductions up to 90 percent in the creep rates of 80 Ni-20 Cr alloys. The results indicate that a real advantage in creep behavior of particular alloys under operating conditions can be achieved by the application of suitable ceramic coatings.

As part of the study of possible mechanisms by which a ceramic coating can affect the creep behavior of metals and alloys, gas diffusion tests were conducted to compare the diffusion rates of hydrogen through ceramic coated nickel and through uncoated nickel. These tests were conducted at 1,400° F under a pressure gradient of approximately one atmosphere. The coating applied was NBS No. A–417, which is a barium silicate ceramic coating containing particles of chromic oxide. Although the layeroc ating was only $\frac{1}{40}$ as thick as the high-purity nickel, its presence reduced the diffusion rate of hydrogen to only about 5 percent of its rate through the uncoated nickel.

Reaction of Portland Cement with Carbon Dioxide. Hydrated portland cement is an alkaline material that reacts with carbon dioxide in the atmosphere. Experiments have been carried out at NBS to study the nature of the carbonation process. These findings show that the rate of carbonation of thoroughly dried cement can be increased manyfold by increasing the relative humidity of the atmosphere in which the process occurs. They further show that there is an optimum moisture content in the hydrated cement itself at which carbonation occurs most rapidly. Investigations have also been made of unhydrated cement. The results indicate that comparatively small percentages of carbon dioxide can reduce the hydration rate of cement.

Refractory Concrete for Jet Aircraft Aprons. The advent of the jet plane has necessitated an investigation of materials suitable for pavements as warmup, power check, and maintenance aprons. These pavements must withstand exposure to high and fluctuating temperatures. Under the sponsorship of the Navy Bureau of Yards and Docks, the Bureau has investigated calcined flint clay,

sintered slag, and two lightweight aggregates for high-temperature resistant concretes. Three types of cement, portland, portland-pozzolan, and high alumina hydraulic, were used with each aggregate. The result of laboratory tests indicate that the concrete formulated with the calcined flint clay or sintered slag appeared to be the best for the special requirements. Because of the comparative weakness of the lightweight aggregates the maximum flexural strength developed was 600 pounds per square inch. Numerous tests were performed on the cured and heat-treated concretes, such as thermal length change, strength in flexure and compression, resistance to abrasion, elastic properties, shrinkage, and weight loss.

Properties of Glass Fibers. The growing need for lightweight, high strength structural materials in aircraft and high speed military missiles has increased interest in the use of glass fibers as a reinforcing material. The Navy Bureau of Ordnance has been supporting a basic investigation into the factors which affect the physical and chemical properties of glass in the fibrous form. From previous studies it was learned that some barium-calcium-aluminate glasses had Young's moduli of elasticity considerably higher than commercial types of glass. A study is being made of the effect of various oxide additions on the Young's modulus, deformation temperature and fiber forming ability of calcium aluminate glasses and on the tensile strength and Young's modulus of fibers of these glasses. The effect of heat treatment on the physical properties of the fibers is also being studied. The quenching that occurs during fiber formation causes a reduction of the elastic moduli of the glass by as much as 20 percent. However annealing of the fibers has regained as much as 98 percent of this loss. Commercially available fibers have a Young's modulus of about 10.5 million pounds per square inch compared with a value of 30 million for steel. The Bureau has produced fibers having an unannealed value of 15.8 million psi which can be increased to 18.5 by annealing.

Special Optical Glasses. Glasses with special optical and physical properties are needed to meet the requirements of new fire control and other optical instruments for the Armed Services. Research on the development of glasses to meet these needs is being sponsored by the Navy Bureau of Ordnance. During the year 7,500 pounds

of optical glass in the form of molded blanks were delivered to defense agencies

The most promising compositions developed to date at NBS are based on the ternary BaO-TiO_2-SiO_2 system. Five stable compositions have been developed which can be made in practical amounts and have refractive indices from 1.83 to 1.93, values which are well above most commercial glasses. These glasses have good transmittances in the near infrared, deformation temperatures above 800° C, and excellent chemical durability over the *p*H range from 2 to 12. A stable glass composition has also been developed which has good flame-working characteristics and a deformation temperature above 700° C.

2.10. Building Technology

Over the past several years the Building Technology Division has conducted a critical examination of present building practices and a search for new practices based on sound engineering principles. The major aim is to increase economy of construction and maintenance. Before full advantage can be taken of the kind of engineering approach that has guided the rapid technological development of other industries, the building profession must be supplied with adequate standards of measurement, new testing procedures, fundamental engineering data, and performance standards. Few industrial organizations have the facilities to obtain the needed fundamental engineering data. The building profession, therefore, depends on the National Bureau of Standards for basic research in the fields of building materials, structures, and equipment (excluding forest products which are studied by the Department of Agriculture Forest Products Laboratory).

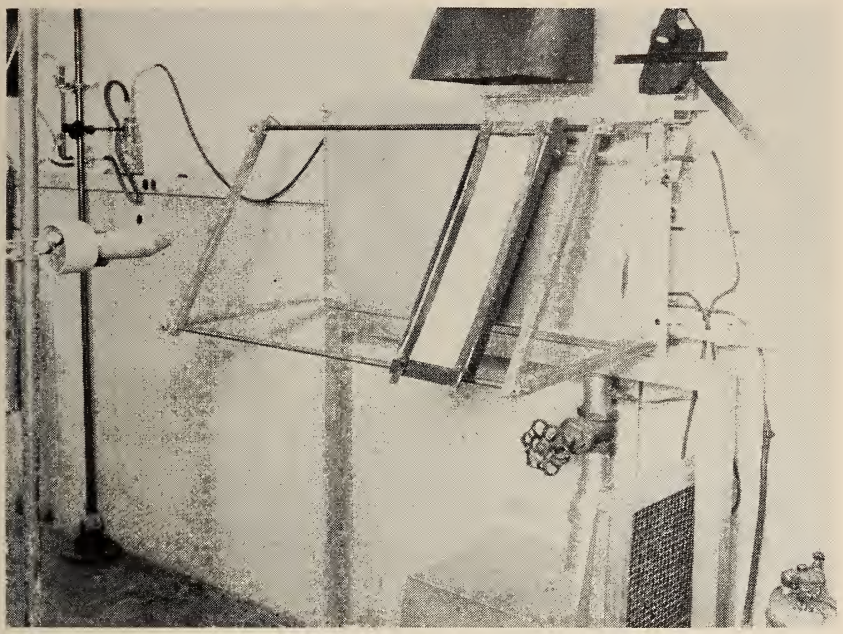
The Bureau's fields of interest include structural engineering, building codes, safety engineering, fire protection, heating, refrigeration, and air conditioning, as well as building materials, such as flooring, roofing, and wall finishes. Typical studies completed during 1955, or presently under way, concern durability of masonry materials, shrinkage stresses of masonry, control of cracking in reinforced concrete, structural and fire resistance properties of precast thin-shell concrete structures, fire endurance tests on building structures, fire detection in aircraft engines, air filters for helicopter engines, insulation of underground pipes, heat insulation and heat conductivity, flooring and roofing materials,

Typical crack pattern at failure of a loaded reinforced concrete beam. Many such tests were performed in a study of the cracking of reinforced concrete.

and development of portable and mobile military refrigerating apparatus. The Bureau continued to render assistance to Federal, State, and municipal bodies on the development of improved building codes and safety standards.

Instrumentation and Measurement. The Bureau laboratories have found increasing application for the NBS internal strain gage developed in 1951. This gage can be cast into concrete or mortar for determination of length changes due to drying shrinkage, thermal expansion, and freezing and thawing. Its use externally for measurement of dimensional changes in stone with wetting and drying is also a new application recently discovered.

Control of Cracking in Reinforced Concrete. Formation of tensile cracks in nonprestressed reinforced concrete cannot be avoided, but the width of cracks can be reduced by increasing the strength of bond between concrete and the steel reinforcement. In order to provide reinforcing bars having higher bond strength, the steel industry during the past 10 years developed improved deformed reinforcing bars. As these bars became commercially available, it became desirable to secure data with beam specimens reinforced with the new types of bars in order to provide a basis for improved design practices with respect to control of cracks. Accordingly, the Research Fellowship of the American Iron and Steel Institute at NBS, in collaboration with the Bureau staff, conducted a systematic study of the effect of various factors on the distribution



Equipment for evaluating flame-spread properties of flammable materials (p. 83). This equipment makes possible a simple but realistic test method for use by both private manufacturing and commercial testing laboratories.

and width of cracks. The studies have shown that the average width of cracks is proportional to the ratio of diameter of the bar to the percentage of reinforcement and to the increase of steel stress beyond that causing initial cracking. The average spacing of cracks decreased rapidly with an increase in steel stress beyond that causing the first crack, and at a stress of about 30,000 pounds per square inch the average spacing approached a constant value. An equation representing the relationship between the average width of cracks and the several factors which influence their formation was formulated and made available to the engineering profession by publication.

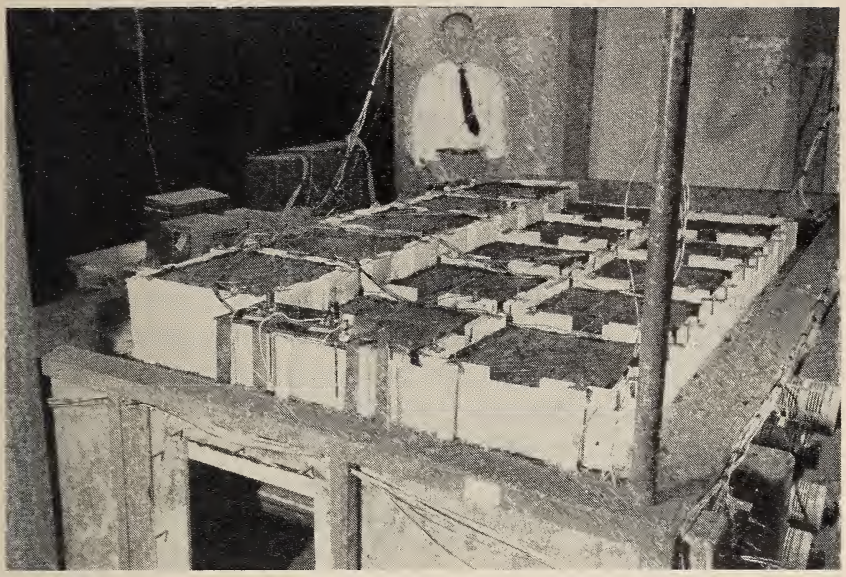
Flame Spread Test Method. When fire breaks out in a building the rate of its growth is largely dependent on the contents of the building and the character of the interior finish. Both in this country and abroad a large amount of time and effort has been expended on development of methods for evaluating the flame spread properties of such interior finish materials. The Bureau has recently completed work that promises a simple but realistic test method suitable for use by both private manufacturing and commercial testing laboratories.

The method consists of equipment for holding a small specimen of the material to be tested in front of a refractory panel radiating in a manner very similar to that of a blackbody at 700° C. The specimen is positioned in such a manner that ignition occurs near the top of the specimen and the flame front progresses downward. The rate of propagation of the flame front and the heat release rate of the material determine a flame spread index. This index appears to correlate well with burnout tests performed in England on model rooms as well as with results of tests performed on similar materials by means of much larger and more complicated test equipment. It is believed that this new method of evaluating the flame spread properties of materials can be used by industry as a method of studying and controlling the flame spread properties of manufactured materials for interior finish application.

Aircraft Fire Detection. The problem of locating and reporting the presence of fire in aircraft engine spaces is a vital one. It is complicated by the fact that exhaust fittings of engines frequently operate at very high temperatures and leakage of combustion gases is not uncommon. The Bureau has recently completed a study, for the Air Force, of the characteristics of flames that might be used in the detection of accidental fires. Although more than 30 different methods were considered for detection of fires, major emphasis was placed on study of their radiating characteristics. The study indicated that a reliable fire detection device could be based on a radiation detector that would function only on receipt of both a low-frequency modulation and a rapid increase of the energy received.

Water Usage for Drinking Water Coolers. A field study of water demand rates from electric drinking water coolers was made to provide a basis for judging the validity of the capacity and peak draw requirements incorporated in the Federal specification for water bubblers. Sixteen stations were selected for study in office buildings, mess halls, classrooms, military barracks, a garage, and a bus terminal. Data were taken by photographic methods to determine the number of individual drinks taken and the duration of the drinking period at each station for periods ranging from 7 to 22 days.

The study showed that an hourly water usage in the range from 0.05 to 0.075 gal/hr per person can be expected in hot weather



Effects of moisture and temperature on insulated concrete roof decks were studied (p. 85). Fifteen roof-deck specimens with eight different insulations were exposed to simulated climatic temperature conditions.

for persons engaged in relatively light work. The average duration of a drink from these bubbler coolers was 6 sec and the average water usage was 0.055 gal per drink. The average hourly water use did not reach the nominal 10 gal/hr capacity of the coolers at any of the 16 stations. The study showed that the ratio of the water usage rate for a 15-min period to the average hourly rate was higher in most of these installations than that now required in Federal specifications.

Effect of Moisture on Roof Deck Insulation. Concrete roof decks of buildings are commonly insulated with thermal insulation laid between the deck and the built-up roofing. Since the roofing is practically impervious to water or water vapor, moisture sealed into the insulation when it is covered, or condensation occurring during service, can seriously affect both the effectiveness and durability of the insulation or cause blistering of the roofing. A study of such effects is in progress for the Office of the Chief of Engineers, involving exposure of 15 roof deck specimens with 8 different insulations to simulated climatic temperature conditions. These include seasonal temperatures representing summer, moderate winter, and severe winter conditions, each for a term of a month

or two of repeated daily cycles of temperature change simulating daily solar heating and night cooling. Results to date indicate a marked effect of moisture on insulating value, the effect being significantly different for different seasonal levels of temperature. Information is also being obtained as to the timelag of under-roof temperatures resulting from daily solar heating, with different types of roof insulations.

Performance of Air Cleaners. At the request of the Public Buildings Service of the General Services Administration, the Bureau has been investigating the air cleaning efficiency and dust-holding capacity of several types of air cleaners and filters. The information is needed to revise the current Government specifications for such equipment, and to include requirements for new types of air cleaners. Tests were performed on 5 electrostatic air cleaners, 2 automatic oil-type air filters, and 3 throwaway or cleanable type air filters. The data include measurements of the dust-arresting efficiency by the Dust Spot method with atmospheric air and with Cottrell precipitate dispersed in atmospheric air.

A Study of a Ceiling Panel Heating System. As a part of the investigation of heating systems for small houses being conducted for the Housing and Home Finance Agency, the performance characteristics of a ceiling panel heating system were studied with a full scale installation in the Test Bungalow. The entire ceiling area of the five rooms of the bungalow was equipped with heating coils of ⅜-inch copper tubing spaced on 4-inch centers and divided into 10 circuits. An electrically-heated boiler permitted accurate measurement of the total heat input to the ceiling panel, and 20 heat flow meters above the panel provided measurements of the reverse heat loss to the attic. Thus the downward heat emission of the panel could be determined with considerable accuracy and could be correlated with the average ceiling temperature as measured by an extensive thermocouple system. The heat transfer rates observed were only about two-thirds of the values published in currently-used handbooks which are based on separate computations of radiation and convection heat transfer. The heat loss of the house was not excessive with this heating system, and was comparable with that observed for a baseboard convector system in the same structure.

Asphalt Roofing. Progress has been made in the study of the mechanism of weathering of asphalt. A chromatographic method has been developed for the separation of asphalt into four distinct groups of components. This method serves as a basis for current studies of chemical and physical changes that occur in asphalt during the weathering process. Work was initiated on about 20 asphalts to determine the chemical composition of the asphalts and their components, before and after weathering.

Several techniques have been developed to collect and identify the degradation products of asphalt. Work is under way to separate the complex mixtures of polyfunctional compounds into individual species by chromatographic and distillation methods.

Roof Maintenance Manual. Very little has been published on the maintenance and repair of roofs, a subject of great importance to the armed services. At the request of the Office of the Army Chief of Engineers, and the Navy Bureau of Yards and Docks, the Bureau made a study of roofing conditions in representative Army and Navy field stations throughout the United States and in Hawaii and Guam. The Bureau analyzed replies to questionnaires concerning roofing practices and problems that were sent to Army and Navy area headquarters throughout the world. With this information and on the basis of previous experience, a comprehensive roof maintenance manual was prepared by Bureau staff members. Use of this manual by field engineers should result in large savings to the Government.

2.11. Applied Mathematics

The Bureau has for a number of years maintained a central applied mathematics facility which conducts basic and applied research and renders advisory services in various mathematical fields. Such services are available both to the Bureau's technical staff and to other Government agencies. Equipped with modern computing aids including high-speed digital and analog computers, the applied mathematics facility has played a significant supporting role to the Bureau's research and development program. During the past year, research emphasis was placed on statistical and numerical analysis, and mathematical physics. Special assistance was rendered to the Bureau's staff and other Government groups

in these areas and in digital computation. In addition to consulting services in applied mathematics, including mathematical statistics, special attention was given to problem formulation and analysis to determine applicability of numerical methods to solution of problems on automatic and nonautomatic computing machines. The work covered a wide range of investigations and applications in the physical and engineering sciences.

The Bureau's applied mathematics program has been strengthened by the active interest and support of other Government agencies. Especially significant is the support of fundamental and applied research in numerical analysis and mathematical physics by the Office of Naval Research and the USAF Office of Scientific Research.

Numerical Analysis. Linear systems were extensively investigated and methods for determining characteristic numbers and functions of matrices were devised and used on the computer SEAC. Such work is essential in certain theoretical analysis, analysis of vibration for example, and in the solution of other important problems arising both within and outside the Bureau. In this connection, special attention was given to the preparation of efficient general-purpose solutions, of wide applicability, yet suitable for solving current problems. For example, a general theorem was proved which established the positiveness of characteristic members of matrices arising in the theory of dielectic relaxation. Theorems were proved on the bounds of the characteristic numbers of matrices. The latter gave important results for use in analyzing critical vibration frequencies as well as for developing effective methods of actually computing the characteristic numbers themselves

The stability of nonlinear differential equation systems was investigated. The Liapunov theory was applied and the various definitions of asymptotic stability were studied with a view toward unifying the great number of presently available results.

A war games model, represented by a system of six nonlinear differential equations was analyzed theoretically. A necessary and sufficient condition was proved for the victory of a party over its opponent. Victory was described by the magnitudes of the offensive forces' ultimate values and the production rates of the antagonists.

SEAC—The National Bureau of Standards Electronic Automatic Computer—in its new quarters.

Important numerical experimentation was conducted during the year. For example, complex orthonormalizing SEAC codes were developed and applied to numerical experiments in conformal mapping, potential theory, and the solution of elliptic type boundary value problems. Also, various methods of generating random numbers were tested to determine their suitability for the Monte Carlo evaluation of highly multiple integrals of the type frequently occurring in statistical mechanics. Experimental computations were performed using this sampling method of evaluating such integrals.

The compilation of a complete file of programs for matrix computation on SEAC was begun. Numerous useful computational codes and devices were developed. SEAC instruction codes were worked out for summing slowly convergent series and for Gaussian quadrature rules of high order. The latter were developed to meet the specific need for numerically evaluating integrals where integration rules of great accuracy are essential.

Digital Computation. During the year the computation program continued at a high level of activity. The Bureau's high-speed digital computer SEAC was in use three shifts daily, except for the 2-month period needed to move it to its new permanent location. Computing services for supporting the Bureau's research and development program were significantly advanced during the year. As part of the computation program, the following mathematical tables were edited and published: *Collected Short Tables of the Computation Laboratory*, *Tables of Secant and Cosecant*, *Tables of the Complex Gamma Functions*, *Tables of the Sine and Cosine Integrals*. In addition, NBS mathematicians and data-

processing experts collaborated in training and providing programers for data processing problems.

The Bureau staff has shown considerable interest in having problems programed for solution on SEAC. This has led to significant time saving services. The following list illustrates the extent of service rendered to other Bureau programs: preparation of high-temperature thermodynamic tables; calculation of virial integrals, involving Morse potential functions; computation of vibration modes and frequencies; Lovibond network for CIE source A; velocity of light calculations; molecular vibrations; compressibility factors of dry air; frequency correlation in a microphone problem; characteristics of conducting resistors; transient heat flow problems; Wiechert distribution functions; electromagnetic radiation from lightning; parameters of the dispersion equation for optical glass; thermometer calibrations; stresses in a wall foundation; temperature distribution in solid wings heated aerodynamically; distribution of light output from neutron spectrometers; aeronomic tidal winds of thermal origin; and optical ray tracing.

A wide variety of problems were solved and cooperative services rendered to other agencies. Typical of these were the following: procurement contract award by linear programing, New York Quartermaster Procurement Agency; atmospheric waves, Weather Bureau; turbulent atmospheric contamination, Applied Physics Laboratory; elastic cross section for neutron scattering, Naval Research Laboratory; integrals arising in supersonic flutter, National Advisory Committee for Aeronautics; dosage integral, Weather Bureau; ball-bearing fatigue data, American Standards Association; Loran computation, U. S. Naval Hydrographic Office; Maryland interindustry study, Department of the Air Force; heat convection analysis, University of Minnesota (AEC); liquid vapor transition problem, Naval Medical Research Institute; neutron transport problem, complete degradation in the neutron, and alpha analysis problem, Atomic Energy Commission; integral of a product of bessel functions, Office of Naval Research; reflection onto a vertical surface on a lambert plane, Armed Forces Special Weapons Group; reactor design, Westinghouse Atomic Power Division (AEC); Missouri River flood problem, Army Corps of Engineers; and data processing problem, Navy Bureau of Supplies and Accounts, U. S. Navy.

Statistical Engineering. The statistical engineering program is designed to advise both the Bureau staff and other Government agencies on the application of modern probability and statistical methods to the physical sciences. To maintain and increase the effectiveness of this program, basic research it probability theory and mathematical statistics was conducted during the year. The Bureau rendered extensive statistical advisory services during the year, and prepared manuals and bibliographies on selected phases of statistical methodology.

During the past year, this research, geared to fit the particular needs of NBS laboratories, fell into two categories: (1) planning and analyzing experiments (design of experiments); and (2) extreme value methods.

Under the first category, research continued on the arrangements known as partially balanced incomplete block designs. These designs have recently been introduced in several Bureau laboratories. By applying the theory developed, the research worker engaged in constructing this design may concentrate his efforts on those arrangements most likely to yield satisfactory results. For this purpose a catalog using selected subsets of all possible combinations was recently prepared, under the sponsorship of the Army Chemical Corps.

The second main research effort concerned the further development of the theory of extreme values. There are many applications in which the primary interest is not average values but the largest or smallest extreme—in the preparation of building codes, for example, where maximum wind loads are of concern. The Bureau has developed new and more precise methods for treating extreme value data.

As a consultant and advisory service, experimental designs were worked out for use in intercomparing four national radium standards. Instead of establishing one standard as correct by definition, the consensus of all four of the national standards was used. The consensus value arose naturally in the statistical analysis associated with the intercomparison. This approach possibly may be generally useful in future international standardization. If each nation's standards are referred to the consensus value they can be intercompared and the value relative to the consensus redetermined, even if one or more of the national standards is absent.

Further, no one nation is charged with the responsibility of maintaining the ultimate standard as is the case with the meter bar.

The dependence of fatigue life of ball bearings on bearing load was studied at the request of the American Standards Association. The primary aim of the study was to determine the best value for a dominant parameter in the life formula used by the bearing industry, giving the number of revolutions needed for a specified percentage of ball bearings to suffer fatigue failure. The need for the study originated from lack of agreement on the parameter within the industry. Because bearings have extremely long lives, many tests are terminated before all bearings in a test group fail. As a result, many test groups contain intact bearings. Therefore, statistical procedures were devised which properly allow for such survivors. This work has also given several useful statistical byproducts.

The extent of statistical services rendered during the year was comparable to the number of testing activities at the Bureau. The design of experiments by the Bureau laboratories has been facilitated by the Bureau's program in statistical engineering. The objective has been to obtain sufficient data for fruitful statistical inference with a minimum of laboratory testing. In addition statistical analysis was employed in the formulation of a number of the problems solved by high-speed digital computation.

Mathematical Physics. Bureau work in this field has been concentrated mainly in theoretical aerodynamics, hydrodynamics, elastic equilibrium, elastic vibrations, and electromagnetic and acoustic diffraction theory. One Bureau problem, for example, concerned the effects of dissipation upon the disturbance rarefaction waves set up in an air brake line, or, more generally, in any type of pneumatic controlled circuit. This question was first studied using the simplified assumptions that frictional effects merely produce retardations of the flow and that entropy changes can be disregarded. The model was then made more realistic and extended to include entropy and energy changes in the gas. This required using the full nonlinear system of differential equations consisting of momentum, continuity, and energy equations. Exact analytic solutions were obtained for both the constant entropy model and the more realistic one.

The work on unsteady gas flow was paralleled by research on the transonic-supersonic region in steady gas flow from nozzles. Wind tunnel nozzles which produce supersonic flow can be designed by known methods, if the nozzle boundaries are restricted to small curvature. Small curvature nozzles are long and expensive. For economy, short nozzles with large curvatures would be desirable. A method of nozzle performance analysis was developed which uses the Mach line originating from the throat of the nozzle (the S-line) as the carrier of the necessary initial data. Using this technique short nozzles can be designed in which the pressure gradient decrease is as uniform as possible.

In the field of elasticity, the vibration problem for plates was attacked from a new standpoint. Previous mathematical attempts on this problem have been confined to rough engineering methods using "influence coefficients" and simple beam theory. Successful solution demands a direct attack using elastic plate theory. The effect upon accuracy of the numerical solution was studied when finite difference expressions are improved only for the boundary derivatives, without refining the mesh width in the interior domain. For the square clamped plate, this technique gave significant improvement in the determination of the lowest mode. At the request of the Air Force the vibration and flutter problem for triangular wings of jet delta-wing craft was investigated. This task required combining knowledge of elastic plate theory with electronic computer experience. Successful formulation covering all delta-wing shapes required solving an unsymmetric matrix eigenvalue problem. Final results await completion of a new SEAC code needed to handle the large matrices involved. However, preliminary results on smaller, sample matrices were obtained that promise great utility for the method.

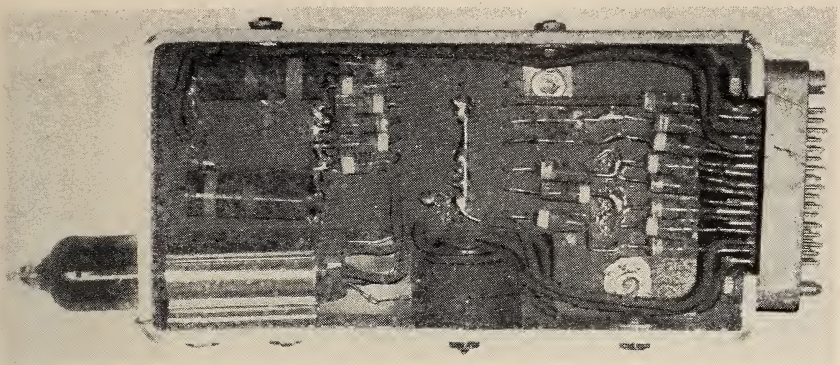
Other mathematical physics investigations concerned displacement and stress characteristics of corrugated elastic diaphragms, the basic element in altimeters and gas pressure instruments, and the solution for the diffraction field (two or three dimensional) from a dipole radiation in the neighborhood of a wedge of arbitrary angle. The result of the latter study applies both to an acoustic wave and to an electromagnetic wave, if in the second case the dipole axis is parallel to the edge of the wedge.

2.12. Data Processing Systems

The Bureau's data processing systems program encompasses research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. This program, developed during the postwar years, originally began with requests from several Government agencies for assistance in evaluating the potential application of automatic electronic digital computers to their problems and in procuring suitable installations. The evaluation studies and procurement eventually led to the Bureau's program of research and development of improved computer components and circuitry and subsequently to the design and construction of SEAC. This machine was the first super-speed electronic digital computer to go into productive operation (June 1950). Since then, SEAC has established an impressive record of solutions for both scientific and management problems for the Bureau and other Government agencies.

This technical effort and the increasing demand from Government agencies for advice on applying these powerful tools led to an expanded workload in research and development of new and improved components, circuitry, and auxiliary devices, in the development and design of more powerful logical systems, and in the analysis and application of data processing systems for the solution of business and management problems. An outstanding achievement of this program was the design and construction of the first mobile high-speed general purpose computer, DYSEAC, designed as an experimental nucleus for a complex data-processing network for the Department of Defense.

Recognizing the importance and potentialities of this expanding technology, the Bureau this year established a separate division which combines the functions of the digital computer laboratory with those of an analog systems laboratory. This unit provides probably the most comprehensive and readily available Government source of information in the new and rapidly growing field of high-speed automatic data-processors. The broad background and experience of NBS laboratories has resulted in an increased number of requests from many Government agencies who seek the Bureau's technical advisory services on high-speed digital techniques in new areas of potential application such as massive paperwork operations, control systems, and simulation, as well



Packaged circuitry of this type (actual size shown) is expected to simplify construction and maintenance of electronic computers (p. 96).

as in the solution of specific technical problems. The possibility of combining digital and analog techniques in the development of simulators and control systems is an area which is now being explored.

SEAC. The experimental modification, operation, and maintenance of SEAC has been a continuing responsibility. During the past year, the complete installation was moved to more permanent quarters. The move included an improved physical layout of the machine, both in space and chassis arrangement. Regulated power supplies for low-voltage distribution were installed in advance, and new circuitry was incorporated for a 3 address-4 address switch at the operator's console. Other minor modifications were made to improve reliability, facilitate maintenance and increase safety of operations, as well as to provide for additions of auxiliaries and the connection of display equipment. The loss of only 2 months of computation time indicated the effectiveness of the preliminary planning and preparations. The machine has returned to its through-shift schedule.

Analog Computers. To provide analog computation facilities to meet the technical needs of the Bureau, a modest analog installation was purchased and put in service. A work program in the development and design of simulators and control systems which may utilize analog and/or digital techniques has also been initiated. One program involves the design of a jet-engine simulator for Navy Bureau of Aeronautics, in cooperation with Aircraft Industries Association. This device will facilitate the development of engine controls simulation concurrent with the development of

new jet engines. Another task is the development of a special fallout computer for the Weather Bureau.

Development of New Computers. At the request of the NBS technical advisory committee, established by the Policy Committee for Mathematics, a preliminary systems study was initiated and tentative system plans devised for a powerful computer, which will be 100 times as fast as SEAC for solving a large class of scientific problems. Preliminary specifications for this machine were presented to the advisory committee.

Studies were also completed on the feasibility of applying digital computer components and techniques to a large-scale naval tactical trainer. A tentative over-all computing and control system was formulated which will be capable of meeting those computational and engineering requirements by means of presently available digital computer techniques.

Computer Circuitry Packaging. Efforts have continued to improve the modular type of circuitry packaging. Several prototype packages were designed and constructed for the Air Force Cambridge Research Center, based on the DYSEAC computer package but having radically decreased power consumption and increased logical capabilities. This should make feasible the building of larger and more powerful computing machines without the necessity of extremely large power supplies and air conditioning equipment.

Diode Amplifier. Research on the application of semiconducting diodes has led to the development of a new class of amplifiers that utilizes the reverse transient phenomenon of these two-element rectifying devices. The diode amplifier—using no vacuum tubes and achieving power gains up to 10 per stage—promises important application in the future design of high-speed electronic digital computers. For example, it may be used as a pulse repeater stage, in varied types of flip-flop circuits, or as a wide-band, flat-response amplifier. Because suitable diodes are now in regular production, commercial applications appear practical at the present time. Future improvement in the manufacture of diodes may make the principle useful for amplification at even microwave frequencies.

Cold Cathode Gas Diodes. With the increasing use of electronic digital computers, complex problems have been presented which require for their solutions high-speed memories so large that

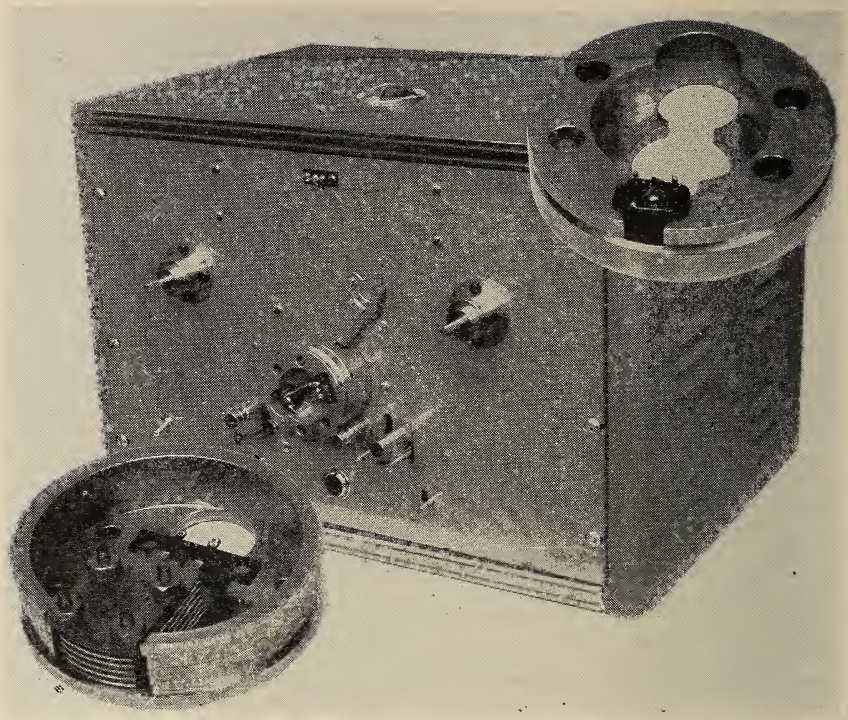
present-day costs make them economically impractical. The cold-cathode gas diode—such as the simple neon glow lamp—offers possibilities for low-cost high-speed memories, once the inherent disadvantages of the tubes are overcome. The Bureau undertook a study of these visual-indicating tubes for memory and indicator circuits. This study has resulted in design of a number of circuits that provide an approach to reducing the cost of digital computer memories from the present dollar per bit (binary digit) to about 10 cents. It has also been found possible to utilize such diodes in indicating devices since in most of the circuits considered the lamp will be luminous in only one of the two stored states.

An inexpensive method for equalizing and stabilizing the voltage characteristics of cold-cathode gas diodes—such as neon indicator lamps—has been developed. The tube characteristics are improved by a process of aging in which pulsed voltages are applied simultaneously to a large number of tubes. Trials of the processed tubes in actual operating circuits show that these aged diodes are reasonably stable. The method promises to provide an inexpensive, easily available component for many practical applications in automatic electronic computer circuitry. The gas diode program was sponsored by the Air Force Cambridge Research Center.

Other Diode Studies. Semiconductor devices promising improved performance in digital data processing machines were tested and evaluated and circuitry using gas diodes and diode amplifier techniques, and magnetic devices was developed for the Air Force Cambridge Research Center. A novel gas-diode indicator memory circuit was developed to be used in the design and construction of a data correlator and classifier for the Naval Research Laboratory. The solution of the indicator memory problem has broad applications in those fields where data must be presented for visual analysis.

Magnetic Core Investigations. Magnetic devices for amplifying and switching pulses have been studied in the hope of replacing vacuum tubes in SEAC type computer circuitry. Two circuit configurations were tried out in the form of simple shift registers. Magnetic core memories are also being studied, with particular emphasis on word organization.

Rotating Reading Head. A reading head that makes possible the close examination of a short section of magnetic tape or wire is now



Rotating reading head for close, repetitive examination of a short section of magnetic tape or wire (p. 97).

being used at the Bureau to locate and investigate faults in magnetic recording media. This instrument, constructed under the sponsorship of the Office of the Air Comptroller, makes use of a reading head mounted on a rapidly rotating drum so that the head is in contact with the tape for a part of each revolution. Since the tape is held stationary, the head reads exactly the same set of signals once each revolution, and the playback can be displayed continuously on an oscilloscope and observed as long as desired.

High-Density Magnetic Tape Recording. A method for closely packing digital pulses on magnetic tape has also been developed for the Office of the Air Comptroller. This method promises future useful application in the field of electronic computers. Such high-density storage can greatly reduce problem solution time by providing more rapid access to information recorded on external magnetic tape units. In a series of experiments at the Bureau, both continuous-current and pulse techniques were investigated to achieve densities in the range of 500 to 700 pulses/in.

Recording and reading circuitry was developed to provide large-amplitude playback signals with error-free differentiation between binary ones and zeroes.

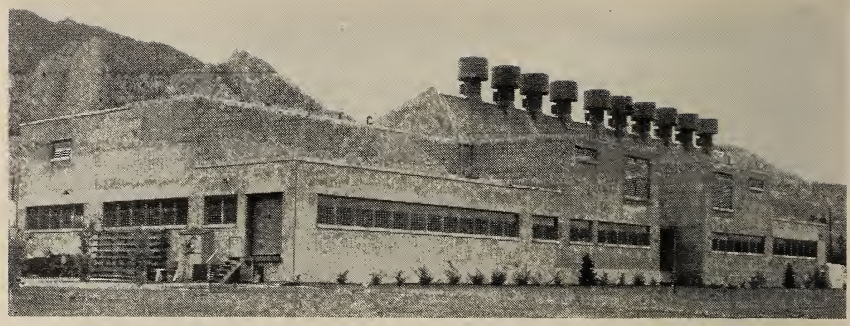
2.13. Cryogenic Engineering

The NBS cryogenic engineering program has as its objectives to provide engineering data on the properties of materials at very low temperatures and to investigate cryogenic (low-temperature) processes and devices that will be of benefit to industry and the national defense. There are today many large-scale applications of cryogenic processes which involve the liquefied gases: oxygen, nitrogen, hydrogen, and helium. For example, all the nation's helium is concentrated by low-temperature processes. All the oxygen for welding and metals refining is produced from the low-temperature distillation of air. In the realm of national defense, many of the new rockets use cryogenic fluids as fuels and oxidants. It has long been recognized that liquid hydrogen is the most powerful of all chemical fuels on a weight basis. As a result of these developments, a variety of complex engineering problems have arisen in this field.

The Cryogenic Engineering Laboratory was established for the initial task of assisting the Atomic Energy Commission with a project requiring large-scale low-temperature technology. Recently the requirements of the Atomic Energy Commission have diminished, and it has been possible to undertake a broader program of research in the field of cryogenic engineering. During 1955 typical projects dealt with flow of liquefied gases, insulation for liquefied gas containers, separation of hydrogen isotopes by low-temperature distillation, transporting helium as a liquid rather than as a gas, and storage of liquid parahydrogen.

Cryogenic Equipment. Basic studies were conducted on the flow of liquefied gases to enable more efficient and economical transfer and to predict the performance of transfer systems. Pumps for transfer of liquefied gases were also investigated. Initial emphasis has been on the problems of cavitation, shaft seals, bearings, and insulation, using commercially available equipment.

Further improvements were made on a vessel for efficient storage of liquid parahydrogen. Loss rates of 0.25 percent per day were



Liquefier building of the Cryogenic Engineering Laboratory, Boulder, Colorado, where low-temperature liquefied gases for research are produced in quantity.

attained by application of improved cryogenic techniques. For instance, improved surface preparation made possible a reduction in radiation heat transfer.

Certain applications require that liquefied gas containers have insulation effectiveness for short periods only. An investigation was started on insulations suitable for this application. Basic consideration is being given to thermal conductivity, ability to withstand thermal shock, ease of operation, and weight-versus-volume relationship.

During the past year the Bureau has been cooperating with the University of California Radiation Laboratory to develop a large (350-liter) liquid-hydrogen bubble chamber. Research in high-energy physics has recently led to development of the bubble chamber as an elementary particle detection device. The use of liquid hydrogen as the bubble-chamber liquid is very desirable. Successful development of this bubble chamber will provide physicists with a powerful new tool, but many problems must first be solved. For instance, large glass windows at low temperatures are necessary for proper observation of the bubble-chamber liquid, and methods of rapidly superheating the liquid hydrogen are required.

Cryogenic Processes. In 1954 research was begun on the separation of hydrogen isotopes by low-temperature distillation of liquid hydrogen. With the advent of electrical energy from nuclear power, a considerably increased demand for heavy water can be expected, and its cost will be a significant factor. Previous studies have indicated that low-temperature distillation will yield

deuterium gas at a potentially low price. Experimental work is aimed toward the design of large distillation columns for separating hydrogen isotopes. Initial results show that the separation is quite feasible. The economy of the process will be evaluated by operating a small pilot plant.

In connection with the distillation studies, experiments have been carried out on heat transfer between a condensing vapor and a boiling liquid. These experiments have yielded results which may have a bearing on other fields—for example, industrial production of oxygen.

A study is being made of the technical and economic feasibility of transporting helium as a liquid rather than as a gas. As a result of accumulated knowledge on Dewar design, excellent storage containers for liquefied gases can now be built, and this makes it possible to store helium in the liquid form for weeks without any loss. A shipping container for a given amount of liquid helium will weigh only about one-sixth as much as the high-pressure steel cylinders required to ship the same amount of gaseous helium. The saving in weight will make emergency air transport quite feasible.

Low-Temperature Properties of Materials. Commercial machines for tensile, fatigue, impact, and hardness testing have been adapted for low-temperature measurements in order to investigate thoroughly the mechanical properties of structural metals, alloys, glasses, and plastics used in cryogenic equipment. Stress-strain data in tension on numerous uranium samples were obtained for Los Alamos Scientific Laboratory, and a beginning has been made in testing aluminum alloys, copper, copper alloys, and glass. The bonding and calibration of commercial resistance strain gages at very low temperatures was studied thoroughly. A comprehensive bibloigraphy of low-temperature mechanical properties is being assembled.

A dual apparatus for measuring thermal conductivities of solids down to 3° K was put into operation. The discovery that a free-machining leaded copper has nearly as high conductivity as high-purity commercial copper will be of value to designers of cryogenic apparatus. An NBS Circular was published giving the results of a comprehensive study of the published data on thermal conductivities of metals and alloys at low temperatures.

The heat flow across laminated solids was examined experimentally down to 20° K. In the case of stainless steel, a poorly conducting alloy, it was found possible, through lamination, to reduce the heat conduction by as much as two orders of magnitude while retaining essentially the full compressive strength of the parent material.

The reflectivities of a large number of good-reflecting metal surfaces were measured at 76° K for thermal radiation having an energy-wavelength distribution characteristic of room temperature. The results of this work now provide a valuable guide to the design of evacuated reflective (i. e., Dewar-type) thermal insulation. In order to predict the long-term performance of such insulation, the slow fouling of reflective surfaces in continuously pumped high vacua was studied.

The transfer of heat across a variety of evacuated powders was measured down to 20° K as a function of interstitial gas pressure. The apparent conductivities of such strikingly diverse materials as silica aerogel, perlite, diatomaceous earth, plastic microbubbles, and flake aluminum were found to differ only a few-fold from each other. Experiments with silica aerogel in which the higher of the two boundary temperatures was varied show the interesting result that radiation is the predominant mechanism of heat transfer.

The recent commercial development of custom or "in-place" foaming of plastics has created interest in this process as a possible means of insulating tanks for cryogenic liquids. During the year, Wright Air Development Center and Redstone Arsenal sponsored tests of the thermal and mechanical performance of such insulations. The apparent thermal conductivities of plastic foams were found to be considerably higher than for either evacuated powders or reflective-high-vacuum insulation, and their resistance to thermal contraction stresses is poor. However, the mechanical simplicity possible with such insulation makes it attractive for some applications.

Liquefaction of Gases. Although requirements for the year were considerably less than for previous years, about 14,000 liters of liquid hydrogen and 285,000 liters of liquid nitrogen were produced. These materials are used extensively at NBS for low-temperature research and engineering development; they are also distributed to other government agencies. In the operation of the plant, emphasis

was placed on economy and maintenance of potential for large-scale liquefaction on reasonably short notice if the need should arise.

Several improvements and modifications were made in the plant. Among these was a supercharging system which increased the capacity approximately 20 percent. This gave the equivalent of sea-level operation at Boulder, Colorado (5,400 feet elevation). Another improvement was a liquid transfer and storage station for safe, economical handling of liquid hydrogen. An interesting modification to the plant was conversion of one of the liquefiers to produce liquid helium instead of hydrogen. A test run of a little over 1 hour gave a yield of 120 liters per hour with the plant operating at two-thirds capacity. Should the demand warrant, the yield of liquid helium could be made to approach 200 liters per hour.

2.14. Radio Propagation Physics

As a part of its program in radio propagation physics the Bureau collects, analyzes, and interprets basic data on radio wave propagation over long distances through the earth's outer atmosphere. It also centralizes and coordinates such information on a national and international basis. Because the ionosphere plays a determining role in the long-distance propagation of radio waves, a major portion of the program is devoted to study of this medium. Theoretical and experimental studies are carried out to obtain a better understanding of the formation of the ionosphere, the causes and characteristics of ionospheric disturbances, and the interaction of radio waves with the ionosphere. Because the sun is active in forming and disturbing the ionosphere, studies of the sun as well as of other cosmic sources of radio noise are included. The program involves direct operation of 8 ionospheric sounding stations; cooperation in the operation of 7 additional stations; and the assembly, analysis, and distribution of data received from approximately 60 other stations throughout the world. In addition, permanent, temporary, and mobile field stations are used for special experiments. The stations are also to carry out research experiments in which geographic location is a matter of importance.

Regularly received ionospheric sounding data are combined with indices of solar activity received from associated solar observatories and are used in preparing advance predictions of optimum fre-

Radio telescopes installed at Gunbarrel Hill, near Boulder, Colorado, for measuring radio noise reaching the earth from the sun and outer space. Such phenomena affect communication and radio navigation service in the VHF range.

quencies for long-distance communication throughout the world. These predictions are published each month and apply to a period 3 months after publication.

Besides the gradual changes in ionospheric characteristics, short-term disturbances associated with magnetic storms at times seriously interfere with radio communications. These interferences are especially common in the important North Atlantic and North Pacific regions. Two radio warning services are therefore operated for these regions. By observation of solar activity, disturbance of the earth's magnetic field, and radio operating reports, the Bureau is able to issue short-term warnings in anticipation of such disturbances.

Marked progress was made during the year in finding the source of discrepancies between current propagation theories and observations made on long propagation paths. A new series of observations on low-frequency radio atmospherics was started, studies of ionospheric absorption were broadened to include observations of cosmic noise during an eclipse, and observations over paths tangent to the auroral zone were begun.

Oblique Incidence Studies. Much higher frequencies are reflected from the ionosphere at oblique than at normal incidence. However, the maximum reliable frequency for radio communication at

oblique incidence is usually inferred from normal incidence measurements. An analysis of communications records has shown that communication (and therefore reflection) often takes place at frequencies several percent higher than current theory would indicate possible. A series of tests is therefore being made primarily to study this effect but secondarily to study ionospheric reciprocity and to determine the origin of backscatter echoes. In this experiment, the prediction techniques are checked for all times of day and all frequencies over chosen paths by means of vertical incidence midpoint ionosphere soundings made simultaneously with oblique incidence soundings over the path. Studies made on a path from Sterling, Virginia, to Boulder, Colorado, showed a scattered echo received at frequencies too high to agree with existing theories of ionospheric reflection. These echoes offer a clue toward resolving the present inaccuracies.

Low-Frequency Propagation. Research at low frequencies bridges the two fields of radio propagation and upper atmosphere physics and is designed to provide new information about the lower ionospheric regions applicable to widely different fields, such as high-altitude rocket flights and ionosphere propagation by means of VHF forward scatter. During the year, the Bureau made simultaneous observations at several widely separated stations of low-frequency atmospherics—the radio signals originating from lightning discharges. In this way it was possible to determine simultaneously the attenuations suffered by low-frequency radio waves throughout a wide frequency band and over long distances.

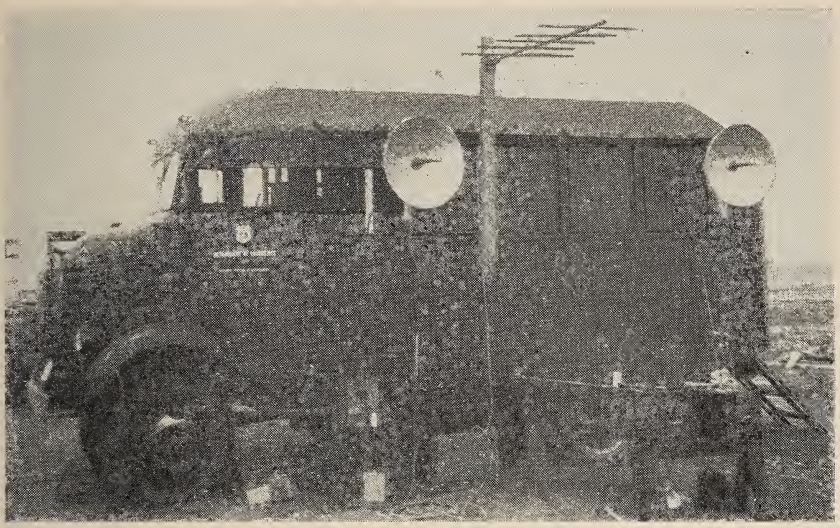
Ionospheric soundings at low frequencies are limited by low radiation efficiency from antennas of practicable size. A 3,400-foot antenna for this purpose is now being constructed across the top of a Colorado mountain canyon.

Cosmic Noise. Cosmic and solar radio waves reaching the earth from outer space limit the minimum usable signal levels for FM broadcasting, television, and communication and radio navigation services in the very-high-frequency range. However, observations of the intensity of this cosmic noise provide a sensitive indication of the absorption undergone by radio waves in passing through the ionosphere. Thus from data on cosmic and solar noise, certain characteristics of ionospheric constitution can be inferred. During the solar eclipse of June 20, 1955, a small expedition was sent to the

Philippines to obtain measurements of cosmic noise at 10 megacycles. The experiment was designed to study the effective rates at which electrons and ions recombine in the lower region of the ionosphere, where daytime absorption mainly occurs.

Arctic Radio Propagation. Although Arctic ionospheric propagation has been studied intensively, much remains to be learned about the auroral absorption zone. It is not known, for example, precisely where the zone exists relative to the visual auroral zone, nor how its location may change with time during magnetic disturbance. Moreover dependable measurements of radio wave attenuation over long paths in or through the Arctic are extremely scarce. Previously a series of observations has been carried out on paths which cross the auroral zone at right angles. Receiving stations are now being installed at Fairbanks and Anchorage, Alaska, to observe signals from Beltsville, Maryland, and from Bismarck, North Dakota. These installations provide paths essentially tangent to the auroral zone, the paths differing primarily in their geographic location. The path lengths are very nearly equal, but the path to Fairbanks crosses the accepted maximum of the visual auroral zone while the path to Anchorage does not. Thus direct and accurate comparisons can be made of the simultaneous relative attenuation over the two paths.

International Geophysical Year. Planning for participation in the International Geophysical Year was begun. The Radio Propagation Physics Division will operate two new ionospheric sounding stations on islands in the Pacific, will be responsible for ionospheric sounding at five stations on the Antarctic Continent (including one located at the South Pole), and will provide technical assistance to four South American countries in installing and operating new sounding stations. The program also calls for controlling the quality of data received from some 24 ionospheric sounding stations and for review and publication of their data. An experiment is planned to study propagation in equatorial regions by ionospheric forward scattering at very high frequencies. A new model of ionospheric sounder has been designed, and contracts let for 12 units. Because of the long shipping time necessary, work is actively under way on the outfitting of the South Pole station.



Control truck used to redetermine the speed of light by a radio-interferometer method (p. 107). The value of 299795.1±3.1 km/sec derived from these measurements is in close agreement with another value obtained independently by the molecular constants method (p. 107).

Speed of Light. A radio-interferometer method has been employed to obtain a new determination of the speed of light. This method makes use of phase-shift measurements on very-high-frequency radio waves to obtain their velocity of propagation. The value of 299795.1±3.1 km/sec derived from the measurements is in close agreement with another value obtained independently at NBS by a molecular constants method (see page 107).

For the interferometer method, two receiving antennas were accurately spaced 1,500 meters apart on a flat dry lake bed. By varying the position of a transmitter over a path which half-way encircled the two antennas, the phase difference between the two was made to change. The wavelength of the radio waves was then calculated by dividing the accurately known distance between the receiving antennas by one-half the total change in phase difference.

2.15. Radio Propagation Engineering

The ultimate objective of NBS work in radio propagation engineering is the more efficient use of the radiofrequency spectrum. This objective can be attained only to the extent that the nature of radio-wave propagation, together with the characteristics and effects of radio noise and interference upon various signals, are

known qualitatively and quantitatively. The program is directed generally toward solution of radio-wave-propagation, radio-noise, and signal-to-noise problems. Quantitative study of these phenomena includes: (1) the collection of statistical samples of data appropriate for their description; and (2) development of suitable methods for predicting, from the samples, the statistical characteristics of the variables required for engineering applications.

Among the projects directed toward this objective were basic radio studies, modulation studies, terrain effects on propagation, tropospheric effects on propagation, design of an airborne microwave refractometer, and phase-stability studies. A new project on sporadic *E* was initiated for studying the efficient use of the 25- to 60-Mc portion of the spectrum.

Radio-Noise Studies and Noise Predictions. A complete revision of existing worldwide radio-noise predictions has been undertaken, including the preparation of new noise grade maps and prediction curves. During the meeting of the International Scientific Radio Union at The Hague in 1954, a preliminary report on these new noise predictions was presented to a group representative of the International Consultative Radio Committee (CCIR) concerned with radio-noise predictions. This group recommended that a representative of the Department of Scientific and Industrial Research of England come to the Boulder Laboratories to work with NBS personnel in finalizing these predictions for use by the CCIR. As a result, agreement has now been reached on the type of presentation to employ and the weight to be attached to the various measurements that form the basis for the revised noise grade maps.

Planning was begun for a radio-noise recorder to be operated in the Antarctic during the International Geophysical Year, after information on requirements for such an installation had been submitted to their planning staff. It is expected also that a large number of the new NBS noise recorders will be in operation throughout the world during the International Geophysical year in 1957–58.

A detailed statistical study of the amplitude and time distribution of atmospheric radio noise has been undertaken to permit more accurate evaluation of errors produced in various radio systems by atmospheric noise. Equipment for making these cumula-

This 500-foot tower at Haswell, Colorado, shown at left is used in studying "tropospheric scatter propagation", the transmission and reception of VHF and UHF signals beyond the line-of-sight. Data for worldwide radio noise predictions are obtained from field recording stations like the one at right located near Boulder, Colorado (p. 108).

tive amplitude and time distribution measurements has recently been completed and is undergoing preliminary tests in the very-low-frequency range. Preliminary results indicate that the communication efficiency of many existing systems can be considerably improved, and that it may be possible to predict the optimum communication capacity for a radio channel contaminated with atmospheric noise.

Tropospheric Forward Scatter Propagation. In the past few years it has been determined that useful VHF and UHF transmissions are not limited to the radio horizon as was previously believed, but can provide reliable service at distances far beyond the line-of-sight limit. This phenomenon, called "tropospheric forward scatter propagation," is believed to result from scattering of radio waves by very small inhomogeneities in the refractive index of the atmosphere. Reliable transmission to distances of approximately 400 miles has been demonstrated, using high-power transmitters and directional antennas. Both industry and the armed services have begun to use tropospheric scatter for new and existing communication circuits with consequent savings through the elimination of many relay stations.

Radio scattering received increasing attention during 1955. An investigation of tropospheric scatter propagation characteristics utilized a chain of five receiving stations in Kansas and eastern

Colorado. These stations automatically record the field strength of five VHF and UHF transmissions originating from NBS experimental transmitters located on mountains near Colorado Springs, Colorado. The investigation has also included a meteorological measurement program centered chiefly around a 500-foot tower at the Haswell (Colo.) receiving station. This tower includes microwave refractometer facilities to measure fluctuations of the refractive index of the atmosphere for the purpose of correlating meteorological parameters with radio field strengths. Some progress has been made in developing an appropriate theory of scatter-type propagation and methods for predicting the reliability of this mode of propagation.

Phase Stability of VHF and UHF Transmissions. A project was begun to determine the phase stability of received VHF and UHF transmissions, or the variation of electrical path length over line-of-sight paths. The project required development of techniques and equipment capable of measuring very small changes in the phase and amplitudes of the received field. This type of measurement should prove very useful in further investigation of tropospheric-scatter propagation and should lead to a better understanding of atmospheric turbulence.

Obstacle Enhancement of Signals. Enhancement of radio transmissions by obstacles was investigated in a short but extensive program. Transmissions in the VHF and UHF band over and adjacent to mountain obstacles (including Pike's Peak) demonstrated that the phenomenon exists and correlates quite closely with knife-edge diffraction theory. Obstacle enhancement of signals has been demonstrated to be of practical value and has been adopted by the armed forces for certain communications circuits.

2.16. Radio Standards

The program in radio standards is concerned primarily with electrical primary standards, measurement techniques, and properties of matter in the frequency range from 30 kilocycles through the highest available microwave frequencies. In the extreme high-frequency ranges, standards and adequate measurement techniques are essentially nonexistent. In the lower frequencies, increasing electronic applications have created a need for greatly improved primary standards and calibration techniques.

Power Measurements.—A self-balancing d-c bolometer bridge for high-precision bolometric power measurements at microwave frequencies was developed and placed in operation. The bridge is expected to have wide application in making accurate microwave power measurements and, in modified form, to other kinds of microwave measurement. The bolometric technique, by means of which the heating effect of rf power is compared with that of a measured amount of d-c power, is extensively used at low power levels for the measurement of UHF and microwave power. Much of the research effort expended in power measurement during the past few years has been directed towards the determination of bolometer mount efficiencies or evaluation of the validity of the rf–d-c substitution principle. The only accessory instrument of sufficient accuracy to utilize the results of these investigations has been a manually operated d-c Wheatstone bridge. The self-balancing d-c bolometer bridge extends both the accuracy and dynamic range achieved with the manual technique, and provides the additional feature of a large measure of operational convenience. The self-balancing feature was achieved by using a d-c amplifier of exceptional gain with freedom from zero drift. A constant-current generator and differential current measuring circuit provide means for extending the dynamic range of the bridge.

For accurate rf power measurements highly stable and frequency-insensitive loads are necessary. In the 50-ohm range, the Bureau developed loads of this type which, by proper choice of materials and design features, can be made with negative, positive, or near-zero temperature coefficients of resistance. For example, some of the loads have temperature coefficients of less than 1 part per million per degree C and show good stability up to the melting point of the solder used (about 170° C).

Voltage Standards. Considerable progress was made in developing reliable voltage-transfer standards. Units employing piston attenuators and thermoelements proved to be stable to ± 1 percent over a period of a year or longer at frequencies up to 300 megacycles per second. Tests and applications of these units at frequencies up to 600 megacycles per second proved them to be the most stable and most efficient devices to date for calibration work.

Attenuation Standards. Attenuation standards are in general necessary to all other precision radio measurements. During the year, two new standard piston attenuators were put into operation and tested for performance. Theoretical analysis of a new type of insertion loss and phase measuring system was continued and developed to a much greater generality. Results showed the system to be self-calibrating. A simple and accurate method was devised to determine the constants of the system. Very-high sensitivity and accuracy are potentially possible but place rather stringent performance requirements on auxiliary equipment. Some work, which is continuing, was done to meet these requirements.

Coaxial Resonance Line for Microwave Impedance Measurements. A 50-ohm coaxial resonance line (Chipman type) was developed to make precise measurements of impedance, voltage standing-wave ratio (VSWR), and reflection coefficient at frequencies from approximately 300 to 18,000 megacycles per second. This instrument represents an advance over present methods of microwave impedance measurement primarily because its internal cross-sectional dimensions are the same as those of the type N connector in which it terminates. This eliminates discontinuities between the measuring line and the load, improving the potential accuracy and the convenience of measurement. The small diameters of the line also make it possible to operate over a wider frequency range than has heretofore been practical with a single impedance-measuring instrument. The lower frequency limit is determined by the maximum permissible length of unsupported center conductor, and the upper limit by the cross-sectional dimensions which determine the cutoff frequency for higher mode propagation. A unique mechanical feature is the small diameter of the coaxial feed line which transmits microwave power from the tiny loop, located in the short-circuiting piston, to the detector output connector. The feed line was difficult to construct because of its unusually small size (outer diameter, 0.050 inch). With this instrument it will be possible to make coaxial impedance measurements over a wide range of microwave frequencies with an accuracy exceeding that obtained with conventional precision slotted lines.

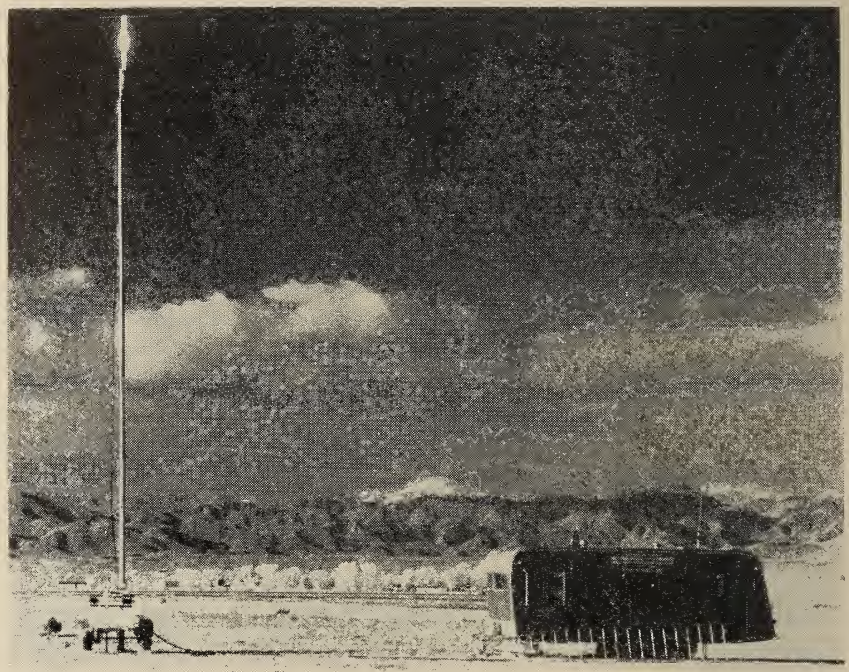
Precision Microwave Interferometer. A project has been undertaken to measure the velocity of light to greater accuracy than ever before. The measurement is to be made in terms of the frequency

and free-space wavelength of millimeter waves. The velocity of electromagnetic waves will be calculated as the product of these two quantities. The wavelength measurements will be made with a precision microwave interferometer now being developed for the purpose. This instrument may also be used for very accurately measuring the lengths of such standards as meter bars and geodetic tapes. For this purpose, the velocity of light can be regarded as fixed, and the measured lengths can be expressed in terms of this constant and an accurately known frequency. Like the NBS mercury 198 lamp, the microwave interferometer offers a means of placing length measurements on an atomic basis. If the necessary frequency were to be derived from an atomic clock, the length measurement would be based wholly on the unchanging properties of atoms.

The interferometer under development is analogous to an optical interferometer. It is designed to measure wavelengths by giving a null on a meter whenever a reflecting body is moved a distance of one-half wavelength. It will thus provide a length standard with graduations every few millimeters. Theoretical studies indicate that measurements with an accuracy exceeding one part per million may be possible. Increased accuracy may be expected as technical advances permit the microwave frequency to be increased.

Dielectric and Magnetic Materials. The physical and electrical properties of dielectric and magnetic materials are widely used in the design of nearly all electrical, electronic, or radio equipment. Accurate measurements on these materials are essential for improving the design of equipment, fabrication of materials, and development of structure theory. During the year a cavity was completed which will measure the dielectric properties of solids and liquids at the lower radiofrequencies. This cavity operates automatically and can be used in the range from direct current to 1,000 megacycles per second and at temperatures from $-40°$ C to 500° C.

An improved temperature-coefficient permeameter was constructed. With this device, temperature coefficients as low as 3×10^{-6} per degree centigrade can be measured for a material with permeability of 10. A method was developed for making permeability and loss measurements in the range of 50 to 300 megacycles per second with the rf primary standard of permeability.



Portable antenna and mobile recording equipment for studying obstacle enhancement of radio signals by mountain peaks. The equipment is shown installed in the Arkansas River Valley south of Pike's Peak, Colorado (center background). This is a direct line over the top of the peak from transmitters on Lookout Mountain near Denver (p. 110).

Microwave Spectroscopy of Gases at High Pressure. The Bureau continued a systematic study of the microwave absorption of gases at pressures from 0 to 60 atmospheres and frequencies from 1,000 to 24,000 megacycles per second. Principal objectives of this project are: (1) to obtain a better understanding of the dielectric behavior of matter through a systematic investigation of gases at progressively higher pressures; (2) to make definitive tests of spectral line-shape theories; and (3) to employ pressure broadening as a sensitive tool for studying molecular interactions in gases.

The absorption in oxygen arising from the presence of a small magnetic dipole moment was investigated in detail up to about 40 atmospheres (600 pounds per square inch). The absorption consists of two parts: a nonresonant or Debye-type contribution and a resonant contribution centered near 60,000 megacycles per second. The nonresonant contribution, which had not been subjected to prior investigation, predominates at the lower micro-

wave frequencies and is therefore of considerable interest to those studying atmospheric attenuation of radio waves. At pressures up to about 10 atmospheres the resonant contribution is consistent in magnitude with predictions based upon existing line-shape theory and line-width data. At higher pressures, however, the resonant frequencies begin to decrease toward zero, and the spectrum undergoes a transition from resonant to nonresonant in a manner analogous to that previously noted for ammonia and deuterated ammonia. While only nonresonant absorption is generally observed in liquids, so that such transitions are to be expected in going from the gaseous to the liquid state, it is noted that the changes to liquid-like behavior can occur long before the molecular density approaches that of the liquid.

Measurements of the nonresonant absorption in a number of symmetric top molecules, such as the methyl halides, were completed. Because an adequate theory of nonresonant relaxation times in gases is lacking, considerable effort was devoted to the theoretical aspects of the problem.

Further measurements of absorption in the nonpolar gas, carbon dioxide, substantiated earlier work. Absorption is not ordinarily expected for nonpolar gases in the microwave region, and a search for this effect in other nonpolar molecules is in progress.

Atomic Standards of Frequency and Time. Work progressed on an ammonia-beam oscillator to be used as an atomic frequency and time standard of high accuracy. This system is patterned after the ammonia-beam oscillator recently developed at Columbia University. Experiments at Columbia have shown a precision of 1 part in 600 million, achieved with simpler equipment than is used with either the Bureau's ammonia-absorption clock or cesium-beam clock. The NBS oscillator should prove helpful in the effort to reach an atomic basis for frequency and time standards.

Frequency Standards and Standard Frequency Broadcasts. Frequency is measured more precisely than any other physical quantity. Its accurate measurement is highly important in using efficiently the limited radiofrequency spectrum to serve the ever increasing radio-communication requirements. During the year the national standard of frequency and time interval was transferred from Washington, D. C., to the Bureau's new facilities at

Boulder, Colorado. Assessment of the transferred groups of standards was begun on July 7, 1954, and by means of the broadcasts from WWV, their performance and rates were determined to the required precisions by October 12, 1954, whereupon the transfer of the National Standard was completed. Three quartz resonators were placed in separate 50-ft wells to provide temperature stability.

The Bureau's two radio stations, WWV (Beltsville, Md.) and WWVH (Maui, T. H.), continuously broadcast standard radio and audiofrequencies, standard time intervals, time signals, standard musical pitch, and radio propagation disturbance warnings to the world. Several improvements were made during the year. For example, at WWV single sideband broadcasts on five carrier frequencies (2.5, 5, 10, 15, and 20 Mc) were initiated, using the upper sideband. Better identification of the minute interval was made possible by adding a double pulse marker (spaced 0.1 second) each minute. The tone modulation was removed for precisely 40 milliseconds each second; during this quiet period the seconds pulse was broadcast so as to mark more effectively each seconds pulse for many uses, e. g., in automatically recording the occurrence of an event to a few milliseconds. Because supplementary services may be needed at low frequencies to transfer a more accurate standard, work was initiated to study the accuracy of low-frequency broadcasts as received.

Recording was begun of the frequency of WWV and WWVH at 5, 10, and 15 megacycles per second as received at Boulder. Preliminary analysis of the records indicates that Doppler frequency errors of 3 to 4 parts in 10^8 occur over these paths at certain times. Theoretical expressions were derived relating the rate of change of ionosphere-layer height to the fractional frequency error for given path length and mean layer heights. These derivations gave a fractional error of 1.3 parts in 10^8 for the WWV-to-Boulder path when the rate of change of layer height was assumed to be 25 kilometers per hour. Apparently the vertical velocity of the layer exceeds the value assumed at certain times of the day. Careful study of this phenomenon will have an important bearing upon the possible use of low-frequency broadcasts for very accurate frequency standards available through radio communication.

2.17. Basic Instrumentation

The Office of Basic Instrumentation was established in 1950 to serve as a research, reference, and consultation center on problems of instrumentation for the laboratories of Government and industry. This program, sponsored by the Office of Naval Research, the Air Research and Development Command, the Atomic Energy Commission, and the National Bureau of Standards, represents an effort to utilize the Bureau's facilities and experience in the field of physical measurements to advance those techniques of measurement and control that are fundamental to progress in science and industrial technology.

Modern developments in instruments and instrument systems must employ principles and concepts from such diverse fields as electronics, mechanics, thermodynamics, optics, chemistry, materials, and atomic physics. The purpose of the Office of Basic Instrumentation is to bring together the specialized knowledge and skills of the Bureau staff in these fields for the solution of measurement problems. It also endeavors to encourage and stimulate research and development throughout the nation on measurement devices and techniques. And it maintains active familiarity with technical progress in other measurement laboratories, in order to fulfill its responsibility as technical consultant to Government and industry on instrumentation.

In furtherance of these objectives, the Office of Basic Instrumentation cooperates with other Government agencies in arranging conferences and symposia in areas of special interest or of rapidly developing importance in the field of instrumentation. It also cooperates with technical societies in promoting instrumentation progress. These activities often help to define areas of instrumentation in which research and development work needs to be done, either at NBS or elsewhere.

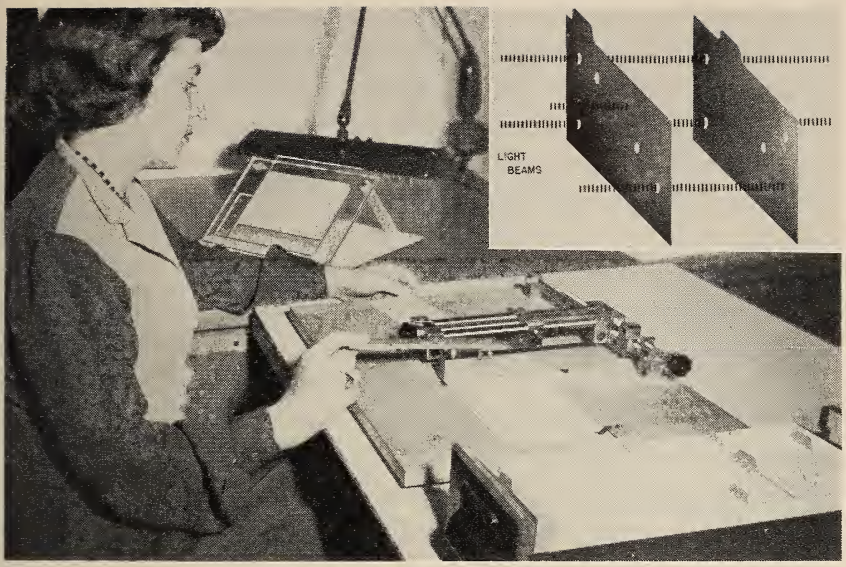
In all phases of the program, emphasis is on the basic fundamentals of measurement and control and on development of the science of instrumentation. Those research projects are favored which seem likely to have broad utility in measurement or to extend significantly the range, reliability, or sensitivity of some general class of instruments. Also of basic importance are theoretical and experimental studies of problems common to many

instruments—such as drift, lag, unsteadiness—or of the limits of performance inherent in various types of instruments.

Because the output of any sensing element is a signal, studies of problems in handling signals may be carried on profitably on a quite general basis, without regard to particular types of measurement. Areas in which such general studies are encouraged include amplification, loss of information in transmission, analogue-to-digital conversion, indication or display, recording, separation of measurement signals from extraneous signals or noise, automatic data correction or reduction, automatic computation, and automatic control.

The technical work of the Office of Basic Instrumentation has two principal objectives: (1) Systematic analysis of available methods and devices in terms of their performance and characteristics, and (2) research on new applications of principles and materials leading to the development of instruments and techniques not now available. This program is carried out largely through the assignment of instrumentation research projects to those NBS laboratories that are best qualified to conduct research in the particular field of science involved. The Office of Basic Instrumentation also maintains a small laboratory staff for investigation of special problems and a group of specialists in instrumentation literature who are developing a reference and consultation service to aid in the solution of instrumentation problems.

Specific Instrument Developments. Projects included in the basic instrumentation program in the past year have been conducted in seven of the technical divisions of the Bureau as well as in the Office of Basic Instrumentation itself. Among the accomplishments of the projects carried on in the technical divisions have been: the successful construction of an extremely sensitive calorimeter for measuring the power in an X-ray beam (page 32); the completion of a preliminary model interferometer using pulsed illumination for measuring vibration amplitudes; design of several high-speed counting circuits for use in computers based on the diode amplifier (page 96); the construction of an instrument for direct measurement of dynamic bulk modulus; and an improved infrared spectrometer that will operate at 130 microns.



Hand-operated indexing equipment used with the NBS instrument reference service. Apparatus consists of: A set of index cards (foreground), manually operated punch (center), and a plastic reading illuminator (background). *Insert:* Descriptive drawing of index term cards showing "peekaboo" method of reference classification.

Work conducted in the Office of Basic Instrumentation laboratory is generally confined to those cases where the need is felt for exploratory studies by a versatile group specializing in instrumentation. When such an activity is seen to merit a full scale project, it is turned over to the proper technical division for further work. Selected projects conducted in the Office of Basic Instrumentation laboratory are discussed below.

Instrument Reference Service. The field of instrumentation has only recently emerged as a new and rapidly expanding coordination of knowledge from a variety of previously existing fields. Both the newness and the rapidity of growth of instrumentation have posed burdens on those desiring to keep abreast of instrument developments. Scientists in Government and industry alike need to have convenient, rapid, and thorough access to instrument information. The major obstacles are the inadequate coverage of instrumentation information provided by existing abstracting and indexing services whose main interest is the information obtained by use of the instrument and the nonexistence of efficient classification systems for instrumentation. These considerations have led to the establishment of an instrument reference center whose

objective is to improve accessibility of instrument information in four ways: (1) by developing improved systems for storage and retrieval of information; (2) by fostering developments elsewhere which will make instrument information more readily available; (3) by surveying specific developments in instrumentation; and (4) by providing consultation services in instrumentation.

Indexing System. Consideration of the various ways in which the problem of classification has been approached in the past led to the recognition of the basic "multidimensional" nature of human knowledge. The concept that information might be located in a system of "coordinates" by the interaction of a number of identifiying terms was studied, and it was concluded that this approach was a desirable one for this specific application. A set of 10 dimensions and corresponding terms within the dimensions was selected to provide the framework of the classification system. In the system there is one card for each descriptive term instead of one card for each document as in conventional library catalogues.

The work of classifying instrument information for indexing is under way. Routine coverage has been extended to 12 current journals and will be augmented as additional analysts are hired. Analysis is performed by full-time analysts of the Office of Basic Instrumentation and by "contributing analysts," NBS staff members who are experts in various fields.

A study has been made to estimate the number of instrument articles to be expected in a year and to determine which of the scientific publications merit routine coverage. The study indicated that coverage of some 137 publications would be desirable and that this would provide some 15,000 instrumentation references per year.

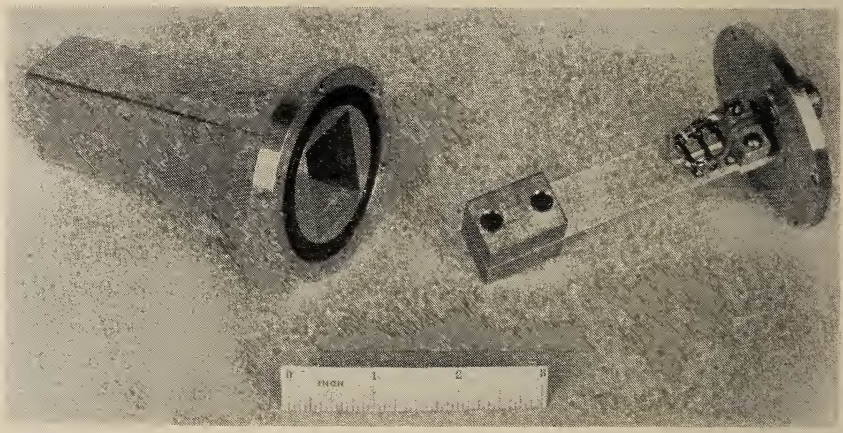
The reference and consultation services are being used more and more with the number of consultation questions exceeding the number of reference questions. Questions are answered on the basis of information obtained by using the new system supplemented by other literature search techniques for earlier literature. Consultation with authorities is also made when needed. A previously prepared report, "Guide to Instrumentation Literature," has been revised and is being prepared for publication as an NBS Circular with the title, "Instrumentation Literature and Its Use."

The usefulness of the previous edition had been shown by the considerable demand for it, and it is believed that the revision will be of still greater value because of the addition of indexes and the greater coverage it provides

Instrument Surveys. Surveys of various areas of instrumentation are conducted in order to provide systematic analyses of available methods and devices in terms of their performance and characteristics. The surveys fill a need generally felt by those charged with planning or conducting research and development on the devices or in areas where they will be needed. As with other portions of the basic instrumentation program, some of the surveys are conducted by the staff members of the technical divisions while others are conducted by the Office of Basic Instrumentation. Two surveys in the basic instrumentation program, made by members of the Mechanics Division, have recently been completed and reports issued. One was the Survey of Dynamic Pressure Instrumentation and the other was the Survey of Stress-Strain Recorders. Surveys which have been under way in the past year in the Office of Basic Instrumentation are: (1) Survey of Thickness Measurements, (2) Survey of Recording Methods and Instruments, and (3) Survey of Recent Developments in Flow Measurement. The last named has been completed.

Studies on Shock and Vibration. The need for the measurement of vibration over wide ranges of frequency and amplitude has grown with the use of higher speeds presented by jet and rocket propulsion and with the use of stiffer structures which must be operated under greater stress. In order to assay the effects of vibration it is necessary to provide suitable transducers and means of calibrating them. The Office of Basic Instrumentation has contributed in this area through work on methods for the design, construction, and calibration of piezoelectric accelerometers.

A system was designed and built for calibrating vibration pickups over the broad frequency band from 0 to 50,000 cps. The system includes a piezoelectric vibration generator to provide vibrations in the desired range. The amplitudes of the vibrations provided by the generator are detected by means of the resonant bridge carrier system, which measures changes in electrical capacitance caused by motion of a steel plate attached to the generator. A resolution of 10^{-9} inch is attainable.



A jerkmeter for studying human heart action is shown partially assembled. When a barium-titanate piezoelectric element is distributed by the forces generated by the patient's blood flow, strains are developed in the element which cause it to produce an electrical signal.

A device known as a jerkmeter has been developed to serve as a prototype for use in ballistocardiography Its output is proportional to the derivative of acceleration (jerk). Other activities in the shock and vibration field include the construction of preliminary models of high-frequency, high-acceleration, low-cost accelerometers using thermosetting casting resins, the development of a test procedure for the evaluation of low noise electrical cables, extension of previously available curves for the effect of Coulomb and viscous damping on mechanical vibration, and the design of a large barium titanate accelerometer for use in shock-velocity measurements.

3. Calibration, Testing, and Standard Samples

The calibration and standard samples programs, stemming from the Bureau's custody of the Nation's basic physical standards, provide a unique service for Government, industry, and the general public. The testing program on the other hand is confined almost entirely to serving other Government agencies in connection with their purchasing, regulatory, or functional responsibilities.

In providing standards of measurement for the Nation, the Bureau makes available the basic standards and encourages those requiring such standards to make their own comparisons and calibrations. Government agencies, industrial firms, and scientific and educational institutions now have need for such a large number

and variety of standards that the Bureau, with its limited resources, can provide, in most cases, only the master standards.

3.1. Calibration Center

The new Calibration Center that is being developed at the NBS Boulder Laboratories illustrates how this policy is being implemented. The principal impetus for creation of the Calibration Center grew out of the urgent need by the Air Force and the Navy Bureau of Aeronautics for accurate calibration of the vast quantity of radio, radar, and other electrical equipment that accounts for more than half the cost of some modern military planes. Thus the Bureau will set up the necessary primary standards, d-c as well as radiofrequency through microwave, and will calibrate transfer standards provided by the Air Force and the Bureau of Aeronautics. These transfer standards will then provide the different air and naval depots with means for calibrating their working standards. The aircraft operating instruments in turn will be checked against these working standards.

The Congress recently appropriated $765,000 to construct a new wing of the Radio Laboratory to house this operation. Space will be provided both for the calibration laboratory operated by NBS personnel and for a depot at which Air Force and Bureau of Aeronautics personnel will receive and perform the necessary maintenance on their transfer standards prior to calibration, and from which these standards will be shipped to the different depots. The Calibration Center is expected to be in operation about January 1, 1957. Its services will, of course, be available to other military agencies and to the public. Development of the necessary primary standards for this service constitutes a major project in itself, since some of them lie in fields in which no standards have as yet been constructed.

3.2. Making Standards Available for Practical Use

Time and Frequency. The ideal solution to the problem of making standards available to all who need them is most nearly realized in the case of standards of frequency and time that are broadcast continuously by the Bureau's radio stations—WWV at Beltsville, Maryland, and WWVH in Hawaii. These stations

provide standards of radiofrequency at 2.5, 5, 10, 15, 20, and 25 megacycles per second. Also, on each carrier frequency is broadcast a 600-cycle standard audiofrequency for controlling the generation of 60-cycle current in the electric power industry, a 440-cycle standard musical note, and precise seconds signals. These signals are received and widely used to check continuously or periodically the standards of the radio-electronics industry, aircraft and ship navigators, research laboratories, armed forces, broadcast stations, and utilities.

During the past year the direct calibration of equipment at radiofrequencies was materially interrupted by the move of laboratory facilities from Washington to Boulder, Colorado.

Seventy-six items of apparatus used for laboratory standards were tested or calibrated including frequency meters, attenuators, inductors, and dielectric and magnetic samples.

Clinical Thermometers. Clinical thermometers afford a more typical illustration of the way in which a national standard of measurement maintained by the Bureau is translated into practical use for the benefit of the public (see diagram on page 125). The basic standard in this instance is the International Temperature Scale maintained by the ice, steam, and sulfur boiling points. These points, experimentally realized with elaborate procedures, are used to establish the scale of a specially constructed platinum resistance thermometer which is taken as the primary standard of temperature. Mercury-in-glass thermometers of suitable construction are then calibrated against the resistance thermometer and are used in turn as secondary standards for testing clinical thermometers.

As shown in the diagram two other groups are concerned with the testing of clinical thermometers. The manufacturers test their output before it goes on the market, and, where the sale is controlled by law or regulation, certain State and local authorities test clinical thermometers from the open market. The Bureau makes tests for other Government agencies and for the public. When large purchases are made the Federal Government tests are made on a sample, usually about 10 percent from each lot, and from the results the quality of the lot as a whole is ascertained by statistical means.

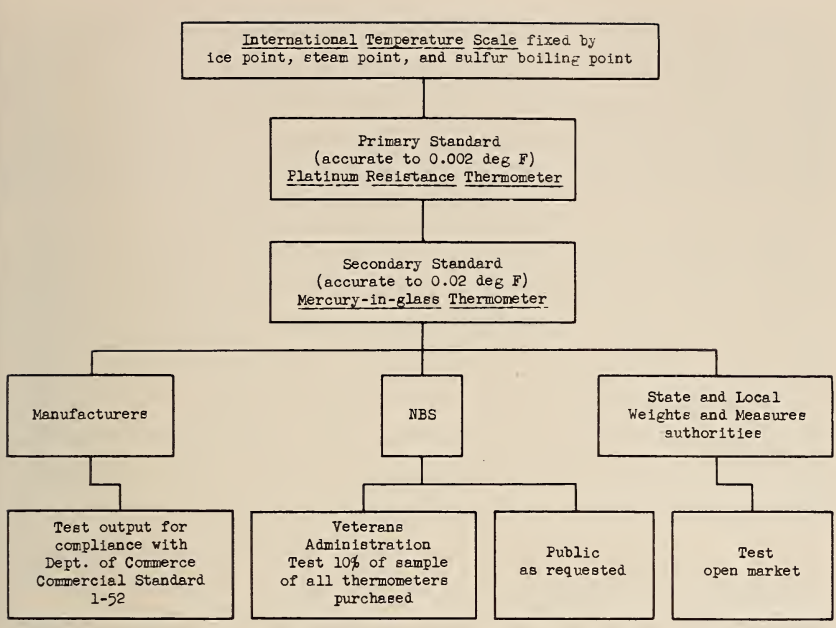


Diagram illustrates how the international temperature scale maintained by the Bureau is translated into practical use for the benefit of science, industry, and the public. Photograph shows thermometers are being calibrated against a "standard" liquid-in-glass thermometer. During 1955 the Bureau calibrated over 33,000 clinical thermometers.

In the past year 33,110 clinical thermometers were tested by the Bureau; 31,911 of these represented a sampling of over 365,650 thermometers purchased by the Veterans' Administration. The fact that only about 1,000 thermometers were tested for the public indicates that there is no longer any large scale demand for the testing of individual thermometers by the Bureau.

The diagram shows that, as in all calibration, there is a loss in accuracy at each stage of comparison from the primary standard to the end object. In order that the clinical thermometer may have the accuracy of 0.2° F that is commonly required, it is necessary that the standard thermometer against which it is compared be accurate to 0.02° F, and that the scale of the primary standard resistance thermometer be established to 0.002° F. Commercial Standard CS 1–52 to which clinical thermometers are commonly made is a standard established by manufacturers and users under a procedure of the Department of Commerce. In addition to the accuracy, it covers the construction, the ease of shaking down, and the permanence of the markings.

Dental Materials. Still another way of making standards available is through codes and specifications. For example, in connection with the maintenance of the List of Certified Dental Materials of the American Dental Association, Research Associates of the Bureau tested 81 samples of dental materials for compliance with ADA Specifications. These samples included investment materials, wrought gold wire alloys, silicate cements, hydrocolloidal impression materials, denture base resins, and mercury. The Association, through the Journal of the American Dental Association, made available to practicing dentists a certified list of 315 items of dental materials.

3.3. Calibration Requests Show Industry Trends

Several trends in the types of tests requested indicate changes in emphasis in the electrical industry. For example, the increase in the number of standard cells of the saturated type that are submitted indicates that greater importance is being attached to the accuracy of measurements. The saturated cells assure a much more stable voltage, but must be used in a thermostated enclosure and hence are less convenient to use than the unsaturated cells which have a lower temperature coefficient.

Another trend is toward the use of higher frequencies. Because of the increasing use of 400 cycle power for aircraft and for computer applications about 20 percent of the requests are for tests at this frequency. Meanwhile, requests for tests at 25 cycles are very infrequent. A few tests are requested at 800 and 1,000 cycles but most of the remainder are at 60 cycles.

There is also a growing industrial interest in the use of reactors and capacitors as power factor standards for the production testing of similar units used in power transmission systems. Because the phase defect represents a continuous loss of energy, once these static devices are connected to a power line for protective or power-factor purposes, small gains that reduce power losses are desirable. Thus the Bureau was called upon for measurements on a large reactor and a capacitor in order that these units might be employed as standards.

There has been an increase in requests that the Bureau report additional significant figures in the calibration of resistors, volt boxes, voltage transformers, and other electrical instruments. Experience with instruments that are returned for periodic calibration indicates that progress in manufacture has improved the stability of the instruments to the point where it is now feasible for the Bureau to make calibrations to higher orders of precision.

Several new and useful instruments tested by the Bureau for the first time included (1) a strain-gage "calibrator," (2) a Standard Ratio Transformer, an autotransformer arrangement that provides a 5-decade division of the supply voltage, and (3) a product resolver, an unusual adaptation of wattmeter elements. All were found to be in rather good adjustment and each represents a useful contribution to the technology of measurements, the calibrator for use in strain gage work, the ratio transformer where accuracy of a-c voltage subdivision is important for computer applications, and the product resolver where the accuracy of analog products must be verified.

3.4. New Standard Samples

One new standard sample of metal—a heat-resisting jet-engine alloy—was added to the standard samples program through which more than 500 materials of certified properties, purity or composition are available to science and industry (NBS Circular 552,

Standard Samples and Reference Standards issued by the National Bureau of Standards). Other new standard samples of metal had been requested but the Bureau's available resources were used in renewing 10 standards of composition that had become exhausted; there were 5 steels, 1 bronze, 2 cast irons, 1 arsenic trioxide, and 1 acid potassium phthalate. Two new standard samples of rubber compounding ingredients were established and two reference lots of synthetic rubber that had been established by the Office of Synthetic Rubber were taken over by the Bureau when the Government-operated plants were sold to private industry. The standard sample of dyed paper, established late in 1954 and designed for use in calibrating carbon arc lamps for use in fading and weathering tests, was quickly exhausted and was replaced with a new lot.

The metallurgical laboratories have undertaken to supply metals, in appropriate form of wire, sheet, rod, or solid pieces, that will be certified for physical properties rather than for chemical composition. A supply of suitable metals is being accumulated and the necessary instrumentation is being developed. One instrument, for example, for this program is a high-sensitivity dilatometer to define temperature-structural change characteristics. Other developments include improved equipment to determine electrical resistivity versus temperature characteristics.

During the year a total of 32,501 standard samples were issued, representing a fee value of $136,784.30. Of the more than 200 standards of certified composition or purity available, about 24,100 samples, with a value of $104,000, were issued. A total of 3,752 samples for rubber compounding and 392 samples of calibration paper were issued at a total value of $10,672.60.

3.5. Testing for Government Purchase

The Bureau tests a wide variety of products purchased by the Federal Government for compliance with Federal Specifications. In a few instances tests by the Bureau control a large part of the procurement by civilian agencies. Testing is done for the public only in unusual cases when the Bureau has facilities or equipment not available elsewhere.

Government contracts for electric lamps which are purchased in large quantity are awarded to suppliers who have passed quali-

fication tests conducted by the Bureau. A staff member conducts tests in the manufacturers' laboratories and takes samples from lots of lamps set aside for Government purchase for additional tests at the Bureau. These tests are applied not only to incandescent lamps but also to fluorescent lamps, photographic flash lamps, and many other types. The lamps tested by the Bureau are representative of purchases amounting to about 3 million lamps of which only 7 percent are rejected. While this testing is done exclusively for the Government it benefits the public indirectly. Precautions that are found necessary to produce lamps that satisfy Federal specifications are in general applied to the entire output of a factory.

The only reliable tests for dry cells require a great deal of time. To overcome this difficulty, a plan has been in operation for many years whereby tests on dry cells from all suppliers desiring Government contracts are conducted continuously. Thus the contract for any given year is awarded to a supplier whose product has met the requirements during the previous period.

The quality of cement purchased by the Federal Government is important because much of it is used in dams, locks, monumental public buildings, and other structures that are designed for high strength and very long life. The Bureau conducts acceptance tests on a considerable part of this cement and maintains laboratories for this purpose in Allentown, Pa., Denver, San Francisco, and Seattle as well as in Washington, D. C. From time to time laboratories are established temporarily in localities in which a large amount of construction is in progress. Considerable economy to the Government is effected by arranging with the producers in certain areas to set up large bins of cement which are tested and sealed for use by any Federal agency that may require cement.

In 1955 about 30,000 samples were tested, representing approximately 15 million barrels of portland cement. In addition, tests were made on 5,800 hardened concrete specimens and on 750 aggregates. In localities where the service was not available from other agencies the engineering properties of 500 soil samples were determined.

Closely related to the cement testing program is the Cement Reference Laboratory, located at the National Bureau of Standards, and jointly supported by NBS, the Bureau of Public Roads,

the Army Corps of Engineers, and the American Society for Testing Materials. This Laboratory provides a voluntary inspection service for maintaining uniform standards in cement testing throughout the country. On request its staff visits laboratories to make a careful evaluation of their facilities, and equipment, and the qualifications of their staff. Reports are made only to the laboratories inspected. In 1955 seventy cement laboratories availed themselves of this service.

At the request of various Government agencies, the Bureau tested a wide variety of building materials. Examples include tests of fire and weather resistance of structures and materials, heating and cooling systems, thermal insulation materials for both underground and above-ground installations, heat and water vapor transfer characteristics of insulating materials, elevator buffers, and concrete masonry walls.

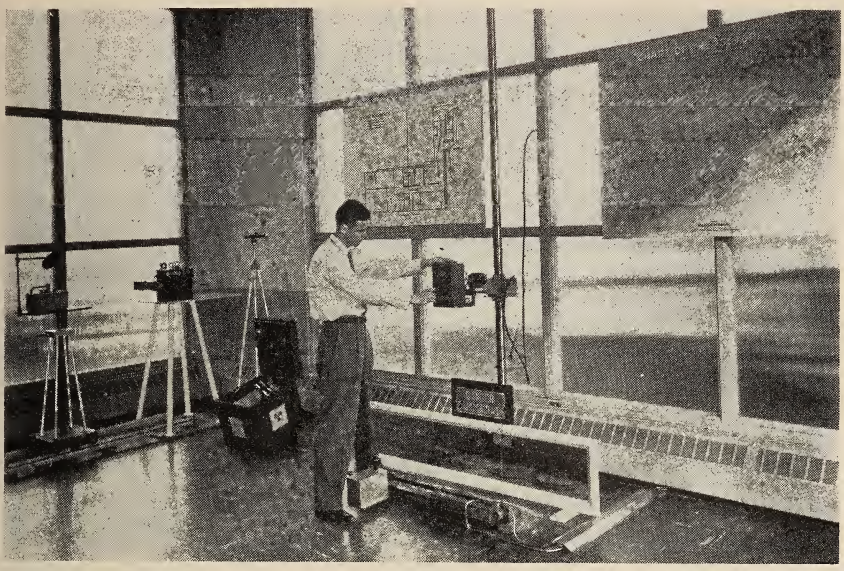
Tests were also performed on such items as: marble, slate, sewer pipe, brick, fire-retardant paints, plastic glasses, fire extinguishers, flush valves, air filters, portable air conditioners, insulated food containers, and bituminous materials.

3.6. Services in Other Areas

Services in specific areas not discussed above are summarized in the following paragraphs.

The Bureau regularly calibrates surveyors' tapes for the Coast and Geodetic Survey and for the Inter-American Geodetic Survey. These tapes are of invar and are used to establish baselines which are used as bases for our geodetic surveying. A complete calibration includes the determination of the coefficient of thermal expansion.

It is now common practice to make contour maps for road building projects, hydroelectric installations, and general topographic purposes by the application of photogrammetric methods to airplane photographs. If satisfactory maps are to result, the photographs must be of good quality and free from distortion. Testing methods developed at NBS are regularly applied each year to a large number of airplane cameras designed for photogrammetric applications submitted by other Government agencies and the public.



The Bureau's new Gamma-Ray Laboratory was built to meet the growing demand in medicine, industry, military and civil defense for gamma ray standards and calibration. Here, a radiation survey instrument is being adjusted before exposing it to gamma rays from a 200-curie cobalt-60 source.

Nearly a thousand radioactive standard samples were issued during the year. In addition, 491 cobalt-60 sources totaling 10,222 millicuries were calibrated, and 839 radium sources totaling 18,155 milligrams were calibrated and certified. Six standard NBS Mercury-198 lamps were distributed to laboratories approved to receive them. Chemical and isotope analyses of 492 samples were reported. Also 750 items of radiological equipment were calibrated. Increasing use is being made of neutron sources and six sources were calibrated together with 2 thermal-neutron dosimeters and 4 fast-neutron meters.

About 2,500 samples of paints and varnishes, soaps and detergents, metals and alloys, raw sugars, and reagent chemicals, were analyzed or tested for compliance with purchase specifications or in connection with research projects or regulatory investigations. This number includes about 350 samples submitted by the Atomic Energy Commission for umpire analysis to settle disagreements between the Commission and suppliers of materials.

A standardizing service essential to the use of "magne gages" is provided in the form of specimens of plated metals with coatings of certified thickness. Some 5,540 of these standard samples were

issued. Five benzoic acid thermometric standards were issued, bringing to 101 the total of these calibrating devices issued since this service was begun in 1947.

As a special service for the Veterans Administration 2,400 dilution pipets were marked with the observed dilution ratios. These were to be distributed as reference pipets to the hospitals and clinics operated by the Veterans Administration.

Tension, compression, bending, torsion, hardness, and other mechanical tests were made on a variety of specimens submitted by other Government departments, State institutions, and private organizations to determine mechanical performance and compliance with specifications. Specimens included reinforcing steel, copper conductors, wire and fiber rope, hand tools, pole top pins, crossarm pins, upset spool bolts, insulator wire holders, pencils, signal flares, file cabinets, fans, spark plugs, and other articles.

In the calibration of mass standards, the items dealt with ranged from microbalance weights to weights used in testing railroad track scales. The largest operation undertaken was the testing and evaluation of aircraft scales using 300,000 pounds of accurately calibrated weights at one time.

4. COOPERATIVE ACTIVITIES

The Bureau's cooperative and consulting activities arise from the diversity of its program, facilities, and staff in the physical sciences. These activities range from the development of codes and specifications in cooperation with other groups to active participation in technical society programs to advisory service for other Government agencies in all areas of the physical sciences.

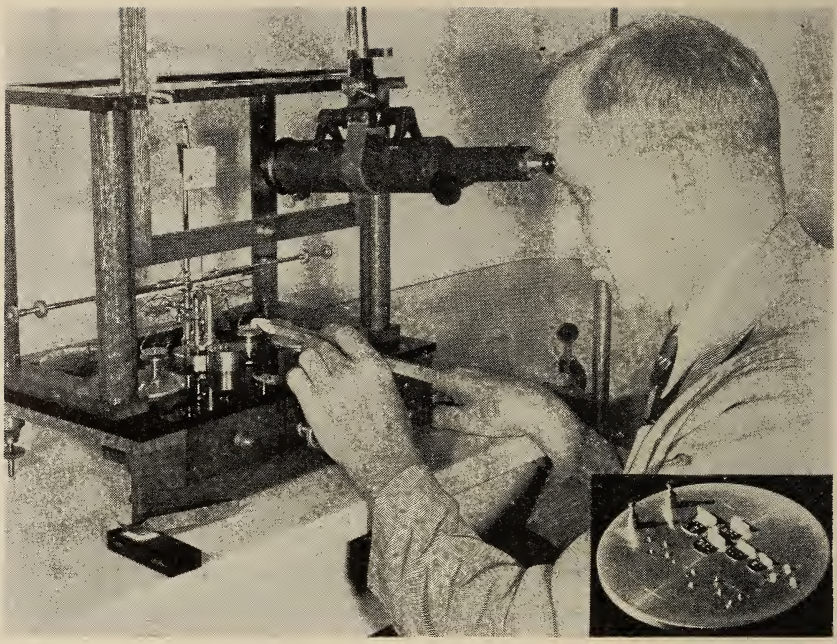
In the area of codes and specifications the Bureau works largely as a collaborator and seldom initiates work or promulgates a finished document. Nevertheless, it often makes a major contribution by providing methods of test, basic scientific and technical information on properties of materials and related subjects, and standards of measurement without which no other standards are possible. Bureau staff members actively participate in national and international professional societies. This work greatly enhances the dissemination and utilization of NBS research, development, standardizing, and testing activities. Also, staff members are able to keep in close touch with technical and scientific advances

elsewhere and to coordinate the standards and specifications used in industry with those employed by Government.

During 1955 staff members participated in the activities of technical committees of more than 120 national societies, serving in many cases as chairmen or secretaries. NBS staff members served as presidents of the International Joint Commission on Spectroscopy, the Society of Plastics Engineers, the Philosophical Society of Washington, the Optical Society of America, and the Instrument Society of America. Numerous directorships and other positions were held in the major national societies. Internationally, Bureau staff members participated in more than 90 committees of 21 societies, serving as chairmen or secretaries of approximately 23 committees.

Federal Specifications. The General Services Administration looks to the Bureau for the preparation or revision of some 175 Federal Specifications. These specifications cover a very wide range of subjects, practically all fields of science and technology in which the Bureau has competence. In drawing up a specification, the Bureau is often able to use knowledge gained in research or development work undertaken for other purposes. Information acquired in the testing of materials purchased by the Government is also utilized in developing and improving specifications. Because of the magnitude and importance of the Government's purchases of paints and portland cement, research projects in each of these fields are carried on in close coordination with the testing operations. In order to find out how well tests of paint work out under practical conditions, the Bureau prepares and circulates reference samples of paint among a number of Government laboratories. The results are brought together and analyzed by the Bureau to find the degree of uncertainty in each of the tests as it is commonly conducted and to determine which of the test methods need to be revised in order to improve their reliability.

In addition to preparing assigned Federal Specifications, the Bureau is often called upon to review proposed specifications drafted by others. During the year the General Services Administration submitted more than 450 proposed Federal specifications and amendments to the Bureau for comment. Most of the comments that were made related to methods of test where the Bureau had special knowledge or experience.



Small high-precision balance on which the Bureau compares standard microbalance weights with standards maintained by the Bureau. *Insert:* A set of microbalance standard weights; values range from 1 g down to 0.05 mg (p. 136).

Methods of Test. The development of test methods is one of the statutory functions of the Bureau. In carrying out this function the aim is to develop general methods that will be applicable to large groups or classes of products—not just individual items. Among the methods for which the Bureau has accepted responsibility in connection with Federal Specifications are the methods for adhesives, cements, detergents, laboratory glassware, leather, paper, plastics, paint, rubber, textiles, and wire and cable. Basic documents on these methods are customarily issued by the General Services Administration as Federal Standards. In specifications for specific products it is only necessary to make appropriate reference to these standards to provide suitable methods of test. While revisions of test methods are issued only periodically, continuing work must be done on all of them in order to keep them in step with the rapid development of modern technology.

Industry Specifications. In order that the Government may purchase economically, Federal and other Government specifications must be closely coordinated with those of industry and must take full advantage of new developments and improved

manufacturing procedures. The Bureau is enabled to make a large contribution in this direction through the extensive participation of its staff members in the work of many national standardizing organizations. Currently Bureau staff members hold more than 400 committeeships in the American Society for Testing Materials, and more than 200 in the American Standards Association.

A new smoothness tester for paper, designed and manufactured in the United States, has been the subject of a cooperative investigation by NBS and members of the Technical Association of the Pulp and Paper Industry. The new instrument is being compared with the present standard in regard to speed and ease of operation, reproducibility of results, and mandel sensitivity. Under the direction of the NBS Plastics Section and with the cooperation of six other laboratories, a revision of the ASTM method for determining the tensile strength of thin plastic films was developed which has been accepted by ASTM Committee D–20 on Plastics.

Building and Safety Codes. The Bureau assists a variety of government agencies—State, county, and municipal—in solving problems relating to building and safety codes. The destructive storms of the fall of 1954 caused the collapse of a number of radio and television towers and led to accelerated activity in the revisons of those portions of codes that relate to wind load on structures. In the building field, cooperative work with representatives of organizations sponsoring model codes has continued to be effective in reducing differences in requirements. During 1955 assistance was given in preparing and revising building codes in New Mexico, New York, and Ohio, as well as in various counties and municipalities throughout the Nation. The Bureau, as either sponsor or cosponsor, assisted in preparing a number of model codes. In 1955 the American Standard Building Code for Masonry was published by the Bureau, and the American Standard Safety Code for Elevators was completed. A third code, the American Standard Building Code Requirements for Minimum Design Loads in Buildings, was completed and referred to the American Standards Association for review. Other model codes in which the Bureau, as sponsor or cosponsor, has continued to take a leading part, are the National Electrical Safety Code, the Code for the Protection Against Lightning, and the Code for the Protection of Eyes, Heads,

and Respiratory Organs of Industrial Workers. In addition, members of the staff have taken an active part in preparation or revision of model codes such as the National Electrical (Fire) Model Code and the American Standard Model Code for Punch Presses.

Radiation Protection. The National Committee on Radiation Protection, an advisory group made up of radiation experts and sponsored by NBS, prepares recommendations for safe operating and handling procedures for radioactive substances and other sources of radiation. These are used by industry, the medical profession, and research workers. At the joint request of the American College of Radiology, the American Medical Association, and the U. S. Public Health Service, the Committee several years ago undertook an intensive study of the problems involved in the legislative regulation of radiation exposure. The request was prompted by repeated inquiries by individuals and groups seeking guidance and information on the subject. This study has culminated in a report, which is now in press as NBS Handbook 61. This comprehensive report includes a description of the general problem of developing legislation for the control of radiation exposure, and gives an extended discussion of the various problems that must be considered by a State in the development of such legislation. The appendices present (1) a sample law covering the whole field of radiation protection for use by a State planning such legislation, and (2) a set of radiation control regulations for use as a basis for the development of uniform regulations by the States. In addition to this Handbook, three radiation protection reports have been published during the year and another is in press.

Weights and Measures. The translation of the national standards of length and mass, and of the derived standards of capacity, to the channels of industry and trade is a matter of great economic importance to the producing, manufacturing, processing, and distributing agencies of this country, and to all purchasers of commodities and services. The individual States have responsibility for the regulation of commercial weighing and measuring devices. However, the Bureau cooperates with the States, promoting uniformity in weights and measures laws and methods of inspection and, by virtue of its custody and maintenance of the national standards and of its related calibration services, translating the

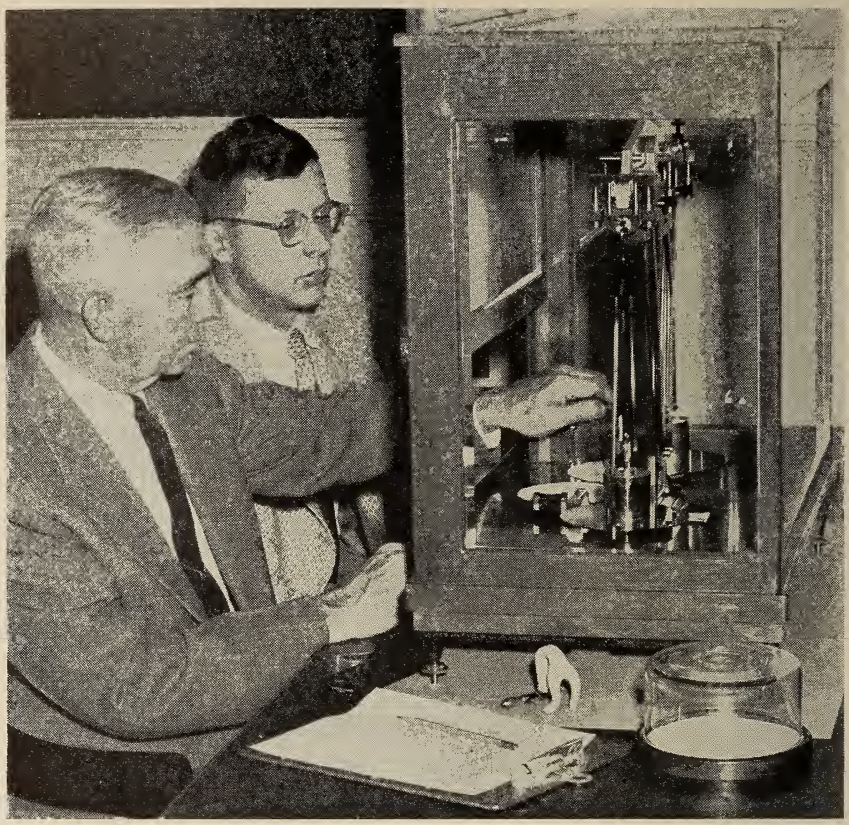
national standards to the channels of trade. To aid in this work, the Bureau maintains an Office of Weights and Measures.

Commerce and industry have become increasingly aware of the importance of adequate weights and measures administration. As a result, greater demands are made upon the Bureau each year for assistance and advice in this field. The NBS Office of Weights and Measures, has been conducting a program of assistance to State and local departments, as well as to business and industry, in the several phases of weights and measures supervision. The range of consultative services is broad, embracing the drafting of new legislation, the development of specifications, tolerances, regulations, and testing methods, the design of testing equipment, the preparation of training films, and the physical adjustment of State weights and measures standards.

During 1955 the Office of Weights and Measures conducted the 40th National Conference on Weights and Measures and planned and attended regional and State conferences. NBS Handbook 44, *Specifications, Tolerances, and Regulations for Weighing and Measuring Devices*, was revised and submitted to the printer. The report of the 39th National Conference on Weights and Measures was compiled, printed, and distributed. An investigation of weights and measures approval seals was completed along with an experiment in farm-milk tank calibration, and a survey on packaged flour and a milk-container study were conducted. Material assistance was rendered to three States toward the development and enactment of extensive weights and measures legislation.

The Bureau during the year released a weights and measures training film entitled "A True Standard." The film has been shown at 10 meetings of weights and measures officials, and prints have been loaned for showing before 60 organizations, including scientific and professional societies, service clubs, high schools, colleges and universities, industrial concerns, and law enforcement agencies of cities, counties, and States. The film has been televised several times. The Bureau has embarked on a new program of providing essential repairs to basic standards when they are submitted by States for calibration.

Research Associate Program. An important area of cooperation between the National Bureau of Standards and American industry is the Bureau's Research Associate Plan. This plan is an arrange-



The substitution method of weighing is recommended for accurately intercomparing test weights with standard weights calibrated by the Bureau. This procedure assures the accurate translation of weight from the International Standard through the Bureau to the test weights used by State and local inspectors. A new color motion picture on substitution weighing entitled "A True Standard" was produced by the Bureau.

ment whereby technical, industrial, and commercial organizations can support work at NBS on projects which are of special interest to them, yet of sufficient general interest to justify use of Government facilities.

Research associate projects must not only be of value to all groups concerned in the particular field and to the Federal Government, but must also be important from the standpoint of the Nation's sum total of technologic knowledge. The arrangement is usually made with an association or group representing a major part of an industry. However, projects may be undertaken in cooperation with single companies or individuals when the results are expected to be of value to the general public. In any case, the

results become a part of the public domain and are published by the Bureau.

Since the Research Associate Plan was established in 1920, about 180 organizations and individuals have supported cooperative research at the Bureau. At present 12 groups are supporting some 40 research associates at NBS. Research associate projects active during the past year are as follows:

Sponsor	*Field of Activity*
Aluminum Company of America	Reflective thermal insulation
American Dental Association	Dental research
American Electroplaters Society	Porosity of electrodeposits
American Iron and Steel Institute	Reinforced concrete
American Society for Testing Materials	Cement reference laboratories
Asphalt Roofing Industry Bureau	Asphalt roofing research
Bone Char Research, Inc.	Research on adsorbents for sugar refining
Calcium Chloride Association	Hydration of portland cement
National Research Council	Masonry research and fire resistance
Porcelain Enamel Institute	Test methods for porcelain enamels
Portland Cement Association	Cement research
Joint Committee of Chemical Analysis by X-ray Diffraction Methods (ASTM & Am. Crystallographic Assoc.)	Standard X-ray diffraction powder patterns.

Many of the projects have been specific and therefore of relatively short duration. Others, such as that supported by the American Dental Association, have been directed toward fundamental research in the field; this project has been active since 1928. Through application of the methods of the physical sciences to the study of dental materials, the program has aided in the solution of many of the problems encountered by the practicing dentist, such as postoperative pain, accurate casting of gold inlays and bridgework, and failure of denture resins.

Optics. The Bureau cooperated in a wide variety of activities in the field of optics over the past year. At the request of the Civil Aeronautics Board, the Bureau analyzed the visibility conditions at the time of a mid-air collision at Port Columbus Airport, Ohio. A meeting on color problems arising in the procurement of textiles for automobile upholstery was held at the Bureau and was attended by representatives of the automobile industry, textile suppliers, and a manufacturer of artificial daylighting equipment.

The Bureau continued its assistance to the Weather Bureau by calibrating pyrheliometers in the 15-foot light integrating sphere and assisted the Virginia Highway Department in the calibration of photometric equipment for highway sign tests.

Heat and Power. During the year, the Bureau assisted other agencies in a consultative capacity on many technical problems associated with the use or purchase of fuels, lubricants, temperature measuring devices, antifreezes, and electrical and pneumatic equipment for aircraft. For example, the Federal Trade Commission was given technical information pertaining to claims made for automotive products, the Department of Justice was aided in patent litigation, and the Civil Aeronautics Administration advised regarding the fire hazards of methyl alcohol solutions. Other work of similar nature included development and revision of the Federal Standard on Fuels and Lubricants and of specifications for antifreezes and petroleum ether. Problems where the Bureau cooperated with national societies include revision of standards for fuels and lubricants, development of a second standard of viscosity, and standards for calorimetry. The NBS low-temperature laboratory is cooperating with the Naval Research Laboratory in work on the development of the helium vapor pressure scale of temperature. Other cooperative work includes active participation in a program of the American Society of Mechanical Engineers for extending to higher pressures and temperatures the international tables of thermodynamic and static properties of steam. This work will aid in the development of more efficient steam turbines and the rating of steam turbines in international trade.

Building Technology. Government agencies, both in Washington and elsewhere, consult the Bureau on building construction, equipment, and practices. Among the recipients of this service are the Office of the Chief of Army Engineers, the Army Quartermaster Corps, the Navy Bureau of Yards and Docks, the U. S. Coast Guard, the General Services Administration, and the Federal Housing Administration. For the Department of the Interior, the Bureau completed a study of the causes of a serious plaster failure in a hospital in Alaska. Continuing a long-range understanding, the Bureau this year furnished consultative service on the elevators in the U. S. Capitol, in the new Senate Office Building, at Carlsbad Caverns in New Mexico, Wind Cave in

South Dakota, and at Perry Monument on Lake Erie. Members of the Bureau staff served as consultants to the Federal Trade Commission and interested trade organizations in the preparation of an amendment to the Flammable Fabrics Act. The Bureau assisted the Atomic Energy Commission in selecting the optimum concrete for the foundation of the magnet of an alternating gradient synchrotron at the Brookhaven National Laboratory. At the request of the Smithsonian Institution, a new type of flooring was recommended for use in the National Zoological Park animal cages.

The Bureau answered a large number of requests for technical information on building technology from the general public. These requests were from home owners, builders, supply dealers, engineering firms, industrial concerns, architects, and educational institutions. In some cases the information furnished has proved of considerable benefit to industry. For example, a number of inquiries were received from insulation manufacturers concerning the application of reflective surfaces as opposed to other forms of thermal insulation. The possibilities and advantages of such insulation have been indicated by work done at the Bureau on reflectively insulated air spaces.

Data Processing. A cooperative program for the Navy Aviation Supply Office concerned the application of a large-scale general-purpose electronic digital computer to the task of calculating the anticipated inventory requirements necessary for the support of projected aircraft operations throughout the Navy. This was a pioneering step in the development of data-processing techniques for supply mangement.

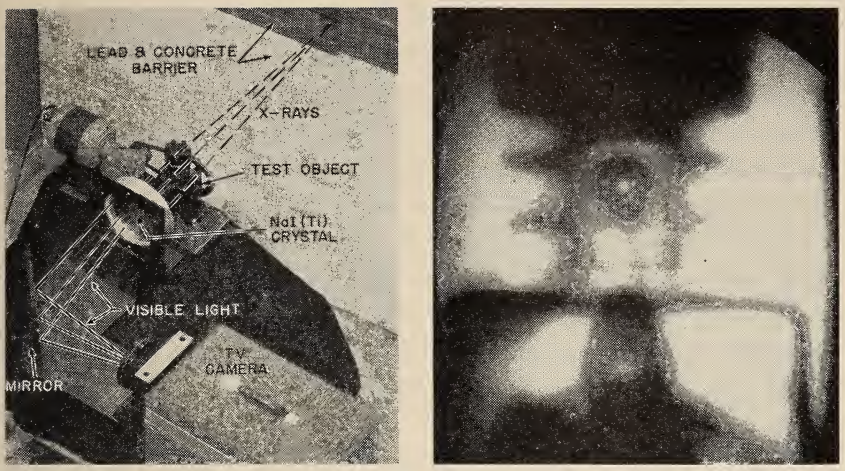
In order to provide an integrated information processing system throughout the supply management organization of the Air Materiel Command, a training course was developed by NBS. The course provides material and instructions for upper and middle management personnel. It will train officers from various Air Materiel Commands to assist in carrying on data-processing programs at their own bases. A training course was also given to Navy supply management personnel on the principles and techniques of automatic data processing for supply management. Texts, lecture notes, charts, slides, and supplemental reading were prepared.

The Bureau staff participated, along with representatives of industry and Government, on the Advisory Committee on Application of Machines to Patent Office Operation, and in the preparation of the final report which recommended an extensive program for mechanizing patent search operations. The Bureau was also invited to participate in and to give technical information on an analysis and development program for processing first-class mail by the Post Office Department. Various aspects of the problem were considered, particularly mail sorting and handling throughout the postal system. The ultimate aim is to find the best practical method for processing first-class mail through the development of suitable electronic equipment.

Radio Propagation. One of the Bureau's most important services is its continuous appraisal and advance warning of ionospheric disturbances which disrupt radio communication. Advance forecasts from 1 to 24 days ahead were continued during the year on a semiweekly basis and medium term forecasts for 24 hours ahead were made once a day. Short-term forecasts were broadcast from WWV every 6 hours. Many reports of ionospheric, solar, geomagnetic, and radio wave propagation data were regularly mailed, telephoned, or telegraphed to Government agencies and commercial users. Reciprocal ionospheric data were received from 76 national and international stations. A total of 15 Signal Corps trainees discussed problems of ionospheric data scaling and processing, diurnal, seasonal and sunspot cycle trends, and methods of predicting skywave frequencies with members of the staff during the year.

Of particular importance over the past year was planning cooperative work in conjuction with the International Geophysical Year, 1957–58. Much consultative work has gone into the design and processing of the new C–4 ionospheric sounder, and of the airglow photometer for use in connection with these programs. In addition, the following Technical Panels of the U. S. National Committee for the International Geophysical Year held meetings at the Boulder Laboratories during the past year: Ionospheric Physics, Aurora and Airglow, Cosmic Rays, and Solar Activity.

Several analyses of possible communication via the $F2$ region were made for the Federal Communications Commission in connection with interference problems. Ratios of expected inter-



An X-ray pattern amplifier demonstrated at the Open House (p. 11) makes it possible to televise the X-ray image of an operating mechanism. *Left:* High-energy X-rays from the NBS betatron emerge from a slot in the radiation shield and penetrate the test object (a single-cylinder compressor). The sodium iodide crystal converts the resulting X-ray image into a visual image (right), which is reflected by a mirror to the television camera.

ference were calculated for the International Frequency Bureau Cochannel Interference Project. An analysis of possible transmission for a specified period at 5,966 kilocycles was made for the Aeronautical Radio, Inc.

Representatives of the Signal Corps and Denver Research Institute were advised of the limitations and possibilities of a digital transmission for television signals. At the request of the Airways Operations Division of the Civil Aeronautics Administration, estimates were made of the service range for ground-wave propagation at 400 kc and at 215 kc in the vicinity of Point Barrow, Alaska. A table of ranges for different values of conductivity likely to be encountered in that area was prepared, based on the CAA's transmitting facility of a 40-foot counterpoise antenna with transmitter power of 400 watts. At the request of the Radio Technical Commission for Marine Services, a study was made of over-water propagation in the frequency band from 152 to 162 Mc. A report was prepared containing a nomogram from which estimates can be made of expected service range over salt and fresh water.

Representatives from the Army Electronic Proving Ground, Fort Huachuca, Arizona, were advised on measurement techniques for tropospheric scatter propagation programs. Advice was given representatives of a private firm on techniques for obstacle gain

measurements. The FCC was supplied VHF and UHF tropospheric propagation prediction curves and advised on the possibilities of new field-strength measurement techniques.

Approximately 10 industrial concerns inquired concerning the possibilities of obtaining better standards for frequency. The State Department, Telecommunications Policy Staff, was assisted in considerable detail throughout the year in studying and formulating documents for the International Radio Consultative Committee (CCIR) of the International Telecommunication Union. The Office of the Assistant Secretary of Defense, Advisory Group on Electronic Parts, was assisted with activities on frequency control devices.

Dental Materials. Since the dental research program is a joint effort of the Bureau, the Federal Dental Services, and the American Dental Association, a large part of the research activities are undertaken in order to provide adequate advisory services to these agencies on the use and procurement of dental materials. Members of the staff served as official consultants to the Division of Dental Public Health of the U. S. Public Health Service and the U. S. Naval Dental School. Advice on dental materials and equipment was given to the Interagency Council on Dental Affairs. Lectures on dental research and use of dental materials were given to dentists in the Air Force, Army, and Navy; to students and faculty of Georgetown Dental School, Howard University Dental School, and the Medical College of the University of Virginia; and to 42 miscellaneous groups interested in these materials.

Because of the difficulties encountered by armed services dentists in the use of improperly stored dental materials as well as materials of foreign manufacture, a special consulting service has been established, handled to a large extent by guest workers stationed at NBS by the military services. If the solution to a given problem cannot be drawn from previous experience, the necessary laboratory work is carried out to provide the answers. During the past year, direct assistance was given on the use of impression materials, duplicating materials, inlay wax, zinc phosphate cements, handpieces, silicate cement, mixing instruments, alginate separating materials, and partial denture casting techniques.

Metals, Mineral Products, and Other Materials. Fifteen reports were issued to the Civil Aeronautics Board on results of examina-

tion of various failed aircraft parts, such as crankshafts, landing gears, and engine components, that had caused or contributed to accidents of civilian aircraft. Advice on the failure of a ship propulsion gear was submitted to the Maritime Administration. Reports were made to the Bureau of Engraving and Printing on the causes and remedies for difficulties encountered in printing presses that developed wavy and "orange peel" surfaces on transfer plates and rolls. Metal castings that could not be obtained elsewhere, because of intricate design, special characteristics, or security reasons, were made for the Naval Observatory, Naval Gun Factory, and Diamond Ordnance Fuze Laboratory.

Suggestions, made to the Post Office Department with respect to properties of the rubber compound used in mail cart tires, should result in worthwhile savings in maintenance and replacement costs. To prevent corrosion of concrete and metal parts due to engine fumes in the railroad tunnels under the Chicago General Post Office, the Bureau advised using plastic panels and coatings for tunnel linings. Assistance was also given the Post Office Department in the development of requirements for a reinforced gummed tape. The improved tape permits the use or 2 strips instead of the 6 strips used previously. This method of sealing is now in the process of adoption for freight shipments.

To eliminate many of the difficulties experienced with plastic parts in National Security Agency equipment, suggestions were given as to the types of plastic to be used for particular purposes. The Corps of Engineers Waterways Experiment Station was given advice on the use of rubber in coal tar for flexible pavements, and a research and testing program was suggested which should result in the savings of several million dollars by guaranteeing a satisfactory pavement in service. As consultant to military agencies in matters pertaining to optical glass manufacture, specifications, and testing, the Bureau technically supervised two development contracts placed with commercial concerns by the Air Force.

Acoustics. The National Institutes of Health need fairly elaborate records of studies on mentally disturbed persons. These records include motion pictures and sound recordings of interviews between patient and physician. Such interviews must be recorded under the most favorable possible acoustical conditions. The Bureau advised the Institute on suitable acoustical design of

interview rooms. The main feature of the design is adequate sound insulation against disturbing external noises, but noise produced in the room itself has also been taken into consideration.

Investigations of the standard for threshold of hearing necessarily require measurements on a large number of persons. Also, the state of the measuring art is such that careful attention must be paid to the choice of earphones used for such measurements. The Bureau advised Walter Reed Army Medical Center on the number of persons necessary, and the types of earphones required, in order to yield a useful measurement of the differences between English and American audiometric thresholds. This required a balance between the number of persons available, the accuracy necessary to measure the differences, and the rather large inherent error in making psychoacoustic measurements.

Smog. The Bureau has continued active cooperation with local authorities in California and the Department of Health, Education, and Welfare on the problem of smog. The Bureau contributed original and effective chemical analytical methods for determining the constituents of smog. Also, extensive measurements were made of the distribution of the spectral radiant energy of the sun coming through the smog. It is hoped that analysis of these data will lead to a better understanding of the source of the smog.

Highway Truck Weighing. The Bureau gave advice to several groups concerned with the enforcement of State highway laws. This involved interpreting test results obtained last year on the weighing of axle loads of motor transport vehicles. The tests showed that the distribution of the total truck weight among the various axles is constantly changing under road conditions. An accurate measurement of the truck weight is possible only if all axles are weighed simultaneously. This sort of information is of considerable importance to State authorities and to the courts who must appraise fairly the claims of truckers. Bureau staff members assisted in the formulation of specifications for four-section motor truck scales under the auspices of the American Railroad Engineering Association. These specifications are available to all Federal agencies and provide for a much more rigid and durable installation than the specifications previously offered.

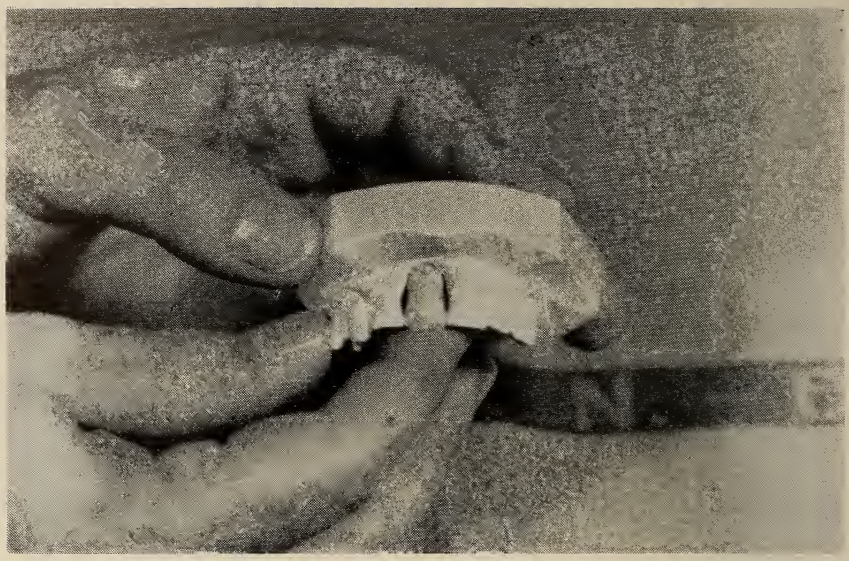
Educational Program. The in-service training opportunities were extended significantly this year by the initiation of a program

of postdoctoral research and study and the expansion of the offerings of the Graduate School to cover a wider segment of the Bureau's technical and supporting staff. The NBS Boulder Laboratories, through their Educational Committee, have also begun a program of graduate studies. Established in 1908, the Bureau's Graduate School is the oldest in-service training activity in the Government. The educational program, which has the cooperation of many universities, provided some 50 courses in the last year in which approximately 600 staff members participated. These courses were chosen to improve job efficiency or to prepare the staff for increased scientific and administrative responsibility in the near future.

During the past year a program for granting Postdoctoral Research Associateships at the National Bureau of Standards was announced and implemented. Under this program arranged jointly by the National Bureau of Standards, the Civil Service Commission, and the National Research Council-National Academy of Sciences, a small number of young scientists of exceptional ability and promise are selected each year for research and study. Selections are made by the National Research Council from a nationwide competition. Seven Associates were appointed under the program in the following fields: quantum chemistry, crystal structure, nuclear physics, physical chemistry, molecular structure and spectroscopy, mathematics, and statistical mechanics.

In applying for the postdoctoral positions, all applicants sought close association with particular NBS staff members. Also, several applicants expressed interest in using some of the Bureau's unusual equipment, such as the special solenoid for the very precise measurement of electrical quantities and the versatile SEAC digital computer.

International. The National Bureau of Standards, in exercising its authorized foreign exchange program and international intercomparison of standards, conducts visitor and training programs with many foreign scientists. The Bureau annually receives about 1,000 foreign scientific visitors, including technicians sponsored by many of the Government technical aid and educational exchange programs. Some of these visitors may spend considerable time in NBS laboratories as guest workers. These workers and the mem-



A new method for making porcelain jacket crowns was developed under the research associate plan and the foreign guest worker program. A color motion picture was produced to make the technique available to the dental profession.

bers of the Bureau staff who visit foreign institutions permit the Bureau to keep in close touch with scientific developments in other countries. Services to foreign countries take the form of tests, calibrations, and exchange of standards and publications. Also, national laboratories of other countries call on the Bureau for advice and assistance on specifications. As an example of the guest worker program, a foreign scientist working in the dental materials field has developed a new method of making procelain jacket crowns. A color motion picture film showing the details of the method was produced and will soon be available for loan to the dental profession throughout the world.

The 50th Jubilee Meeting of the International Electrotechnical Commission was held in the United States during September 1954. In addition to participation in its technical sessions, the Bureau, in cooperation with other local technical groups, planned a 2-day Washington program for over 200 IEC delegates, including a tour of NBS laboratories. Other international meetings in which staff members participated were those of the International Commission on Illumination, International Organization for Standards, International Union of Pure and Applied Physics, International Joint

Commission for Spectroscopy, International Union of Pure and Applied Chemistry, International Commission for Uniform Methods of Sugar Analysis, International Congress for Mathematicians, International Association on Dental Research, the Joint Commission on Radio Meteorology, International Scientific Radio Union, International Radio Consultative Committee, International Telecommunications Union, and the International Committee on Weights and Measures.

Members of the staff have been active in international as well as national planning for the International Geophysical Year (page 106), and in discussions and plans for national and international work of the International Scientific Radio Union (URSI), the International Radio Consultative Committee (CCIR), the International Astronomical Union, and the International Union of Geodesy and Geophysics. The XIIth General Assembly of URSI will be held at Boulder, Colorado, in the summer of 1957, with the NBS Boulder Laboratories serving as one of the host organizations.

5. Appendices

5.1. Organization of the National Bureau of Standards*

Allen V. Astin, *Director*

Associate Director for Chemistry
Wallace R. Brode

Associate Director for Physics
Robert D. Huntoon

Associate Director for Testing
A. T. McPherson

Associate Director for Planning
Nicholas E. Golovin

Assistant Director for Administration
R. S. Walleigh

Director Emeritus
Lyman J. Briggs

*As of September 1955.

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY AND ELECTRONICS

F. B. Silsbee, *Chief*

Resistance and Reactance — J. L. Thomas
Electron Tubes — C. P. Marsden, Jr.
Electrical Instruments — F. M. Defandorf
Magnetic Measurements — I. L. Cooter, Acting
Process Technology — L. P. Tuckerman
Engineering Electronics — G. Shapiro, Acting
Electronic Instrumentation — C. Stansbury
Electrochemistry — W. J. Hamer

OPTICS AND METROLOGY

I. C. Gardner, *Chief*

Photometry and Colorimetry — L. E. Barbrow
Optical Instruments — F. E. Washer
Photographic Technology — R. Davis
Length — L. V. Judson
Engineering Metrology — I. H. Fullmer

HEAT AND POWER

F. G. Brickwedde, *Chief*

Temperature Measurements — J. F. Swindells
Thermodynamics — C. W. Beckett
Cryogenic Physics — R. P. Hudson
Engines and Lubrication — P. M. Ku, Acting
Engine Fuels — F. L. Howard

ATOMIC AND RADIATION PHYSICS

L. S. Taylor, *Chief*

Atomic Physics Laboratory

Spectroscopy — W. F. Meggers
Radiometry — E. K. Plyler
Mass Spectrometry — F. L. Mohler
Solid State Physics — E. K. Plyler, Acting
Electron Physics — L. L. Marton
Atomic Physics — L. M. Branscomb, Acting
Radiation Physics Laboratory — H. O. Wyckoff
Nuclear Physics — U. Fano
Radioactivity — W. B. Mann
X-rays — H. O. Wyckoff
Betatron — H. W. Koch
Nucleonic Instrumentation — L. Costrell
Radiological Equipment — S. W. Smith
Radiation Instruments Branch, Atomic Energy Commission — R. L. Butenhoff

CHEMISTRY

E. Wichers, *Chief*

Organic Coatings	— P. T. Howard
Surface Chemistry	— J. I. Hoffman
Organic Chemistry	— W. H. Smith
Analytical Chemistry	— H. A. Bright
Inorganic Chemistry	— R. Gilchrist
Electrodeposition	— A. Brenner
Gas Chemistry	— E. R. Weaver
Physical Chemistry	— E. R. Smith
Thermochemistry	— E. J. Prosen
Spectrochemistry	— B. F. Scribner
Pure Substances	— C. P. Saylor

MECHANICS

W. Ramberg, *Chief*

Sound	— R. K. Cook
Mechanical Instruments	— E. C. Lloyd
Fluid Mechanics	— G. B. Schubauer
Engineering Mechanics	— B. L. Wilson
Mass and Scale	— D. R. Tate
Capacity, Density, and Fluid Meters	— H. S. Bean
Combustion Controls	— E. F. Fiock

ORGANIC AND FIBROUS MATERIALS

G. M. Kline, *Chief*

Rubber	— L. A. Wood
Textiles	— W. D. Appel
Paper	— R. B. Hobbs
Leather	— J. R. Kanagy
Testing and Specifications	— R. D. Stiehler
Polymer Structure	— N. Bekkedahl
Organic Plastics	— F. W. Reinhart
Dental Resarch	— W. T. Sweeney

METALLURGY

J. G. Thompson, *Chief*

Thermal Metallurgy	— T. G. Digges
Chemical Metallurgy	— L. L. Wyman
Mechanical Metallurgy	— J. A. Bennett
Corrosion	— G. A. Ellinger

MINERAL PRODUCTS

I. C. Schoonover, *Chief*

Porcelain and Pottery	— R. F. Geller
Glass	— C. H. Hahner
Refractories	— S. Zerfoss
Enameled Metals	— W. N. Harrison
Concreting Materials	— R. L. Blaine
Constitution and Microstructure	— H. F. McMurdie

BUILDING TECHNOLOGY

D. E. Parsons, *Chief*

Structural Engineering	— D. E. Parsons
Fire Protection	— A. F. Robertson
Heating and Air Conditioning	— R. S. Dill
Floor, Roof, and Wall Coverings	— H. R. Snoke
Codes and Specifications	— J. A. Dickinson

APPLIED MATHEMATICS

E. W. Cannon, *Chief*

Numerical Analysis	— J. Todd
Computation	— M. Abramowitz
Statistical Engineering	— C. Eisenhart
Mathematical Physics	— R. F. Dressler

DATA PROCESSING SYSTEMS

S. N. Alexander, *Chief*

Components and Techniques	— R. D. Elbourn
Digital Circuitry and Devices	— S. Greenwald (*acting*)
Digital Systems	— A. L. Liener
Analog Systems	— H. K. Skramstad (*acting*)

OFFICE OF PUBLICATIONS

Wallace R. Brode, *Chief*

OFFICE OF WEIGHTS AND MEASURES

W. S. Bussey, *Chief*

OFFICE OF BASIC INSTRUMENTATION

W. A. Wildhack, *Chief*

OFFICE OF TECHNICAL INFORMATION

W. R. Tilley, *Chief*

ADMINISTRATIVE DIVISIONS

Accounting — P. McClenon
Personnel — G. R. Porter
Administrative Services — H. P. Dalzell
Shops — F. P. Brown
Supply — G. B. Kefover
Management Planning Staff— Ivan Asay
Budget — W. W. Bolton, Jr.
Plant — C. A. Dieman

BOULDER LABORATORIES

F. W. Brown, *Director*

CRYOGENIC ENGINEERING

R. B. Scott, *Chief*

Cryogenic Equipment — B. W. Birmingham
Cryogenic Processes — P. C. Vander Arend
Properties of Materials— R. J. Corruccini
Gas Liquefaction — V. J. Johnson

RADIO PROPAGATION PHYSICS

R. J. Slutz, *Chief*

Upper Atmosphere Research — T. N. Gautier
Ionospheric Research (Wash.) — R. Bateman
Regular Propagation Services — W. B. Chadwick
Ionospheric Research (Boulder)— R. C. Kirby

RADIO PROPAGATION ENGINEERING

K. A. Norton, *Chief*

Frequency Utilization Research — W. Q. Crichlow
Tropospheric Propagation Research— J. W. Herbstreit

RADIO STANDARDS

H. A. Thomas, *Chief*

High Frequency Standards Branch— W. D. George
Microwave Standards Branch

ADMINISTRATIVE DIVISION— S. W. J. Welch

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

National Bureau of Standards, Boulder, Colo.
Cheyenne Mt. Field Station, Colorado Springs, Colo.
Standard Frequency Transmitter WWV, Beltsville, Md.
Standard Frequency Transmitter WWVH, Puuene Maui, T. H.
Radio Field Station, Ft. Belvoir, Va.
Radio Propagation Field Station, Sterling, Va.
Radio Propagation Field Stations

- Anchorage, Alaska
- Guam
- Narsarssuak, Greenland
- Panama Canal Zone
- Point Barrow, Alaska
- Puerto Rico
- Puuene Maui, T. H.
- Gunbarrel Hill, Longmont, Colo.
- Front Royal, Va.

Lamp Inspector, Brookline 46, Mass.
Master Railway Track Scale Depot, Clearing, Ill.
Materials Testing Laboratores

- Allentown, Pa.
- Denver, Colo.
- San Francisco, Calif.
- Seattle, Wash.

5.2. Fiscal Data on NBS Program

PROGRAM AND SOURCE OF FINANCING	Obligations Incurred Fiscal Year 1955
SUPPORTED BY NBS APPROPRIATIONS	
Operating Programs:	
Research and Testing	3,207,618
Radio Propagation and Standards	2,088,165
Operation and Administration	740,000
Total	6,035,783
Construction and Facilities Programs:	
Operation and Administration	234,598
Construction of Laboratories	304,950
Total	539,548
Total, NBS Appropriations	6,575,331
SUPPORTED BY OTHER AGENCIES	
Department of Defense and AEC	11,928,000
Other Agencies	1,483,100
Total, Other Agencies	13,411,100
Total Program	19,986,431

5.3. Advisory Committees

STATUTORY VISITING COMMITTEE

[Reports annually to Secretary of Commerce on NBS activities (Dates indicate expiration of appointment.)]

Professor J. H. Van Vleck, Dean, Division of Applied Science, Harvard University (1956)
Dr. M. J. Kelly, President, Bell Telephone Laboratories, Inc. (1957)
Dr. Clyde E. Williams, President, Battelle Memorial Institute (1958)
Dr. Crawford H. Greenewalt, President, E. I. du Pont de Nemours & Co. (1959)
Dr. Detlev W. Bronk, President, National Academy of Sciences (1960)

NBS TECHNICAL ADVISORY COMMITTEES

[Designated by leading scientific and technical societies to advise NBS Director in specific technical areas.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Dr. C. G. Suits, General Electric Company
Dean F. E. Terman, Stanford University
Dr. E. W. Engstrom, Radio Corporation of America
Mr. Robert C. Sprague, Sprague Electric Company
Dr. Ralph Bown, Bell Telephone Laboratories
Dr. J. A. Hutcheson, Westinghouse Electric Corporation

INSTITUTE OF RADIO ENGINEERS

Dr. A. W. Straiton, University of Texas
Dean F. E. Terman, Stanford University
Professor Henry G. Booker, Cornell University
Mr. Harold O. Peterson, Radio Corporation of America
Mr. Stuart L. Bailey, Jansky & Bailey
Dean William L. Everitt, University of Illinois

AMERICAN INSTITUTE OF PHYSICS

Professor F. Seitz, University of Illinois
Professor D. M. Dennison, University of Michigan
Dr. E. M. Purcell, Harvard University
Professor J. A. Bearden, Johns Hopkins University
Dr. M. Deutsch, Massachusetts Institute of Technology
Dr. Hale Sabine, Celotex Corporation
Professor R. B. Lindsay, Brown University
Dean R. A. Sawyer, University of Michigan
Professor Cecil T. Lane, Yale University
Professor Mark W. Zemansky, City College of New York
Professor A. O. C. Nier, University of Minnesota
Dr. L. D. Marinelli, Argonne National Laboratory

POLICY COMMITTEE FOR MATHEMATICS

Dean Mina Rees, Hunter College
Professor Philip M. Morse, Massachusetts Institute of Technology.
Dr. Edward Teller, University of California

Professor David Blackwell, Howard University
Professor A. H. Taub, University of Illinois
Professor Mark Kac, Cornell University
Dr. E. U. Condon, Berkeley, California

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

Dr. Walter A. Dean, Aluminum Company of America
Mr. Earle E. Schumacher, Bell Telephone Laboratories
Dr. Maxwell Gensamer, Columbia University
Mr. Clarence E. Sims, Battelle Memorial Institute
Dr. E. C. Smith, Republic Steel Corporation
Dr. Cyril S. Smith, University of Chicago

AMERICAN CHEMICAL SOCIETY

Professor N. Howell Furman, Princeton University
Professor C. S. Marvel, University of Illinois
Dr. Milton Harris, Harris Research Laboratories
Dr. C. F. Rassweiler, Johns Manville Corporation
Dr. J. R. Ruhoff, Mallinckrodt Chemical Works
Dr. Norman A. Shepard, Stamford, Conn.
Professor Farrington Daniels, University of Wisconsin

AMERICAN CERAMIC SOCIETY

Mr. Ray Birch, Harbison-Walker Refractories Company
Dr. K. C. Lyon, Indiana Glass Company
Mr. E. P. McNamara, Cambridge Tile Company
Dean Elburt Osborn, Pennsylvania State University
Mr. Wayne Deringer, A. O. Smith Corporation
Dr. Allan Bates, Portland Cement Association
Dr. A. C. Siefert, Owens-Corning Glass Corporation
Mr. Joe W. Kruson, Big Savage Refractories Corporation

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mr. James W. Parker, Ann Arbor, Michigan
Professor Dana Young, Yale University
Professor S. R. Beitler, Ohio State University
Professor C. Harold Berry, Harvard University
Mr. Paul V. Miller, Taft Pierce Manufacturing Company

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

Mr. John P. McBride, Director of Standards and Necessaries of Life, Boston, Mass.
Mr. W. M. Harks, Bowser Inc.
Mr. Bruns H. Dreese, Hobart Manufacturing Company
Mr. Alvin V. Hokanson, National Association of Retail Grocers
Mr. Charles M. Fuller, Sealer of Weights and Measures, Los Angeles, California
Mr. Harry J. Kennedy, Continental Oil Company
Mr. Seth T. Shaw, Safeway Stores, Inc.
Mr. C. J. McCaffrey, Ralph N. Brodie Company, Inc.

AMERICAN SOCIETY OF CIVIL ENGINEERS

Dr. G. H. Hickox, National Science Foundation
Dr. A. T. Ippen, Massachusetts Institute of Technology
Mr. Raymond C. Reese, Toledo, Ohio

AMERICAN STANDARDS ASSOCIATION

Mr. Roger E. Gay, The Bristol Brass Corporation
Mr. John R. Townsend, Sandia Corporation
Mr. Arthur S. Johnson, American Mutual Liability Insurance Company
Vice Admiral G. F. Hussey, Jr., USN (Ret), American Standards Association
Mr. Cyril Ainsworth, American Standards Association

AMERICAN SOCIETY FOR TESTING MATERIALS

Mr. Norman L. Mochel, Westinghouse Corporation
Dr. A. Allan Bates, Portland Cement Association
Mr. T. A. Boyd, General Motors Corporation
Mr. Aiken W. Fisher, Fisher Scientific Company
Mr. R. E. Peterson, Westinghouse Research Laboratories

5.4. Awards and Honors

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from academic, industrial, and professional groups. The following list reflects such recognition bestowed on Bureau staff members during the fiscal year 1955.

RECIPIENT	HONOR	SOURCE
Bean, Howard S.	Worcester Reed Warner Medal	American Society of Mechanical Engineers
Blandford, Josephine M.	Certificate of Achievement	University of Maryland, Alumni Board of Home Economics Assn.
Brode, Dr. Wallace R.	Honorary Doctor of Science degree.	Whitman College, Walla Walla, Wash.
Davis, Dr. Philip	Awarded Fellowship	John Simon Guggenheim Memorial Foundation.
Davis, Raymond	Awarded Fellowship	Society of Photographic Engineers.
Dental Research Section Film, "Hazards of Dental Radiography"	Awarded Second Place	International Exhibition of Cinematographic Art in Venice, Italy.
Gardner, Dr. I. C.	Frederic Ives Medal	Optical Society of America
Gibson, Dr. K. S.	Elected to Fellow	Illuminating Engineering Society
Hamer, Dr. W. H., and Craig, Dr. D. N.	First Prize for Outstanding Paper, 1954	American Institute of Electrical Engineers
Kanagy, Dr. J. R.	Awarded $1,000 for Best Paper on Leather	American Leather Chemists Assn.
Norton, K. A.	The Stuart Ballantine Award for 1954	Franklin Institute
Paffenbarger, Dr. G. C. (Research Associate, ADA)	1955 Award of Merit	Georgetown University School of Dentistry
Sweeney, W. T.	Honorary Membership	American Dental Assn.
Taylor, L. S.	Annual Gold Medal	Radiological Society of North America
Thompson, G. N.	Award of Merit	American Society of Testing Materials
Valore, R. C.	Wason Medal	American Concrete Institute

HONORED BY U. S. DEPARTMENT OF COMMERCE

RECIPIENT	HONOR	FIELD OF WORK
Altman, A. J.	Meritorious Service Award	Instrument Development
Costrell, Louis	Meritorious Service Award	Nucleonic Instrumentation
Davis, Dr. Marion M.	Meritorious Service Award	Physical Chemistry
Gardner, Dr. I. C.	Exceptional Service Award	Optics
Hagaman, Earle M.	Meritorious Service Award	Photometry & Colorimetry
Harris, Dr. F. K.	Meritorious Service Award	Electrical Measurements
Kiess, Dr. C. C.	Exceptional Service Award	Spectroscopy
Marton, Dr. L. L.	Exceptional Service Award	Electron Physics
McIntosh, Jessie H.	Meritorious Service Award	Chemistry Administration
Parsons, D. E.	Exceptional Service Award	Building Technology
Pendergast, W. L.	Meritorious Service Award	Refractories
Shartsis, L.	Meritorious Service Award	Research on Glass
Shelton, Dr. G. R.	Meritorious Service Award	Ceramics Research
Weissberg, Dr. S. G.	Meritorious Service Award	Polymer Structure

Recognition in the form of Superior Accomplishment Pay Increase Awards was given 81 Bureau employees. Twenty-three employees were recipients of cash awards for suggestions adopted by the Bureau.

5.5. Publications

Publications in the Bureau's Series

Journal of Research. The *Journal*, issued monthly, presents research papers in various fields of physics, mathematics, chemistry, metallurgy, and the engineering sciences. (Annual subscription: domestic, $4.00; $1.25 additional for foreign mailing.) Research Papers published from July 1954 to June 1955, inclusive:

Volume 53, July—December 1954

2510. Correlation of polarized light phenomena with the orientation of some metal crystals. C. J. Newton and H. C. Vacher.
2511. Separation of iodide, bromide, and chloride from one another and their subsequent determination. Thomas J. Murphy, W. Stanley Clabaugh, and Raleigh Gilchrist.
2512. Relative humidity-temperature relationships of some saturated salt solutions in the temperature range 0° to 50° C. Arnold Wexler and Saburo Hasegawa.
2513. Disintegration rate of carbon-14. R. S. Caswell, J. M. Brabant, and A. Schwebel.
2514. Testing of large optical surfaces with small test plates. James B. Saunders.
2515. Bacher and Goudsmit theory of complex spectra. R. E. Trees.
2516. Self-ignition temperatures of combustible liquids. Nicholas P. Setchkin.
2517. Delta ferrite-austenite reactions and the formation of carbide, sigma, and chi phases in 18 chromium-8 nickel-3.5 molybdenum steels. H. C. Vacher and C. J. Bechtoldt.
2518. Determination of hydrogen by slow combustion over platinum in excess oxygen. Shuford Schuhmann and Martin Shepherd.
2519. Anhydrous sodium hydroxide: the heat content from 0° to 700° C., the transition temperature, and the melting point. Thomas B. Douglas and James L. Dever.
2520. Heat content of molybdenum disilicide from 0° to 900° C. Thomas B. Douglas and William M. Logan.
2521. Precise comparison method of testing alternating-current watt-hour meters. A. W. Spinks and T. L. Zapf.

2522. Mass spectra of the deuteroethylenes. Vernon H. Dibeler, Fred L. Mohler, and M. de Hemptinne.
2523. Spectral distribution of energy from the sun. Ralph Stair, Russell G. Johnston, and Thomas C. Bagg.
2524. Factors affecting the thermal stability of polytetrafluoroethylene. R. E. Florin, L. A. Wall, D. W. Brown, L. A. Hymo, and J. D. Michaelsen.
2525. Optical rotations, refractive indices, and densities of dextran solutions. C. F. Snyder, H. S. Isbell, M. R. Dryden, and N. B. Holt.
2526. Calorimetric properties of normal heptane from 0° to 520° K. Thomas B. Douglas, George T. Furukawa, Robert E. McCoskey, and Anne F. Ball.
2527. Sensitivity—a criterion for the comparison of methods of test. J. Mandel and R. D. Stiehler.
2528. Infrared emission spectra of cyanide and dicarbon radicals. W. S. Benedict and Earle K. Plyler.
2529. Refractivity measurements on thick plates. James B. Saunders.
2530. Installation for adiabatic demagnetization experiments at the National Bureau of Standards. D. de Klerk and R. P. Hudson.
2531. Index of refraction of fused-quartz glass for ultraviolet, visible, and infrared wavelengths. William S. Rodney and Robert J. Spindler.
2532. New experimental designs for paired observations. W. J. Youden and William S. Connor.
2533. Application of infrared spectroscopy to the determination of impurities in titanium tectrachloride. Rolf B. Johannesen, Charles L. Gordon, James E. Stewart, and Raleigh Gilchrist.
2534. Some properties of porcelains and phase relations in the ternary systems of beryllia and zirconia with titania, ceria, and chromia. S. M. Lang, R. S. Roth, and C. L. Fillmore.
2535. Effects of recent knowledge of atomic constants and of humidity on the calibrations of the National Bureau of Standards thermal-radiation standards. Ralph Stair and Russell G. Johnston.
2536. Synthesis of D-galactose-1-C^{14} and D-talose-1-C^{14}. Horace S. Isbell, Harriet L. Frush, and Nancy B. Holt.
2537. Determination of carbon-14 in solutions of C^{14}-labeled materials by means of a proportional counter. A. Schwebel, H. S. Isbell, and J. D. Moyer.
2538. Extension of the arc spectra of palladium and platinum (6500 to 12000 A). Karl G. Kessler, William F. Meggers, and Charlotte E. Moore.
2539. Influence of molecular shape on the dielectric constant of polar liquids. F. Buckley and A. A. Maryott.
2540. Temperature dependence of compression of linear high polymers at high pressures. Charles E. Weir.
2541. Turbulent flow in shock tubes of varying cross section. Robert F. Dressler.
2542. Separation of titanium, tungsten, molybdenum, and niobium by anion exchange. John L. Hague, Eric D. Brown, and Harry A. Bright.
2543. Vapor pressure of nitrogen. George T. Armstrong.
2544. Comparison of four national radium standards.
Part 1. Experimental procedures and results. T. I. Davenport, W. B. Mann, C. C. McCraven, and C. C. Smith.
Part 2. Statistical procedures and survey. W. S. Connor and W. J. Youden.
2545. A radiation balance for the macrocalorimetric comparison of four national radium standards. W. B. Mann.
2546. Standard potential of the silver–silver-chloride electrode from 0° to 95° C and the thermodynamic properties of dilute hydrochloric acid solutions. Roger G. Bates and Vincent E. Bower.

2547. The gold-uranium system. R. W. Buzzard and J. J. Park.
2548. A study of absolute standards of mutual inductance and in particular the three-section National Bureau of Standards type. Frederick W. Grover.
2549. The deuterium-sulfide band at 4,590 cm^{-1}. Harry C. Allen, Jr., Robert E. Naylor, and Earle K. Plyler.
2550. Synthesis of α-D-xylose-1-C^{14} and β-D-lyxose-1-C^{14}. H. S. Isbell, H. L. Frush, and N. B. Holt.
2551. Creep of high-purity nickel. William D. Jenkins, Thomas G. Digges, Carl R. Johnson.
2552. Determination of nickel, manganese, cobalt, and iron in high-temperature alloys, using anion-exchange separations. John L. Hague, Edwin E. Maczkowske, and Harry A. Bright.
2553. Thermal degradation of polymers as a function of molecular structure. S. L. Madorsky and S. Straus.
2554. Some properties of strontium hydroxide and its monohydrate. Elmer T. Carlson.
2555. Refractivity measurements on Canada balsam by interferometry. James B. Saunders.
2556. Bounds on a distribution function that are functions of moments to order four. Marvin Zelen.
2557. Aerological sounding balloons. Gordon M. Martin, John Mandel, and Robert D. Stiehler.
2558. Plate-separation requirements for standard free-air ionization chambers. Frank H. Attix and LeRoy DeLaVergne.

Volume 54, January—June 1955

2559. Calibration of meter line standards of length at the National Bureau of Standards. Benjamin L. Page.
2560. Enthalpy and specific heat of four corrosion-resistant alloys at high temperatures. Thomas B. Douglas and James L. Dever.
2561. Effect of temperature on the tensile properties of a commercial and a high purity 70-percent-nickel—30-percent-copper alloy. William D. Jenkins, Thomas G. Digges, and Carl R. Johnson.
2562. The system lime-water at 21° C and high pressures. Charles E. Weir.
2563. Absorption of radiant energy by solid particles in suspension. James E. Stewart.
2564. Branching ratio in the decay of polonium-210. R. W. Hayward, D. D. Hoppes, and W. B. Mann.
2565. Mechanism of high-speed-waterdrop erosion of methyl methacrylate plastic. Olive G. Engel.
2566. Geometric factors in electrical measurements relating to corrosion and its prevention. W. J. Schwerdtfeger and Irving A. Denison.
2567. Pore-size distribution in collagen and leather by the porosimeter method. Robert R. Stromberg.
2568. Collagen pores determined by electron microscopy. Max Swerdlow and Robert R. Stromberg.
2569. Effect of low temperatures on the mechanical properties of a commercially pure titanium. Glenn W. Geil and Nesbit L. Carwile.
2570. Reactions at wet-dry interfaces on fibrous materials. Robert Schaffer, Wm. D. Appel, and Florence H. Forziati.
2571. Scintillation spectrometry of low-energy bremsstrahlung. Margarete Ehrlich.
2572. A method for the numerical integration of differential equations of second order without explicit first derivatives. Rene de Vogelaere.

2573. Selected positive and negative ions in the mass spectra of the monohalomethanes. Vernon H. Dibeler and Robert M. Reese.
2574. Variation in distortion with magnification. Arthur A. Magill.
2575. Heats of combustion and isomerization of six pentadienes and spiropentane. Frances Maron Fraser and Edward J. Prosen.
2576. Solid-state reactions and dielectric properties in the system magnesia-lime-tin oxide-titania. L. W. Coughanour, R. S. Roth, S. Marzullo, and F. E. Sennett.
2577. Chromatographic method for the fractionation of asphalt into distinctive groups of components. Lawrence R. Kleinschmidt.
2578. Nature of stark rubber. Donald E. Roberts and Leo Mandelkern.
2579. Partially balanced incomplete block designs with two associate classes and two treatments per block. Willard H. Clatworthy.
2580. Solid-state reactions and dielectric properties in the systems magnesia-zirconia-titania and lime-zirconia-titania. L. W. Coughanour, R. S. Roth, S. Marzullo, and F. E. Sennett.
2581. Synthesis of α-D-glucose-2-C^{14}, α-D-mannose-2-C^{14}, and α-D-galactose-2-C^{14}. Horace S. Isbell, Harriet L. Frush, and Robert Schaffer.
2582. The system of lime, silica, and water at 180° C. Richard B. Peppler.
2583. An algorithm for solving the transportation problem. A. Gleyzal.
2584. An X-ray study of the system uranium monocarbide-uranium dicarbide-beryllium carbide. M. D. Burdick, H. S. Parker, R. S. Roth, and E. L. McGandy.
2585. An analysis of within-the-hour fading 100- to 1,000-Mc transmissions. H. B. Janes.
2586. Astigmatism of skew pencils in optical systems containing toric surfaces. Walter Weinstein.
2587. Osculatory interpolation in the complex plane. Herbert E. Salzer.
2588. Macromethods for reducing aldonic lactones to sugars: the preparation of L-glucose. Harriet L. Frush and Horace S. Isbell.
2589. Stress-strain relationships in yarn subjected to rapid impact loading: 1. Equipment, testing procedure, and typical results. Walter K. Stone, Herbert F. Schiefer, and George Fox.
2590. Stress-strain relationships in yarns subjected to rapid impact loading: 2. Breaking velocities, strain energies, and theory neglecting wave propagation. Frank L. McCrackin, Herbert F. Schiefer, Jack C. Smith, and Walter K. Stone.
2591. Waterdrop collisions with solid surfaces. Olive G. Engel.
2592. Effect of Darling-Dennison and Fermi resonance on the thermodynamic functions. Harold W. Woolley.
2593. Titrations of bases with diphenyl phosphate in some aqueous and non-aqueous solvents. Marion Maclean Davis and Hanna B. Hetzer.
2594. An improved method of measuring efficiencies of ultra-high-frequency and microwave bolometer mounts. R. W. Beatty and Frank Reggia.
2595. A study of some strontium aluminates and calcium-strontium aluminate solid solutions. Elmer T. Carlson.
2596. A measurement of the velocity of propagation of very-high-frequency radio waves at the surface of the earth. Edwin F. Florman.
2597. A study of the system magnesium oxide-magnesium chloride-water and the heat of formation of magnesium oxychloride. Edwin S. Newman.
2598. Dielectric relaxation for spherical molecules in a crystalline field: Theory for two simple models. John D. Hoffman and Benjamin M. Axilrod.

Technical News Bulletin. Summaries of current research at the Bureau are published each month in the *Technical News Bulletin.* Lists of Bureau publications during the preceding month are given. (Annual subscription: domestic, $1.00; 35 cents additional for foreign mailing.)

Basic Radio Propagation Predictions. The *Predictions* provide the information necessary for calculating the best frequencies for communication between any two points in the world at any time during the given month. The data are important to all users of long-range radio communications and navigation, including broadcasting, airline, steamship, and wireless services, as well as to investigators of radio propagation and the ionosphere. Each issue, covering a period of 1 month, is released 3 months in advance and contains 16 pages, including pertinent charts, drawings, and tables. (Annual subscription: domestic, $1.00; 25 cents additional for foreign mailing.)

Circulars. Compilations of information on various subjects related to the Bureau's scientific and technical activities. Results of Bureau studies and data of general interest from other sources are included.

539. Volume IV. Standard X-ray Diffraction Powder Patterns. Howard E. Swanson, Ruth K. Fuyat, and George M. Ugrinic.
544. Formulas for Computing Capacitance and Inductance. Chester Snow.
547. Section 1. Precision Laboratory Standards of Mass and Laboratory Weights. T. W. Lashof and L. B. Macurdy.
548. Miniature Intermediate-Frequency Amplifiers. Robert K–F Seal.
549. Computation of Achromatic Objectives. Robert E. Stephens.
550. Mechanical Failures of Metals in Service. John A. Bennett and Willard Quick.
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554. Cheyenne Mountain Tropospheric Propagation Experiments. A. P. Barsis, J. W. Herbstreit, and K. O. Hornberg.
555. Testing of Hydrometers. J. C. Hughes.
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558. Bibliography and Index on Dynamic Pressure Measurement. W. G. Brombacher and T. W. Lashof.
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57. Photographic Dosimetry of X- and Gamma Rays. Margarete Ehrlich.
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