RESEARCH HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

ANNUAL REPORT 1958

Errata to Accompany Miscellaneous Publication M226

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January 30, 1959

USCOMM-NBS-DC

UNITED STATES DEPARTMENT OF COMMERCE
Lewis L. Strauss, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

Research Highlights
of the
National Bureau
of Standards

Annual Report, Fiscal Year 1958

December 1958

Miscellaneous Publication 226

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 45 cents

The National Bureau of Standards, Washington, D. C., laboratories (top) and Boulder, Colorado, laboratories (bottom).

Contents

1. General Review

During this past year the National Bureau of Standards was encouraged to examine its programs and responsibilities critically and to estimate its needs in meeting modern requirements for standards, measurement techniques, and data on the properties of materials.

For some time, the Bureau had called attention to the rapid advancement of technology and to expansion of research noting that these changes have placed a strong burden upon NBS—a responsibility to enlarge its technical programs in support of growing national scientific activities. In the past year, the Bureau received added support from the Congress and from the Administration to strengthen its capability for leadership in the science of physical measurement.

The responsibility for the Nation's fundamental standards of measurement demands a continuous search for new scientific knowledge and for improved measurement processes. As new areas of science and technology become active or productive, new standards must be developed, adequate measurement methods established, new instrumentation devised, and appropriate calibration services provided. All this must be done while advancing the established areas of measurement and in such a manner as to maintain and insure continued consistency and coherence within the whole complex chain of measurement.

The work is basic to the measurement, understanding, and control of physical phenomena. This is especially true in relation to the exploration of new aspects of the physical world. For this reason, it is essential that NBS technical programs be as modern as contemporary scientific research.

This report highlights some of the Bureau's activities during 1958. It will describe in varying detail a wide range of scientific studies, laboratory experiments, instrument developments, and technical publications. However varied these technical programs may seem, they have this in common: they contribute to the improvement of the measurement sciences. This is an area of broad import. Even if the details of all Bureau projects of 1958 could be presented in this report, they would represent only that area of the Bureau's total responsibility which could be implemented for that year. Thus the program is always a selection of technical projects of highest relevance to current technological need.

Because the Bureau's responsibilities are so broad yet so directly important to science and the national economy, it may be well to summarize in this introduction these responsibilities, as defined by the Congress:

> (1) Development and maintenance of the national standards of measurement, and the provision of means for making measurements consistent with those standards;

(2) determination of physical constants and properties of materials;

(3) development of methods for testing materials, mechanisms, and structures, and the making of such tests as may be necessary, particularly for government agencies;

(4) cooperation in the establishment of standard practices, incorporated in codes and specifications;

(5) advisory service to government agencies on scientific and technical problems; and

(6) invention and development of devices to serve special needs of the government.

Technical Activities

The following paragraphs briefly summarize some of the more important accomplishments of the technical program during fiscal 1958. As in previous years, the program was concerned primarily with the development and improvement of standards and methods of physical measurement. A second major focus of activity was the precise determination of fundamental physical constants and the basic properties of materials. More complete details of the research and development projects discussed below may be found in section 2, page 11 et seq.

Standards and Measurement Methods. In work directed toward improved *electrical standards*, apparatus was developed which markedly increases sensitivity and precision in the precise intercomparison of small capacitors. To realize fully the advantage provided by this apparatus, an improved standard of capacitance, based on a theorem in electrostatics recently published in Australia, was constructed. The design of this standard permits its value to be calculated in terms of a single measured length to an accuracy of about 3 parts per million.

Efforts continued to improve *pressure calibration techniques* throughout the pressure range. For static calibrations at high pressures (up to 200,000 lb/in.^{2}) piston gages were further developed, and the characteristics of air-lubricated piston gages were investigated for use as standards in the range of differential pressures from those presently covered by mercury columns up to several hundred pounds per square inch.

Under sponsorship of the Air Force, work was completed on a mercury U-tube standard for calibration of instruments over the pressure range corresponding to high altitudes. In work on dynamic pressure calibrations sponsored by the Department of Defense, an improved shock tube was developed and placed in operation providing step pressures up to 1,000 lb/in.^{2}

High-temperature measurements also received emphasis. Research was conducted to increase the accuracy of pyrometer calibrations at temperatures between 2,500° and 4,000° C. Zirconium and carbon arcs were adapted for calibration use to permit direct observations up to about 3,800° C.

Progress was made in developing an *atomic beam source* of mercury radiation whose wavelength may provide a very accurate means of measuring length. The *dielectric constant of heavy water* was experi-

mentally determined from 0° to 100° C. The certification of the Bureau's *pH standards*, formerly available for the temperature range from 0° to 60° C, was extended to 95° C to meet the requirements of *pH* control in many industrial processes.

Studies were conducted to improve methods of *determining molecular weights*. For this program an absolute photometer was designed and built to measure precisely the light scattered by solutions of polymers. With data obtained with this instrument, more reliable values can be determined for molecular weights and radii of molecules.

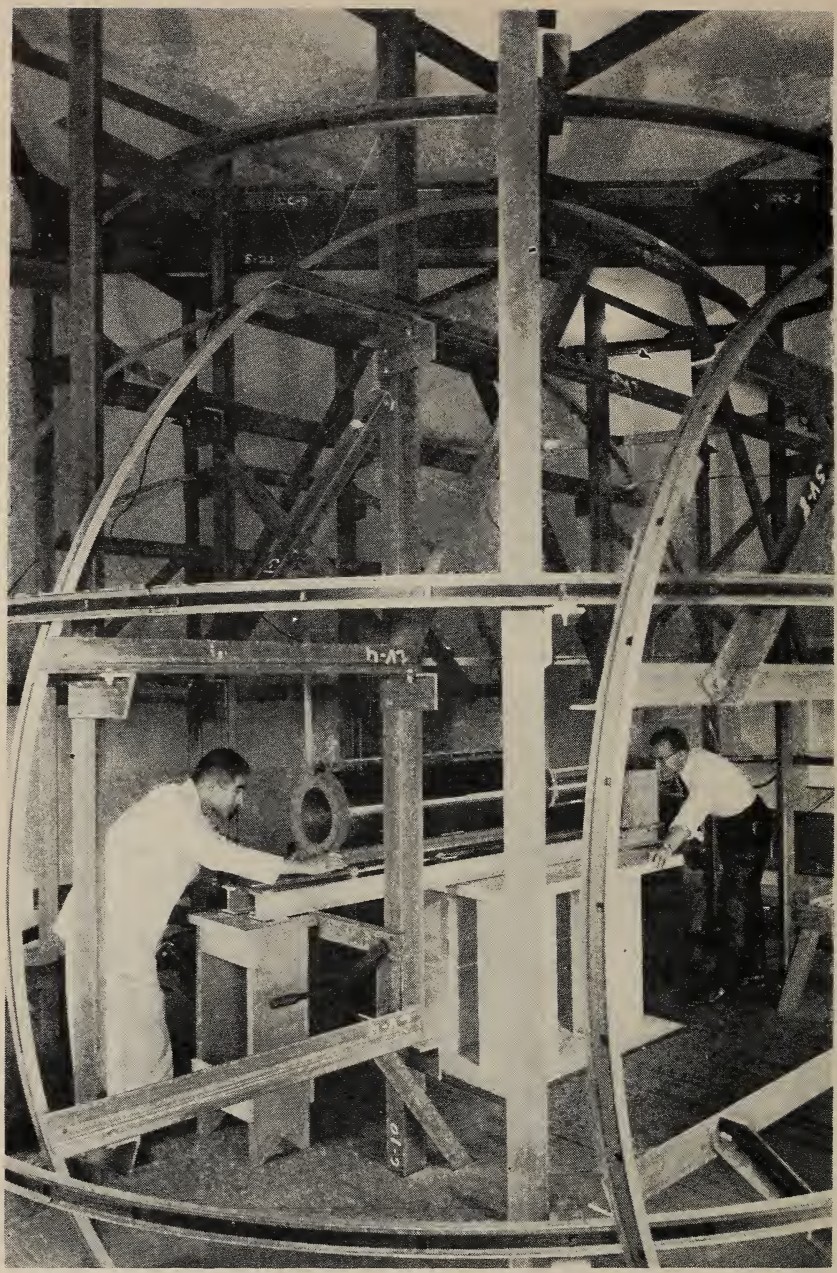
Recent developments in rocketry, jet propulsion, and high-speed turbines have increased the need for accurate *vibration measurements* at very high acceleration levels. To meet this need, a method was developed for calibrating lightweight vibration pickups at acceleration levels more than 1,000 times the acceleration of gravity, over the frequency range from 500 to above 10,000 cycles per second.

Further progress was made in a research program on *high-precision gage blocks* which is partially supported by industry. This program seeks regular methods for calibrating industry's master gage blocks to an accuracy of 1 part in 10 million. These gage blocks, which ultimately control the tolerances of mass-produced machine parts, are now calibrated at the Bureau to an accuracy of 1 part in 1 million, that is, to the nearest millionth of an inch for inch-long blocks. However, American machine tool manufacturers have requested an even higher degree of accuracy in gage-block calibration in order to keep pace with the needs of the aircraft and other industries.

In 1958 emphasis in this project was shifted from the development of improved measuring instruments to the application of these instruments to the development of more precise gage blocks. Studies were made of the suitability of different steels for constructing the blocks. Optimum conditions were also established for heat-treating and stabilizing several of the steels commonly used for gage blocks.

Physical Constants. An important advance in the field of physical constants was the redetermination of the *gyromagnetic ratio of the proton*. By measuring the precession rate of protons in a magnetic field, a preliminary value of $(2.67515 \pm 0.00001) \times 10^4$ radians/(sec gauss) was obtained. However, when combined with a recent determination of the ampere at the Bureau in absolute units, the value becomes $(2.67513 \pm 0.00002) \times 10^4$ radians/(sec gauss).

As this value is considerably more accurate than the earlier one obtained in 1949, it should make possible more accurate values for many of the fundamental constants of physics such as the electron charge-to-mass ratio e/m, the magnetic moment of the proton, and Planck's constant h. The new value will also be useful in the design and development of scientific and industrial apparatus (e. g., cyclotrons, servo mechanisms) in which it is important to know accurately the spatial distribution of a magnetic field or to regulate it closely.



Apparatus used to redetermine the gyromagnetic ratio of the proton. The new value will make possible more accurate determination of many of the fundamental constants of physics, and will provide a better standard for magnetic fields (pages 3, 31).

Another fundamental constant investigated during the year was the *faraday*. For several years the Bureau has been engaged in research to determine a more accurate value for this constant. In 1958 the work had progressed to the point that a provisional value of 96,523 coulombs per gram equivalent on the physical scale could be given. This value agrees within 1 part in 100,000 with the average value determined at the Bureau on the omegatron (a miniature cyclotron) in 1953.

Properties of Matter and Materials. A number of techniques were developed for determining very small amounts of impurities in materials.

At the request of the Diamond Ordnance Fuze Laboratories, Department of the Army, procedures were devised for detecting small amounts of impurities in *barium titanate*. Because of its piezoelectric properties, pure barium titanate is of considerable interest in the field of communications. A photometric method for the determination of *tungsten* in steel and in titanium alloys was completed, and flame photometry was successfully applied to the determination of *sodium*, *potassium*, *calcium*, and *strontium* in the presence of other alkali and alkaline earth ions. In work sponsored by the Office of Naval Research, an improved procedure was developed and used to prepare very pure *halides of titanium*.

Although *sulfur* has been known since ancient times, accurate data on many of its properties have been lacking, largely because it is difficult to purify and exists in many crystallographic forms. During the year 99.999-percent pure sulfur was used to make accurate measurements of the heat capacity of this element. These data should aid in predicting the reactions of sulfur and its compounds at high temperatures, as in petroleum refining.

Volume III of "Atomic Energy Levels" was published and distributed. This volume included analyses of optical spectra of the elements Molybdenum through Lanthanum (Z=42 through 57) and Hafnium through Actinium (Z=72 through 89).

In work sponsored by the Navy Bureau of Aeronautics, the "plasma jet," an electrical source for exciting the spectra of materials, was developed. This source, which has been applied to the analysis of *stainless steel*, shows considerable promise for the determination of the major constituents of complex alloys.

Isotopically *labeled carbohydrates* provide a powerful tool for probing the mysteries of biological chemistry. Development of methods for synthesizing sugars and related compounds position labeled with carbon-14, which has been sponsored by the Atomic Energy Commission, was continued and extended to tritium-labeled compounds. Procedures were developed for the production of a variety of tritium-labeled compounds and for their convenient analysis.

Basic *thermodynamic data* are required for the design and performance evaluation of such equipment as gas turbines and jet and rocket engines, and in the solution of many aerodynamic, astrophysical, and astronautical problems. In 1958 high-speed automatic computing techniques were

developed to extend such data over a wide range of temperature and density. These techniques were applied to a systematic generation of extensive tables of ideal-gas thermal functions of atoms, molecules, and their ions.

Studies of the thermochemical properties of *boron compounds*—of particular interest in the search for high-energy fuels—were continued under the sponsorship of the Navy Bureau of Aeronautics. Mass-spectrometric methods were utilized to determine the energies of the chemical bonds between boron and other atoms.

In a program on *statistical thermodynamics*, significant progress was made in the development and application of theoretical methods to such problems as quantum effects on surface tension of simple liquids; isotope effects on the compressibilities of isotopic hydrogens; statistical mechanical description of the transport, equilibrium, and magnetic properties of electron gases; molecular orbital calculations of the H_3 molecule; and partition-function representation of atoms and atomic ions to 1,000,000°K, and molecules and molecule ions to 25,000°K.

The development of new and improved *textiles* has made necessary a continuing effort to devise adequate analytical methods for these products. During the year a rapid, convenient method was developed for identifying the components of very small specimens of finished and coated textiles. The method is also applicable to related materials such as coated papers, adhesives, and plastics.

The stability of *polyvinyl chloride* and its copolymers has been a major problem to the plastics industry. These polymers are sensitive to heat, sunlight, and traces of metals. An investigation showed the mechanism of decomposition to be a free radical chain reaction. This result provided a basis for the selection of stabilizers on a rational rather than an empirical basis.

Applied Mathematics. Work in applied mathematics was principally concerned with the solution of problems in numerical analysis and certain areas of mathematical physics, in the compilation of specialized mathematical tables, and in the application of modern statistical inference to problems of experimental design and sampling.

In *numerical analysis* significant progress was made in the development of eigenvalue theory for differential operators. Other projects dealt with such topics as numerical integration of periodic and analytic functions, calculation of the best (Chebyshev) polynomial approximation to a given function, testing of matrix codes, and location of the eigenvalues of matrices.

Research in *mathematical physics* was concentrated principally on the continuum mechanics of elastic and fluid media, magnetogasdynamics, the theory of orbits, and mathematical analysis related to problems in mathematical physics. In fluid mechanics, the Stokes flow problem was solved for several axi-symmetric bodies not hitherto considered, and

certain new theorems in the theory of Stokes flows were proven. An exact solution of the problem of the unsteady water wave in a straight channel of arbitrary slope was given. Previously, only numerical solutions of this type of problem have been available. Also completed was an analysis of bending and stretching of corrugated diaphragms, with important applications in the field of instrumentation.

Statistical studies of the *reliability of components* and assemblies led to the formulation of mathematical models for the analysis of experiments on the aging of components, and methods of estimating pertinent parameters were worked out. This work, which is applicable to a variety of aging studies, formalized and improved methods of analysis that had previously been based on intuitive grounds.

Work was begun on a *Handbook of Mathematical Functions*. When completed, the volume will cover the entire field of special functions and will contain mathematical properties, graphs, and comprehensive tables.

Data Processing Systems. The system design plans for a new *pilot electronic data processor* were essentially completed and the engineering necessary for constructing the machine was well under way. This general-purpose machine is designed to process digital information at very high speed. It will be used for experimental investigations of such large-scale problems as air-traffic control and patent searching.

Research in collaboration with the U. S. Patent Office for the *mechanization of patent search* operations continued. A program for comprehensive search of chemical patent literature was extended, and a program was developed for general search, with emphasis on mechanical arts.

Radio Propagation. The Boulder Laboratories continued to conduct research on the *forward scatter* of radio waves. First reported in 1955, this new mode of radio propagation is greatly extending the limits of long-distance communication. An improved formula for predicting the expected transmission loss on tropospheric forward scatter circuits was developed, making possible more accurate predictions particularly for propagation paths with unusual terrain profiles or climatology, for very high antennas, and for the lower frequencies.

As in 1957, a part of the technical program of the Boulder Laboratories was concerned with United States participation in the *International Geophysical Year* of 1957–58. For this cooperative scientific effort the Bureau's principal activities were the gathering and analysis of data on upper atmospheric phenomena and radio propagation.

As part of the IGY program, the Bureau intensified its study of the reflection of very high frequencies from the ionosphere—a phenomenon known as sporadic-*E*—which causes FM and television signals to be transmitted over distances of more than 1,000 miles. To detect differences in the ionosphere over the Eastern and Western Hemispheres, carefully controlled circuits for studying sporadic-*E* were set up between the Philippine Islands and Okinawa, between the Panama Canal Zone and Cuba, and within the United States.

The Bureau's Electronic Calibration Center initiated operations in 1958. The Center was established to meet the urgent need by Government, industry, and the military services for electrical and electronic standards. Above, a large audience of scientists and other invited guests gathered for the formal dedication ceremonies in Boulder, Colo. (pages 9, 96).

Experimental transmitting and receiving stations were also operated in Chile, Peru, Ecuador, Argentina, Brazil, and Panama in order to study special forms of oblique-incidence ionospheric scattering that occur in the vicinity of the magnetic equator.

Calibration, Testing, and Standard Samples. The Bureau continued to perform an important service to science and industry through its calibration activities, which insure the accuracy of countless measuring instruments throughout the Nation. More than 134,000 calibrations and tests were carried out in fiscal year 1958. In addition, about 55,500 individual standard samples of chemicals, metals, and other materials were distributed to analytical and research laboratories for use in controlling chemical processes and in matintaining the accuracy of apparatus and equipment. Thirty-eight new standard samples were developed during the year, bringing the total number of standard samples available to well over 600. The calibration and testing activities are discussed more fully in section 3, page 95 et seq.

Cooperative and Consulting Services. Cooperative activities ranged from advisory services for other Government agencies to the development of codes and specifications in cooperation with scientific and technical groups. During 1958 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. Cooperative activities are discussed more fully in section 4, page 105 et seq.

Administrative Activities

Bureau programs are financed by four sources of funds: Direct appropriations from the Congress, transferred funds from other Federal agencies, fees paid by private organizations for calibration services and standard samples, and gifts from private sources.

During 1958, the total funds obligated, including construction and facilities, were $29,158,000. Of this total, $9,724,000 came from the direct appropriation for the Bureau's research and technical services and $473,000 from the direct appropriation for construction and facilities. The remaining $18,961,000 came from other agencies and private sources (see appendix 5.2).

At the close of the year the Bureau's staff of 3,260 included 1,430 in the professional categories and 1,830 in other classifications. In the professional group were some 560 physicists, 300 chemists, 240 engineers, and 120 mathematicians. Almost three-fourths of the total were in Washington, D. C., and a little less than one-fourth at Boulder Laboratories, with the remaining few scattered among the Bureau's field stations.

During the year, the Electronic Calibration Center at the NBS Boulder Laboratories was activated. This Center will serve both defense agencies and industry in the calibration of electronic equipment and working standards in terms of the Bureau's primary standards of electrical quantities at frequencies above the audiorange, and will supplement the services available at the Washington laboratories at direct current and low frequencies (see page 96).

Bureau management undertook, during the year, a major reassessment of the adequacy of the Bureau's programs in terms of the needs of science and industry and with particular regard to international technological competition. The need for strengthened research programs in a number of areas was identified and additional emphasis was given to the Bureau's policy of shifting program emphasis from other-agency-oriented programs to programs more closely related to the Bureau's primary responsibilities.

The review of NBS responsibilities, programs, and capabilities also directed increased attention to the problems of research equipment and laboratory facilities. Additional effort went into the preliminary planning of new laboratory facilities, and at the close of the year funds were appropriated to finance detailed architectural design of new laboratories to be located at Gaithersburg, Maryland.

During the year, the Bureau revised its arrangements for program review and advice from scientists and engineers in universities and industrial organizations. The advisory committees were re-established as committees of the National Academy of Sciences, which will coordinate their activities and reports. This change is expected to increase the value to Bureau management of the consultation and program advice provided by these prominent representatives of the nation's scientific and technological community.

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 that 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 1,412, exclusive of calibration and test reports and of general administrative documents. Some 760 classified and unclassified reports were issued to other government agencies, particularly the Department of Defense, while 652 papers and documents were published formally.

Of the formal publications, 109 were published in the *Journal of Research of the National Bureau of Standards* (a monthly periodical) and 388 in the journals of various professional, engineering, and trade organizations. There were 128 summary articles published in the Bureau's monthly *Technical News Bulletin*. Twenty-seven papers were published in the Bureau's nonperiodical series of publications: 4 in the Applied Mathematics Series, 5 in the Handbook series, 14 in the Circular series, 1 in the Building Materials and Structures Report series, and 3 in the Miscellaneous Publication series.

The third monthly periodical of the Bureau, *Basic Radio Propagation Predictions*, which is published each month for a 1-month period 3 months in advance, presented radio-propagation data needed in determining the best frequencies to use in long-range radio communications.

A list of publications for the fiscal year is given in the appendix, section 5.5 (page 122).

2. Highlights of the Research Program

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

2.1. Electricity and Electronics

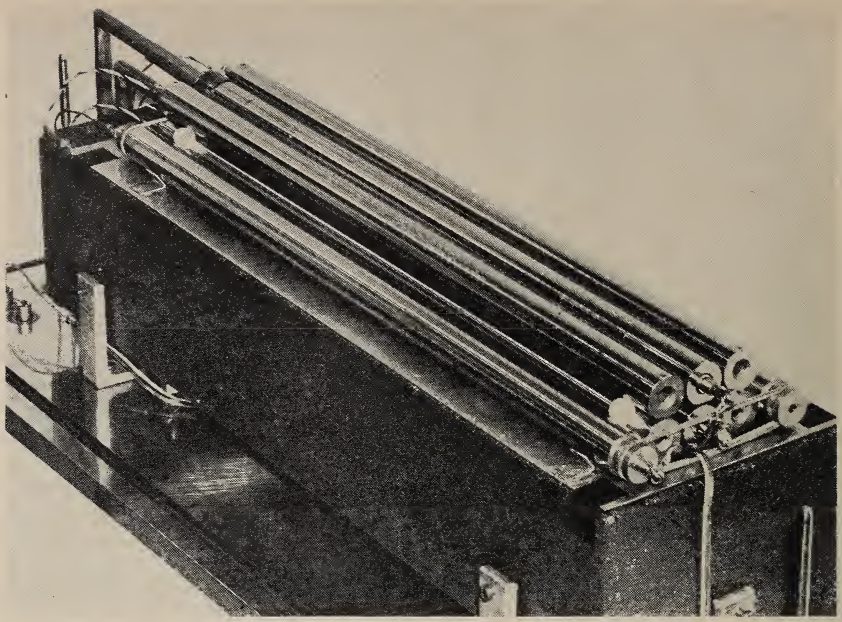
The Bureau's work in electricity is primarily the development, improvement, and dissemination of the standards of measurement for electrical quantities, and the study of the properties of materials that are important in all applications of electricity and magnetism. The object is to provide electrical standards that are, as far as possible, constant over long periods of time, uniform throughout the Nation, and consistent with the fundamental mechanical units. The work includes the dissemination of standards of electrical resistance, inductance, capacitance, dielectric constant and loss, electromotive force, current, power, energy, magnetizing force, and magnetic induction.

The electronic activities include the standardization of test methods for electronic components, the study of materials and processes for component fabrication, and the establishment of optimum designs of electronic equipment for maximum life and reliability. In areas in which the Bureau is uniquely qualified, electronic development programs are undertaken to meet the special requirements of the Bureau and of other governmental agencies.

Capacitance Measurements Based on the Calculable Capacitor. The performance of such complex assemblies as automated systems or guided missiles ultimately depends on the stability and the accuracy of adjustment of the system components. Even now the accuracies required in some electrical components are approaching those with which the standard electrical units themselves are known. Based on recent pioneering work at the Australian National Standards Laboratory, the NBS facilities for the establishment, maintenance, and dissemination of the unit of capacitance were improved during the past year.

The capacitance unit is determined on a bridge that makes precise measurements possible over a range from 10^{-6} to 1 microfarad. The heart of the bridge is a three-winding transformer with extremely low secondary impedances, and ratio errors less than 3 parts in 10 million. Incorporated into the bridge is a calculable capacitor of the cylindrical cross-capacitance type. Its value is calculated from the measured lengths of the precision gage bars from which it is constructed. Indications are that the capacitance unit so established is consistent with the basic mechanical units to within a few parts in a million.

Semiconductor Research. Semiconducting materials are intrinsically interesting from a scientific viewpoint because the study of their structure and behavior leads to increasing knowledge of the fundamental



An improved standard of capacitance of the Thompson-Lampard type was constructed utilizing gage bars of precisely known lengths. Its value can be calculated in terms of the primary standard of length to better than 10 parts in 1 million (page 11)

properties of matter. Also of importance is the applicability of their special electrical properties to practical engineering devices. The materials are numerous, and practical application of some of their more unusual properties appears to have only begun.

Conductivity versus temperature was determined for a number of samples of semiconducting materials. These included barium titanate containing controlled amounts of the elements samarium, aluminum, silicon, and neodymium. One useful discovery is that conductivity decreases rapidly with temperature in the region of a critical temperature depending upon the composition of the material. Simple temperature controls and current regulators may be useful applications of this effect.

Additional phases of this program are the measurement for the Air Force Cambridge Research Center of thermoelectric, Hall-effect, and electroluminescent properties of these and other materials. Electrical measurements are being correlated with physical measurements made in the Bureau and elsewhere to derive eventually a basic structural theory.

Surge Voltage Measurements. Most electrical insulating materials can withstand, for very short intervals, a somewhat higher voltage than is sufficient to produce electric breakdown or flashover on continuous 60 cycles per second voltage. Because the effect is large enough to represent some additional protection in the case of direct lightning strikes, it

is important to make reliable measurements of electrical breakdown values on steeply rising voltages. Better measurements of voltage values for such surges are now being obtained by using an improved design of surge resistor unit developed during the year. These 50 kv units, 7 in. long, are required to withstand repeated 60-kv chopped surges. In order to obtain a low-time constant, metal resistance-tape instead of wire is used for the two reversed windings on a notched methyl methacrylate card. The high order of insulation required is achieved by encapsulating the wound card in an air-bubble-free molding of clear epoxy resin.

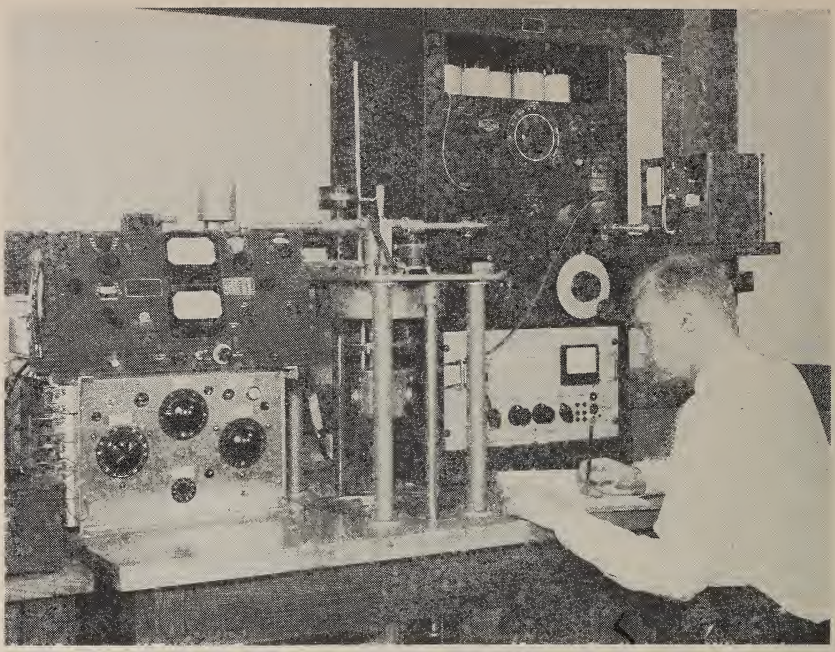
Cunife Wire Magnets. The need for extremely small permanent magnets led to a study of the magnetic properties of Cunife wire. This alloy (60-percent copper, 20-percent nickel and 20-percent iron) has a high coercive force and yet is sufficiently ductile to be cold drawn to fine wires. This investigation showed that it is possible to produce satisfactory permanent magnets as small as 0.005 in. in diameter by cold drawing larger sizes of Cunife through dies. If the cold-drawn wire is subjected to a simple heat treatment, the resulting permanent magnet properties are satisfactory for many magnetometer and galvanometer uses.

Ultra-Low Frequency Measurements of Dielectric Properties. During investigations of the electrical properties of polymeric insulating materials, it was found that ultra-low frequency dielectric data would be useful in understanding the nature of molecular motions in the crystalline and supercooled liquid, glassy states of such materials. Accordingly, a three-terminal bridge was constructed that yielded dielectric constant and loss measurements from 0.1 to 200 cycles per second. The results obtained with the apparatus were shown to be accurate to about 0.005 for the dielectric loss factor and about 0.4 percent for the dielectric constant. Measurements were made on polychlorotrifluoroethylene over a wide temperature range and work is now in progress on other polymers.

Electron-tube Material Sublimation. There is much evidence that an electron tube often fails prematurely because of changes in the emissive properties of the materials from which it is made. The metallic parts of the cathode, for example, vaporize and recondense on other parts of the tube structure. The tube's electrical parameters are changed by this sublimation, and the emission efficiency of the cathode is lowered.

Under the sponsorship of the Air Force Cambridge Research Center, the sublimation of electron-tube materials is being measured with a sensitive vacuum microbalance developed at the Bureau. The results of these measurements are expected to lead to improvements in electron-tube materials and in tube production methods.

Noise in Fixed Resistors. Undesirable electrical noise is generated by composition- or film-type fixed resistors that carry direct current. A standard test set was developed for the Navy Bureau of Ships to measure this property of a resistor. Copies of the test set are being installed in several Navy and Air Force laboratories. Their use is expected to



Special cell and recording equipment used to measure the dielectric constant and dissipation factor in high polymers at very low frequencies. These measurements, which are made down to liquid nitrogen temperatures, are a part of the studies of the basic electrical properties of dielectric materials (page 13).

improve the military specification for resistors, since resistor noise quality is not now included in the specification.

The Bureau is examining similar techniques for measuring the noise generated by variable resistors. The knowledge provided by this program should suggest design improvements in these important electrical parts.

A Provisional Faraday Value. The Bureau is constantly striving to make increasingly accurate determinations of the constants of nature. One such constant which received particular attention in the past year is the faraday, i. e., the number of coulombs or ampere-seconds required to deposit or dissolve an equivalent weight of an element. This work has now progressed to the point where a provisional value of 96,523 coulombs per gram equivalent on the physical scale may be given. This value agrees within 1 part in 100,000 with an average value determined by the omegatron and reported by the Bureau in 1953. However, determination of the purity of the silver used in this work still needs improvement.

Electric Cells at High Temperature. As a part of the Bureau's program to establish an electromotive force series of the elements at high temperatures, comparisons of the potentials of zinc and bismuth in fused salts were made from 45° to 510° C. At 450° C the electric poten-

tial of zinc was observed to be 0.67 volt higher than bismuth. Zinc, therefore, has a higher reducing power than does bismuth at elevated temperatures. This work has been in large measure supported by the Office of Ordnance Research of the Army.

Recharging of Dry Cells. Because of the pending exhaustion of the world's supply of natural manganese dioxide ore for the dry cells employed in flashlight, radio, and hearing-aid batteries, etc., the Bureau investigated the possibility of recharging dry cells whereby exhausted cells could be restored to initial full capacity. The Bureau has found that dry cells may be recharged by an a-c–d-c method several times, thus increasing their ultimate usefulness.

Internal Resistance of Dry Cells. For the first time, an unambiguous measurement of the internal resistance of dry cells was achieved. Heretofore, it was believed that the internal resistance of dry cells changed with the value of the current used in the measurement. By imposing a square-wave current pulse across dry cells for periods of microseconds duration, the Bureau observed that the same value for internal resistance of dry cells was obtained even when the current in the pulse was varied widely. Also there was no change in the internal resistance of cells when the direction of the pulse was reversed or when the frequency of the pulse was altered.

Heats of Adsorption. A theory whereby the heats of adsorption of gaseous metals on solid metals and of gases on metal can be calculated from electrochemical data was formulated. Work functions, ionization potentials, and the electron affinities of the materials all enter into the theory. Results at room temperature agree within a few percent with those found experimentally. The theory may also be used to calculate the hydrogen overvoltages on metals.

Aircraft and Missile Batteries. Under the sponsorship of the Navy Bureau of Aeronautics, the Bureau investigated lead-acid, nickel-cadmium, and zinc-silver storage batteries at altitudes as high as 50,000 ft at $-10°$ F ambient temperature. For the unsealed types a study was made of the flooding of electrolyte under such conditions; flooding occurs under abrupt changes in altitude but not under gradual changes. Studies were also completed on effects of position (angles of tilting), vibration and thermal shock on battery performance. The relation between charging currents, temperatures, and vicious cycling (overheating with subsequent burning up or explosion) was investigated for all three types of batteries. Missile batteries utilizing alkaline electrolyte have heretofore been believed to be adversely affected by atmospheric carbon dioxide; the Bureau found that carbon dioxide does not cause deleterious effects until 70 percent of the alkaline electrolyte is converted to carbonate.

Postal Automation. The Bureau is assisting the Post Office Department in studying certain aspects of methods for handling mail by automatic machines. An experimental letter-sorting machine was developed.

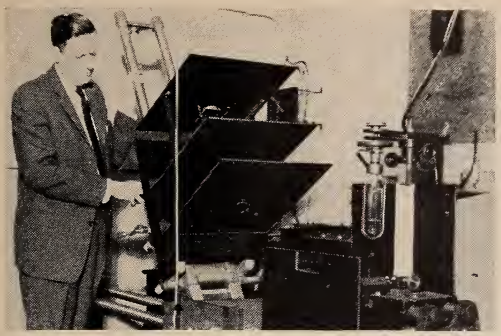
and its operation is being analyzed to compare its performance with that of other proposed sorting systems. Postage stamps of altered design to permit machine recognition were studied to find the most economical and reliable design. Methods of coding address information on envelopes (a dot pattern on a paper label attached to the envelope, for example) were also examined. And finally, the logical design of the mail-handling machinery is being studied to determine the best way to store address information in the machine and to modify this storage with changes in the frequency and distribution of the mail. (Additional work in the mail-handling problem is discussed on page 77.)

2.2. Optics and Metrology

The Bureau's work in optics and metrology is principally concerned with the development of standards for classical optics and for length measurement, and with the establishment of procedures for the precise use of these standards. Efforts are now being made to set up a primary standard for recalibration of basic candlepower standards. Since color is becoming an increasingly important factor in merchandizing, a method has been devised for rapid color analysis with a high-speed electronic computer.

During the past year procedures for designating the metrical performance of an airplane camera lens were standardized. To assure the maintenance of uniform length standards throughout the country, methods for calibrating end gages have been further refined. Atomic beam lamps that will produce coherent light over a maximum path difference and interferometer equipment are being developed to facilitate the application of a new wave-length standard for length calibration.

Photometric Standards. The International Bureau of Weights and Measures, Sevres, France, proposed international adoption of uniform units of candlepower and luminous flux for the carbon-filament lamp, the vacuum-tungsten lamp, and the gas-filled tungsten lamp. These units are to be based on their average magnitudes found by applying the primary standard of light (blackbody at the freezing point of platinum) developed at the Bureau. The national standardizing laboratories of seven countries are participating in the effort. As this country's contribution to the program, the Bureau made the primary standard available for continued routine use; completed a tentative recalibration of candlepower standards for carbon-filament lamps; and determined the ratio of luminous flux to candlepower for groups of vacuum-tungsten and gas-filled lamps. In addition, gas-filled, clear-bulb lamps commonly used as basic candlepower standards, were critically evaluated and found to be deficient. Consequently, a gas-filled, frosted-bulb lamp with far superior characteristics was developed by the Bureau in cooperation with a lamp manufacturer.



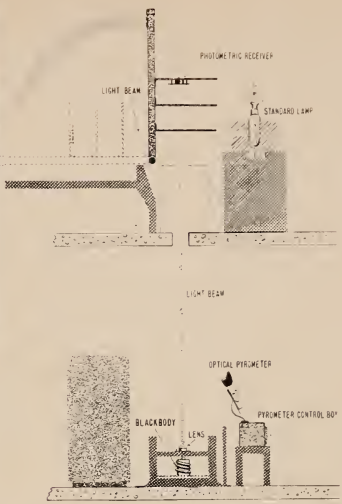


Diagram (right) of equipment used to recalibrate the national candlepower standards against the primary standard of brightness, a blackbody radiator maintained at the temperature of freezing gold (1,063° C). The photometric receiver used to make the comparison is shown above (page 16).

Spectrophotometric Data Electronically Computed. Since 1931 the internationally accepted method of defining the color of any light has been to specify the amounts of primary red, green, and blue light which when added together produce a particular color. The fundamental measurement of a color standard is the spectrophotometric determination of the fraction of incident light transmitted or reflected by the standard in successive parts of the visible spectrum.

To find the portions of red, green, and blue light required to match the color of a standard, a computation is first made of the amount of the standard's transmitted or reflected light for each part of the visible spectrum. This amount is then multiplied by the known portions of red, green, and blue primaries required by the average human observer to match a particular segment of an equal-energy spectrum, and the products are added together.

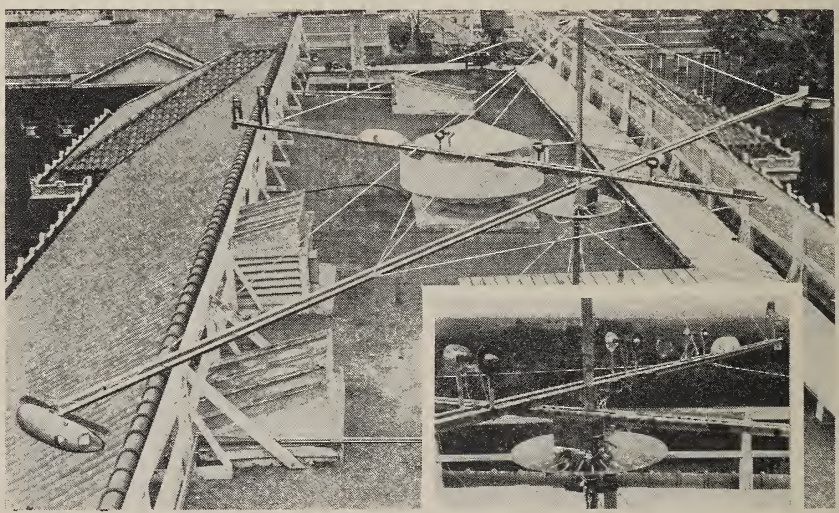
Each of these computations, made for years with a desk calculator, required half an hour. Last year, the work was programed for the Bureau's electronic digital computer, which automatically corrects any photometric scale errors of the spectrophotometer and completes the computations in only a fraction of a second for each color standard.

Conversion of Colorimetric Data to Munsell Terms. During the past 30 years the Munsell scales of hue, value, and chroma have been widely used by American science and industry for color and color tolerance specifications. These scales have an almost uniform perceptual spacing, and they closely correspond to the hue, lightness, and saturation of a color perceived under daylight viewing conditions. In addition, they are defined in terms of the internationally accepted tristimulus values (amounts of primary red, green, and blue required to produce any color). These scales are generally preferred because the colors can be readily visualized.

Finding the Munsell notation of a color expressed in tristimulus values requires a tridimensional interpolation among the 5,000 points defining the Munsell scales, and a verification by means of tables and graphs. Since this work takes about 20 min for each color, it was also programed for the Bureau's electronic digital computer. By scanning a tape carrying specifications of the 5,000 defining points until a color's 8 limiting points are located, and then by determining the Munsell hue, value, and chroma through linear interpolations, the computer finds the Munsell notation in 20 sec.

Anticollision Lights for Airplanes. Today's heavy air traffic with its attendant mid-air crashes points up the need for evaluation of the anticollision lights now installed and proposed for installation on airplanes. The Bureau made such an evaluation for the Navy Bureau of Aeronautics under controlled experimental conditions. The Navy cooperated in designing tests for the evaluation of lighting systems under actual flight conditions. Experimental results brought into focus the characteristics essential to an effective lighting system.

In a separate phase of the work a new type of emergency exit light for aircraft was developed. This light employs self-contained incandescent light sources that transilluminate a phosphor-coated panel with exit designations. After a power source failure the panel remains visible for about a 10-min period.



Half-scale rotatable mockup, representing the fuselage and wings of a DC–3, used to evaluate aircraft anticollision light systems. The three complete light systems on the boom can be rotated to present different headings of the plane to observers, who are stationed 1, 3, and 7 miles away (page 18).

Refractive Index of Synthetic Sapphire. Synthetic sapphire indices of refraction for the ordinary ray, N_o, were measured over almost the entire range of transmission (0.2 to 6.0 microns) at controlled room temperatures near 19° and 24° C. Thermal coefficients of index were computed for each wavelength, and all data were reduced to exact temperatures of 19° and 24° C. Also, refractive indices and thermal coefficients for 7 visible wavelengths were determined at 17°, 24°, and 31° C.

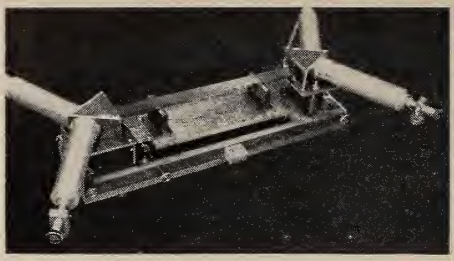
Sapphire was found to have a large reciprocal dispersion for the index of refraction, and there was also evidence that the thermal coefficient of index decreased with increasing wavelength. It appears that the extended wavelength transmission region and unusual dispersion will make sapphire a valuable material for optical instrumentation.

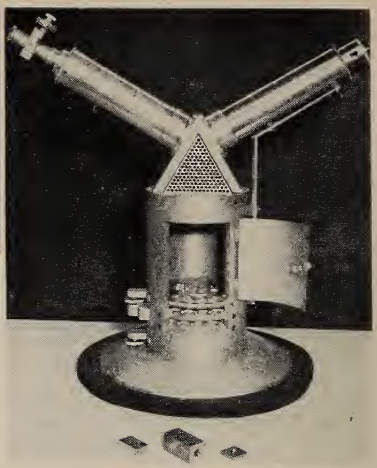
Calibration of Airplane Cameras. At the request of the Air Force, a thoroughgoing analysis of random errors that affect the accurate calibration of airplane cameras was completed. Factors studied include camera tilt, plate curvature, and prism effect. Of these, the mos pernicious is prism effect since it produces radial asymmetric and tan gential distortion of a type that cannot readily be compensated. Experiments conducted in the course of the investigation showed that various corrective methods may be employed to eliminate the random errors when they become apparent. However, lenses showing an excessive amount of prism effect should not be used for precise photogrammetric mapping.

Standards for Spectacle Lenses. Prescriptions for spectacle lenses usually specify only the power at the center of the lens and not that near the edge or margin. In an attempt to insure 20/20 vision from all parts of prescribed lenses, the axial and marginal powers of about 300 lenses from 5 different manufacturers were measured. Tolerances based on the results will be used by the Veterans Administration in purchasing ophthalmic lenses. Of the lenses tested, 80 percent gave acute vision near the margin of the lens.

Automatic Lens Design. The Air Force sponsored a study for coding a high-speed digital computer to design lenses automatically. First a method was developed for using a single number, called the optical merit function, to describe the quality of a lens. A routine was then devised for improving the optical merit function on the electronic computer. In a sample run, some of the geometric aberrations of a triplet lens were reduced, demonstrating the feasibility of automatic design techniques. A great deal of time-consuming work may now be eliminated with computers adjusting a given design to its optimum.

Atomic Beams for Defining Length. By applying atomic beam techniques, extremely monochromatic optical radiations (λ=2537 A) were produced. The band widths of these radiations are one-fourth as wide as the narrowest lines conventionally produced, thus interference can be observed over a path length exceeding 2 meters with a precision of 1 part in 10^9.





As part of an effort to meet industry's demand for gage blocks accurate to 1 part in 10 million, two novel type interferometers were designed. The one above determines the parallelism of the ends of long gage blocks, and the other, right, tests the parallelism and optical planeness of gage blocks up to 4 inches in length (page 20).

An emission beam source utilizing natural mercury has also been tested and found quite satisfactory within the limits imposed by natural mercury. A revised version of this source will be filled with isotopic mercury and tested in the near future.

Another atomic beam device that has given good results in preliminary tests employs the absorption line of mercury at 2537 A. The device serves as a detector, sensitive to radiations over only a very narrow band or curve. The wavelength of this narrow and precisely defined sensitivity curve can be used as a definition of the meter. A third instrument, developed during the past year, utilizes a properly balanced Michelson interferometer. The device, now being tested, produces an emission line from an absorption process in an atomic beam of mercury.

High-Precision Gage Blocks. In the high-precision gage block program, supported in part by American industry, emphasis is shifting from the development of improved calibrating instruments to the development of more precise gages. An ideal gage would be unchanging in length, but almost any material will gradually grow or shrink with time. To detect the small changes that occur in a relatively short period a method was developed by which comparisons accurate to approximately 1 part in 10,000,000 are achieved. The method, providing measurements 10 times more precise than any previously attained, is being used to study the relative desirability of various steels for gage construction, and to determine the coefficients of thermal expansion of these steels (see page 54).

In one phase of the program a design was completed for a new interferometer to measure lengths in terms of a wavelength of light to a part in 10 million. An extensive study was undertaken of phase change of light in reflection. This change is a source of error in interferometric length measurement necessitating corrections.

The group of manufacturers working in cooperation with the Bureau are the Dearborn Gage Co., DoAll Co., E. I. du Pont de Nemours & Co.,

Fonda Gage Co., Inc., General Electric Co., Greenfield Tap & Die Corp., Hughes Aircraft Co., International Business Machines Corp., Link Aviation, Inc., New Departure (General Motors), Pratt & Whitney Co., The Sheffield Corp., Taft-Peirce Foundation, Timken Roller Bearing Co., and the Van Keuren Co.

Screw Thread Standards. Part I of NBS Handbook H28 (1957), *Screw Thread Standards for Federal Services*, was published and the original supply of 13,000 copies was quickly exhausted. However, a 17,000-copy reprint recently came off the press. Part I established standards for screw threads to be applied to bolts, screws, nuts, and tapped holes used by government departments. Part II, providing standards for pipe threads, hose-coupling threads, and related items, is being published. Part III will include standards that are in the process of formulation by Government and industry, such as acme and buttress threads; publication date has not been fixed. It is anticipated that part I will have to be revised when current negotiations for international standardization of threads are completed.

2.3. Heat

To provide a basis for precise measurements of heat, the Bureau maintains temperature scales covering most of the range of accessible temperature, and continually develops and extends these scales. In addition, standards are determined and maintained for viscosity, for engine-fuel performance, and for heat measurements such as thermal diffusivity, heat capacity, and heat of combustion.

A broad program of basic research in related areas is being conducted to extend these heat standards. Fundamental studies are carried out in heat measurements, statistical thermodynamics, molecular structure, high-pressure thermodynamics, low-temperature physics, rheology, and high-temperature processes. Special emphasis is given to research on free radicals in an effort to determine the properties of the solids which contain appreciable quantities of trapped reactive radicals.

During the past year, these activities were characterized by efforts to obtain new extremes of temperature and pressure, to increase the degree of automation of precision measurements, to extend knowledge of statistical thermodynamics of dense systems, and to study the mechanisms of high-temperature processes with greatly improved instrumentation.

Statistical Thermodynamics. The continued advancement of scientific and industrial activity to the extremes of temperature and pressure has thrust more and more responsibility on theoretical methods for describing the thermodynamic and transport properties of substances. To extend these data a program of statistical thermodynamics is being directed toward the development of new theoretical techniques for describing these properties.

Significant progress was made during the past year both in the development and application of theoretical methods to such problems as quantum effects on surface tension in simple liquids, isotope effects on the compressibilities of isotopic hydrogens, statistical mechanical description of the transport, equilibrium, and magnetic properties of electron gases, molecular orbital calculations of the H_3 molecule, and partition function representation for atoms and atomic ions to a million degrees, and molecules and molecule ions to 25,000° K.

Basic thermodynamic data are required for engineering calculations encountered in the design and performance evaluation of such equipment as gas turbines and jet and rocket engines, and in the solution of various aerodynamic, astrophysical, and astronautical problems. To extend such data over a wide range of temperature and density, high-speed computation programs were designed. Codes are being applied to a systematic generation of extensive tables of ideal-gas thermal functions of atoms, molecules, and their ions. They also cover equilibrium compositions, and thermodynamic and transport properties of complex mixtures of reacting gases.

International Temperature Standards. Temperature is generally accepted as one of the fundamental quantities necessary to describe completely the physical state of matter. So that all measurements of temperature in different laboratories have the same basis, an International Temperature Scale has been developed which has been generally accepted by all nations. In the temperature range from −183° to 630° C, the scale is fixed by the use of a suitable platinum resistance thermometer calibrated at the normal boiling points of oxygen, water, and sulfur, and at the ice point. A primary function of the Bureau is to improve and extend the ITS in the United States and to develop instruments for the practical utilization of the scale.

To insure that all laboratories throughout the world are realizing the same temperature scale, occasional international comparisons are made. This is accomplished by the exchange or circulation of standard platinum resistance thermometers. Such a check was made over the past 5 years to determine the uniformity of the accepted steam point. Three thermometers were sent to the national laboratories of Great Britain, Germany, the Netherlands, Russia, Japan, Canada, and the United States. Results indicate that the same steam point is realized in these countries to within 0.001 deg C.

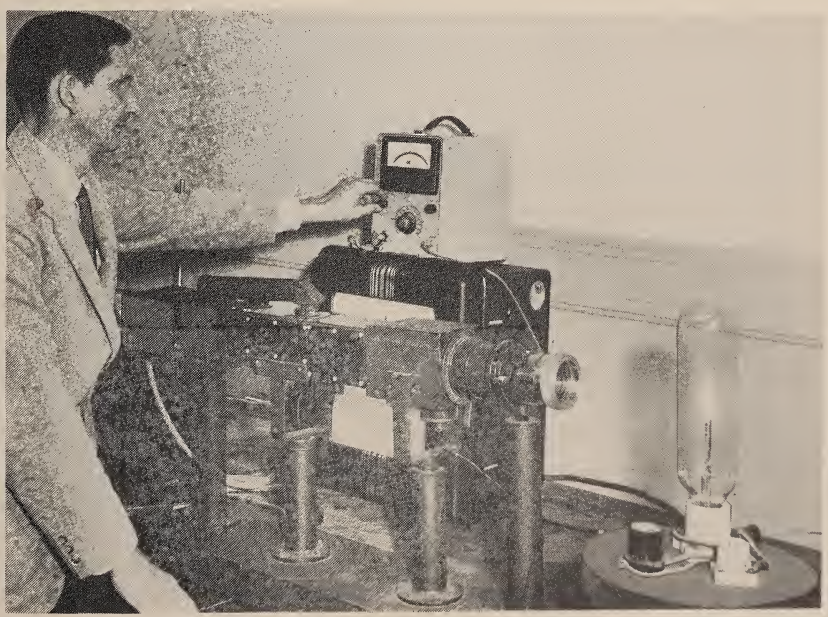
A similar but somewhat less extensive check was made between the Bureau and the National Research Council of Canada in connection with the realization of the primary fixed point at the normal boiling point of sulfur. This check indicated that the temperature realized as the sulfur point is in agreement within 0.002 deg C.

Considerable effort was also expended in the important task of rewriting the text of the International Temperature Scale. Revision of the 1948 text was done in order that this document reflect both recent

actions of the International Committee on Weights and Measures and recent improvements in techniques. Although the text of the scale was favorably received by the Advisory Committee on Thermometry and Calorimetry in June 1958, some further revision will be necessary because of the new proposed replacement of the sulfur-boiling point by the zinc-melting point as a fixed point of the scale.

Resistance Thermometry. To provide additional facilities for temperature calibrations and related work, new equipment was installed in the resistance thermometry laboratory. One addition is a multiple-reflection galvanometer which utilizes multiple reflections from a moving galvanometer mirror, thus increasing the instrument's sensitivity in measuring resistance by a factor of 4. Other new equipment includes a potentiometer, which measures the current through the resistance thermometer with an accuracy of 1 part in 5 thousand. This is necessary in order to measure and control the heating effect of this current. In addition, a control device automatically maintains the pressure of specific equipment at about 1 atmosphere, constant within 1 part in 10 million.

High-Temperature Pyrometers. In research at very high temperatures, work is in progress to improve the accuracy of pyrometer calibrations at temperatures between 2,500° and 4,000° C. During the past year, zirconium and carbon arcs were adapted for use in the calibration of pyrometers which now permit direct observations up to about 3,800° C. However, because the instability of these sources limits the accuracy of



In an effort to extend and improve its temperature measuring capabilities, the Bureau developed this photoelectric pyrometer for temperatures above 1,000° C. Greater precision is possible than with the optical pyrometer presently in use (page 23).

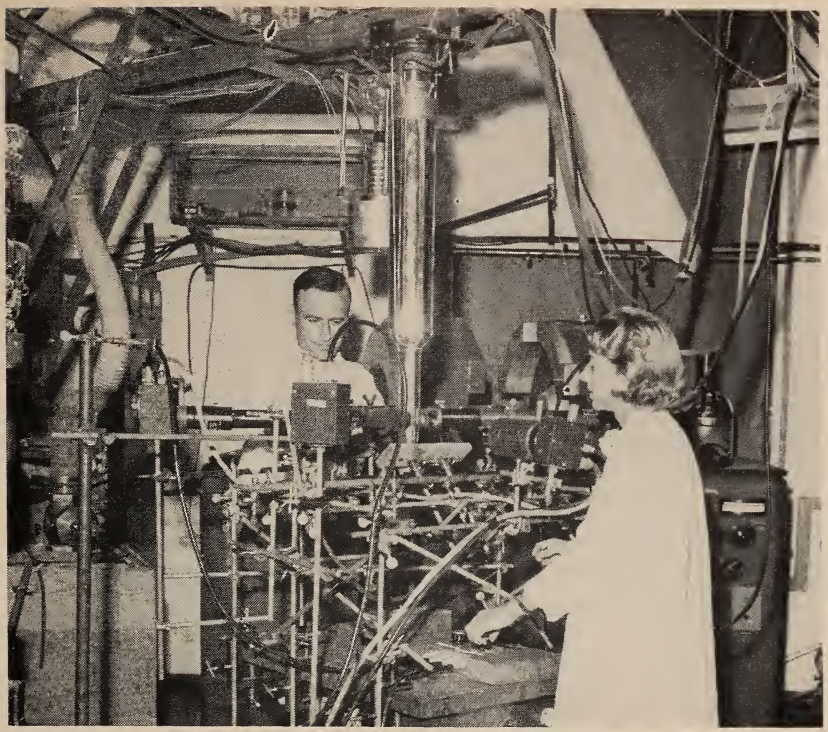
routine calibration to about 40° at 3,800° C, attempts are being made to develop a more stable source for this temperature region. One promising design consists of an electrically heated graphite tube mounted in an inert gas atmosphere. The first model was constructed, and studies on the effect of size, mounting, and gas pressure as a function of stability are being planned.

Parity and Time Reversal. The original NBS experiment in 1956, indicating that parity was not conserved in beta decay, stimulated an enormous amount of research in other laboratories throughout the world engaged in the basic fields of weak interactions and fundamental particles of matter. Investigations at the Bureau were made on the directional asymmetry of emission of beta particles from polarized nuclei of Co^{60}, Co^{58}, Co^{56}, and Mn^{52} and the angular correlation of these beta particles with following gamma radiation. All of these experiments gave information on the dynamical details of the beta interaction and, in particular, information on the question of time reversal invariance in beta decay. It is now apparent that invariance under space reflection (parity conservation) and invariance under charge conjugation are both violated to a maximum, while invariance under time inversion—time symmetry in subatomic interactions—is not. Experiments are proceeding to ascertain whether time reversal invariance is actually exactly conserved.

These experiments involve a study of the emission pattern of radioactive manganese-52. This radioactive disintegration includes the simultaneous emission of a beta particle (or electron) and a neutrino from the manganese nucleus. Making use of theoretical work by previous investigators, Bureau scientists developed a technique by which they can determine the relative proportions of the emitted beta particles which have a spin either in the same or the opposite direction as that of the neutrino emitted at the same time.

Besides giving information of fundamental nature, experiments on the beta decay of oriented nuclei also give considerable information on the details of nuclear quantum states and thus afford a powerful new tool for the study of the nucleus.

Heat Measurements on Sulfur. Because sulfur is of basic importance in the chemical, rubber, and petroleum industries, data on its thermodynamic properties will aid in the theoretical interpretation of the complex behavior of the element as well as in predictions of the reactions of sulfur and its compounds at higher temperature—such as occur in petroleum refining. Although sulfur has been known since ancient times, accurate thermodynamic data has been limited because it is difficult to purify, exists in several crystallographic forms, and reaches equilibrium slowly. For example, the liquid form consists of sulfur atoms in different molecular combinations ranging from 8-atom rings to 10,000-atom chains. As the temperature is raised, the concentrations of the various molecular species change slowly, causing corresponding shifts in the thermodynamic properties. However, accurate measurements



Experimental equipment used in continuing studies in low-temperature physics relating to parity and time reversal (page 24).

of the heat capacity, which allow for changes in the molecular species at each temperature, were completed by the Bureau in a project partly supported by the American Petroleum Institute and the Allied Chemical Corporation. The measurements were made with 99.999 percent pure sulfur in a high-temperature adiabatic calorimeter designed especially for such substances.

Thermodynamic Properties of Rubber. In the development of synthetic rubbers and associated polymers for industrial use, accurate thermodynamic data are needed to calculate maximum efficiency and yield of chemical production processes, and to predict thermodynamic properties of related polymeric substances. To determine these data, the Bureau completed a long-range project, sponsored by the National Science Foundation, involving the thermodynamic properties of rubber polymers. Experimental and theoretical research dealt with the basic raw materials, the intermediates from which the polymers are made, and the rubber polymers themselves. Results were combined with data from previous measurements to obtain the thermodynamic properties of the system.

Viscosity Standards. To test the suitability of *n*-hexadecane (cetane) as a calibration standard for viscosity measurements, a study of the viscosity of cetane purified by several techniques was completed

by the Bureau. Although water is the material almost universally used for this standard, an additional calibration standard has long been desired because of the difference in surface tension between water and hydrocarbons. Therefore, a few years ago, the Bureau was asked by the Society of Rheology to undertake this study, with cetane suggested as a possible hydrocarbon.

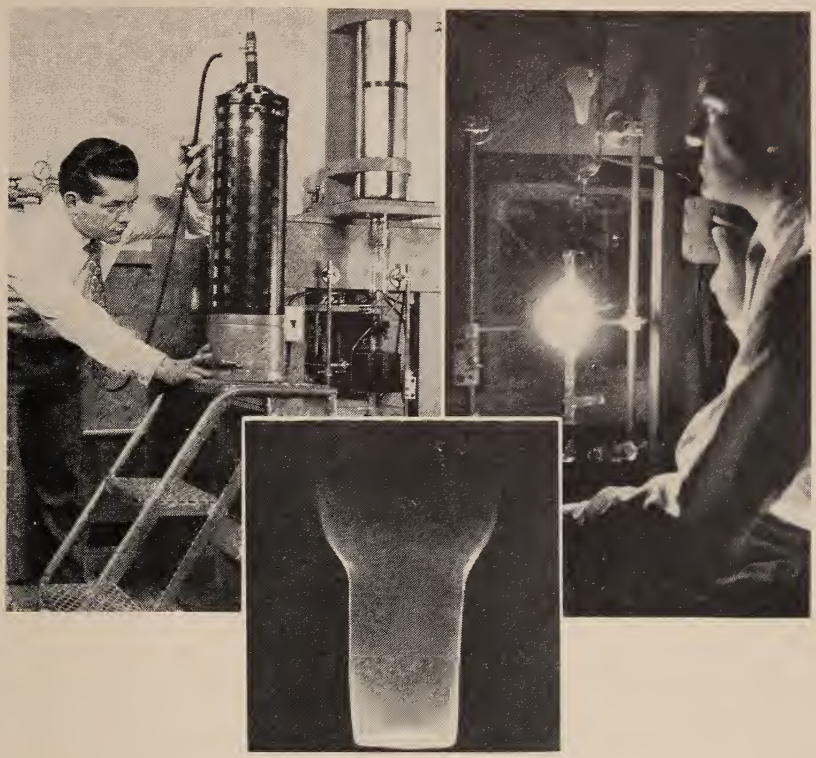
Because of the range of purity of the samples measured—from 93.6 to 99.94 mole percent—the viscosity of the sample varied irregularly over a range of 0.18 percent. Without the exact composition of a given sample, and without more information on the variation of viscosity with composition than is now available, cetane could be relied on as a calibration standard only if an elaborate purification procedure was first performed. Thus it appears more feasible to continue using water as the standard, making the required surface tension corrections.

Rheology. To widen the range of basic knowledge on the deformation and flow of such polymers as lubricating greases, synthetic rubbers, and motor oils, the Bureau has been studying the rheological properties of polymers. One of the investigations this year concerned a modification of a theory which gives the time-dependent mechanical response of a rubberlike polymer in terms of its molecular properties.

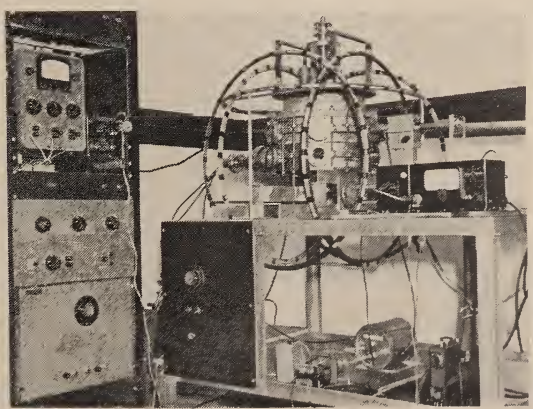
A number of equivalent theories have been developed to give the time-dependent response of such polymer systems by combining the kinetic theory of elasticity and a theory attributing viscosity of polymers to the entanglements of long chains. While these previous theories introduce the effect due to entanglements by calculating the total response in two arbitrarily separated parts, the present modification includes all the observed effects in a single model. By applying this theory, extremely close reproductions of experimental results were obtained. The calculated and observed values—using constants appropriate for the "standard" polyisobutylene—show exactly the same behavior qualitatively, and over most of the range the quantitative agreement is within the experimental uncertainty.

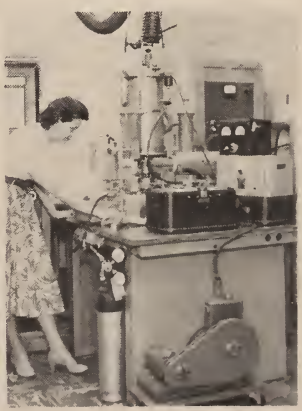
Free Radicals. For some time there has been considerable interest in the study of free radicals because knowledge of the properties of these highly reactive molecular fragments is valuable in basic research as well as in certain areas of applied physics and chemistry. Therefore, the Bureau, under the sponsorship of the Department of Defense, is conducting a large scale program devoted to free radicals. One way of classifying the numerous projects concerning free radicals is by dividing them into the broad categories of preparation, characterization, and application.

Preparation. Since stable molecules may be transformed into reactive free radicals by breaking chemical bonds, researchers are studying techniques of electric discharge and thermal dissociation of the gas phase followed by condensation, or electron bombardment and photolysis of the solid phase with gamma rays and ultraviolet radiation. To trap the free radicals for convenient study, the reactive substances are collected



A comprehensive program is directed toward charting the properties of free radicals. (Above left) Transferring liquid helium through an evacuated siphon to the refrigerated tube of the apparatus used to collect free radicals. (Above right) Condensing nitrogen atoms (produced in electric discharge, center of picture) on the liquid helium refrigerated tube (upper center of picture). Inset shows glow of radicals condensed on the tube. (Below left) Apparatus for measuring energy losses of bombarding electrons passing through a free radical condensate. (Below right) Equipment for X-ray diffraction studies of solids containing free radicals (page 26).





immediately after production by freezing on extremely low-temperature surfaces. Because each method of production is useful for a specific type of experiment, the over-all investigations are needed to evaluate the effectiveness of possible preparations.

Characterization. X-ray diffraction techniques are used to determine the structure of the solid lattices which contain trapped radicals. In many cases, these structure determinations on a particular material are the first to be made at low temperatures (as low as 1°K). Identification of the frozen radicals by means of electron spin resonance and optical spectroscopy from the vacuum ultraviolet to the infrared has demonstrated that such unusual species as N, O, H, OH, and HNO may be stabilized for long periods at low temperatures. The quantity of radicals trapped by these techniques is very important in understanding the nature of forces holding the radicals in the solid matrix, but the measurement of radical concentration in such systems is extremely difficult. However, some estimates of concentration are now being made by such methods as calorimetry, electron spin resonance, and magnetic susceptibility. Other properties of the solids such as electrical and thermal conductivity, dielectric constants, and index of refraction are also being studied.

Application in Chemical Processes. A number of these studies involve the type of reactions that may proceed in solids containing atoms or radicals as a function of the nature of the solid. One investigation resulted in the production of ozone from oxygen radicals in yields of nearly 100 percent while another resulted in the direct preparation of radicals in the solid by addition of hydrogen atoms to condensed hydrocarbon molecules. By studying the latter controlled production, uncertainties of associated reactions can be eliminated.

Finally, it was found that the deposition of magnesium vapor in a suitable matrix produces a red transparent solid quite different in appearance and behavior from the metallic magnesium deposit customarily obtained by condensing the vapor. This form of magnesium, which is stable only at very low temperatures, is not only indicative of a new form of a familiar substance, but is also representative of a potential means of storing energy. (See also pages 29, 38.)

2.4. Atomic and Radiation Physics

The rapid rate with which basic discoveries in atomic and nuclear physics are being applied to practical problems in technology places an ever-increasing demand on the Bureau for services and information. Industry and the medical profession, as well as research institutions and government laboratories, require new and more accurate data on basic properties and fundamental reactions, new techniques and more reliable methods of measurement, and new as well as improved standards.

To meet these needs, research, development, and standardization programs are carried out in such areas of modern physics as the properties

of particles (atoms, ions, nuclei, electrons, neutrons, and photons for example) and the interactions of particles with each other and with electric and magnetic fields. The aim of this basic research program is to provide a clearer understanding of the individual properties and fundamental laws governing the behavior of particles in order to discover new and better ways for control and measurement. These data in turn lead to more accurate and reliable units and standards.

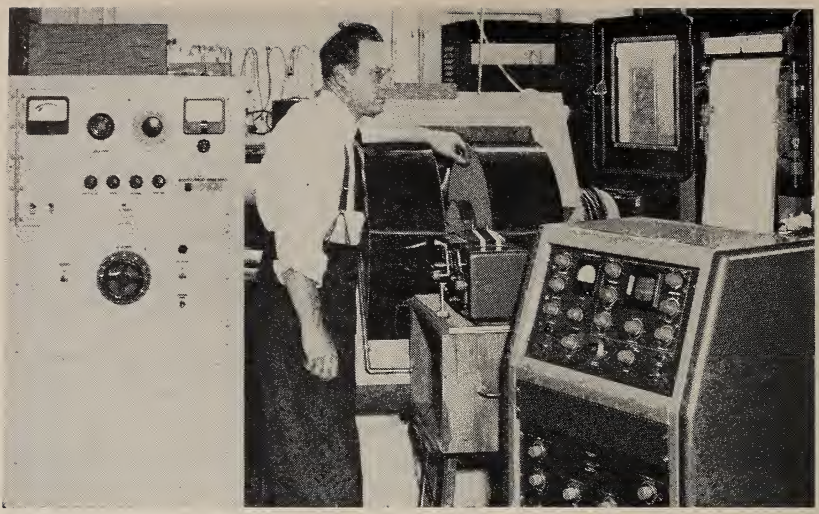
Solid state physics, which probes the nature of solid materials; spectroscopy, which investigates the atom; and radiation studies, which provide data on fundamental particles and nuclei, as well as atoms; are important phases of the program.

Spectroscopic Research. Analysis of the light emitted by atoms and their ions is an accurate and widely used method for obtaining detailed information on atomic structure and chemical composition. The wavelengths are measured by interpolating between values of iron lines calibrated in terms of cadmium radiation. However, because of the high temperature of the iron arc, its operation at atmospheric pressure, and the relatively small mass of iron atoms, the spectral lines are unduly coarse and wide. Moreover, the nature of the iron spectrum prevents the selection of uniform standards evenly distributed throughout the spectrum. Because the iron standards are inadequate for modern precision measurements in complex atomic spectra, the Bureau has substituted the green radiation from mercury 198 as a primary standard and a thorium-halide lamp as a source of secondary standards lines. Because thorium atoms are more than four times heavier than iron atoms and emit lines entirely free from hyperfine structure and isotope shifts, they yield spectral lines about one-tenth the width of iron lines. Furthermore, thorium spectra contain four times as many lines as iron, permitting the selection of uniformly distributed standards of superior quality.

Preliminary measurements of 222 thorium wavelengths ranging from 3287.7885 to 6989.6562 A in standard air were presented to the International Astronomical Union. The error in relative value of these measurements is less than 1 part in 20 million.

Free Radicals Studies. Mass spectrometric methods were used to obtain information on the mass and energy states of free radicals, as part of a general research program on radicals (see p. 26) sponsored by the Department of Defense. The concentration of nitrogen atoms and their recombination in the nitrogen afterglow were measured in this way by the use of a specially designed flow system. A technique was developed which employs nitric acid to "titrate" the nitrogen atoms formed in a high-frequency discharge. It was thus possible to measure the rate at which nitrogen atoms recombine by collision with nitrogen molecules, by collisions with rare gases, and by wall collisions.

Other mass spectroscopic studies were conducted on hydrazine and the methyl hydrazines, which are of scientific interest and of practical value as high-energy fuels for rockets and missiles. Until recently little was



Nuclear magnetic resonance offers a tool for the investigation of the solid state. A study of the absorption of energy by atomic nuclei in solids provides a better understanding of the local electric and magnetic fields that the nuclei experience (page 30).

known concerning their molecular-bond strengths and other thermodynamic properties. An investigation of the ionization and dissociation processes following electron bombardment afforded detailed information on the bond strengths and heats of formation of radicals for the hydrazine compounds.

Behavior of Semiconductors. The increasing industrial use of semiconducting devices, such as rectifiers and transistors, along with the present interest in employing semiconductors as infrared photodetectors and thermoelectric generators, emphasizes the need for a better understanding of the unusual mechanical and electrical properties of these solids. To meet this need, studies on the behavior of materials such as the intermetallic InSb are being continued and new materials are being investigated. Experiments on the intermetallic InAs for example, showed that its galvanomagnetic properties are similar to those of InSb. Both exhibit a magnetic field dependence in which the resistance as a function of field strength shows oscillatory behavior at liquid-helium temperatures. A study of the theory of such an effect clarified understanding of the phenomenon, which is closely related to the DeHaas-Van Alphen effect. Other behavior studied is the temperature dependence of the spin relaxation time in NaCl. This investigation and similar work underway on AlSb was made possible by recently completed equipment for the measurement of nuclear magnetic absorption and relaxation times.

In addition to the behavior of semiconductors, their basic nature is investigated by obtaining data on the mechanical properties of the crystals. In this research, supported by the Air Research and Development Command, piezoelectricity was observed at liquid-helium temperatures in InSb.

Electron Polarization. The Bureau has developed apparatus for the production of photoelectron beams from thin ferromagnetic film, and for the detection of spin polarization in these beams. The detection system constructed makes use of the asymmetric properties of Mott scattering at 120 kev. With this instrument new information was obtained concerning the critical thicknesses of metallic target foil needed for the measurement of spin polarization.

Scattering of Low-Energy Electrons. In a program jointly supported by the Atomic Energy Commission and the Bureau, a detailed study of low-energy electron scattering was pursued. Particular emphasis has been placed on the characteristic energy losses of electrons in solids. To facilitate this work two high resolution spectrographs were put into operation. One is capable of high resolution in both energy and angle, and the other—designed to work at liquid helium temperatures—measures only in the forward direction with high resolution. Angular distribution measurements were made of a number of new substances, the effect of crystal orientation and aggregation on the energy-loss spectrum was investigated, and a thorough study of the character of the energy-loss scheme in sodium is in progress. In addition, temperature dependence of the energy loss in aluminum was noted as part of low-temperature experiments. Measurements of the energy losses of electrons in condensed gases are presently underway.

Proton Gyromagnetic Ratio. The gyromagnetic ratio of the proton—a measure of its interaction with magnetic fields—was redetermined with significant increase in accuracy. This result not only provides a better standard for magnetic fields but also makes possible more accurate values for many of the fundamental constants of physics whose values depend upon magnetic field measurements. Examples are the electron charge-to-mass ratio e/m, the magnetic moment of the proton, and Planck's constant h.

The new value for the proton's gyromagnetic ratio will be especially useful in the design and development of scientific and industrial apparatus in which it is important to know accurately the spatial distribution of a magnetic field or to regulate it closely. Here the proton can be used as a very sensitive probe to determine magnetic intensity in terms of the precisely known gyromagnetic ratio. Problems of this sort arise widely in the use of scientific apparatus—cyclotrons, mass spectrographs, and beta-ray spectrometers—and in industrial equipment such as servo mechanisms and electromagnets. In the method used for the redetermination, the hydrogen protons in a water sample are caused to precess in a magnetic field, and the precession rate is obtained from the frequency of the voltage induced in a pickup coil surrounding the sample. The gyromagnetic ratio is then obtained as the ratio of the angular precession frequency to the field strength.

Increased accuracy was obtained by using a magnetic field that can be calculated to very high precision. This field was produced by an accu-

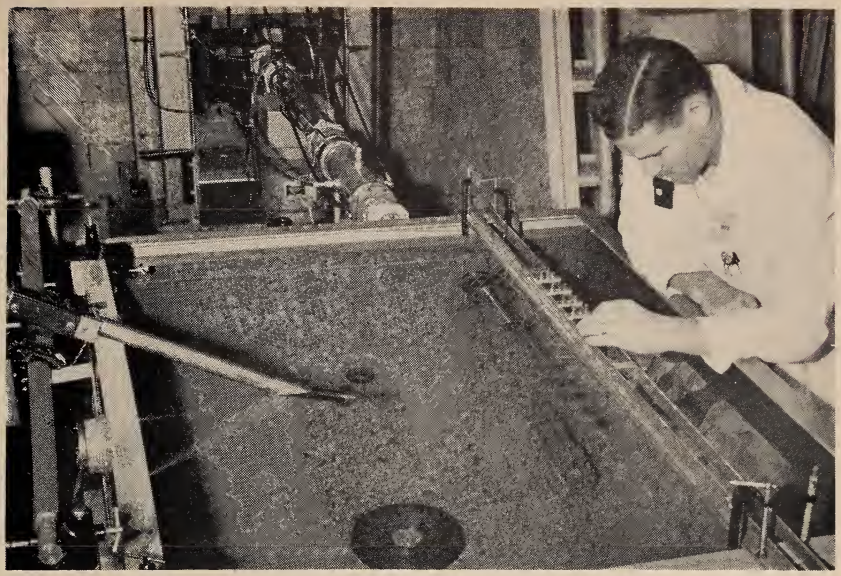
rately measured current flowing through a solenoid whose important dimensions are known to one part in a million. To avoid the interfering magnetic fields from nearby objects, experiments were performed at the Fredericksburg Magnetic Observatory of the U. S. Coast and Geodetic Survey.

Rubidium Vapor Magnetometer. A simple, accurate magnetometer suitable for measurements of the earth's magnetic field was constructed. It utilizes resonance absorption lines in rubidium vapor. This project was undertaken in cooperation with the Fredericksburg Magnetic Observatory of the U. S. Coast and Geodetic Survey. Measurements made with the instrument show that the International Magnetic Standard, in terms of which almost all earth's field measurements are made, differs from the absolute unit by 1 part in 10 thousand.

Structure of Negative Ions. The photodetachment method developed at the Bureau for the Office of Naval Research for studying the structure of negative ions was refined and its accuracy substantially improved. Careful measurements of the photodetachment cross section for the atomic hydrogen negative ion, H^-, now provide an experimental evaluation of several theoretical studies of H^-. The photodetachment method also gave an unambiguous and accurate determination of the energy-level structure of the oxygen negative ion, O^-. This accurate measurement of the O^- photodetachment spectrum provides information of great value for theoretical studies of electron-oxygen-atom collisions. The results of these studies are applied to astrophysical and other high-temperature phenomena as well as ionospheric phenomena.

Neutron "Age". The second of a series of experiments, supported by the Atomic Energy Commission, on the penetration of neutrons in water was completed. This experiment measures the "age," or one-sixth of the mean square of the crow-flight distance that fast neutrons travel while being slowed down to a particular energy. The age of 2 to 3.1 Mev neutrons from the (deuteron-deuteron) reaction for slowing down to indium resonance energy was measured. The result agrees with theoretical calculations, and is of particular interest because the energy of these neutrons is near the average of the energies of fission neutrons. For a number of years, there has been a discrepancy of about 20 percent between the experimentally measured age of fission neutrons in water and the age obtained from theoretical calculations. The agreement of this experiment with theory seems to indicate that the source of the discrepancy is in the experimental value for the age of fission neutrons in water, and not in the theoretical calculations.

Phosphor-in-Plastic Fast Neutron Detectors. Both the speed and efficiency of a widely used scintillation method for neutron detection are improved by substituting organic plastic scintillators for the inorganic phosphors previously used as indicators in plastic buttons. The use of organic plastic scintillators in the plastic medium yields a transparent button which can be made much thicker and therefore about 10 times



Experimental setup for studying neutron slowing down in water. The experiments have shed light on the discrepancies that exist between theory and experimental values for the "age" of fission neutrons in water (page 32).

more efficient than the older type of button. The new button has advantages for many problems in neutron detection and also shows potentialities for use as a neutron dosimeter for all neutron energies.

Penetration of Gamma Radiation. In a continuing program supported jointly by the Department of Defense, the Federal Civil Defense Administration, and the Atomic Energy Commission, the penetration of gamma radiation through matter was studied theoretically and experimentally. Results of this work will aid the development of suitable shelters against radiation from nuclear weapons, particularly fallout-gamma radiation. The theoretical work resulted in large scale tabulations of basic penetration data, while the experiments, carried out at the Nevada proving grounds, provided a measure of the penetration of fallout-gamma radiation through concrete.

Gas Radioactivity Standards. The first gas radioactivity standards were prepared and distributed, and counting equipment for emitters in gaseous form was constructed. The precision of results obtained with this type of counter makes a recalibration of the Bureau's carbon-14 standards desirable. This will be accomplished by counting the C^{14} nuclide in the form of the gas carbon dioxide. A redetermination of the half-life of C^{14} will also be performed in this way.

X-ray Studies. In the investigations of X-rays produced with electron energies between 0.05 and 50 Mev, data was obtained for the energy and angular distribution and for the polarization of the X-rays as a function of electron energy and target material. Special attention was given to the high-frequency limit of the X-ray spectrum, where it

has been possible to obtain good agreement between experimental results and theoretical predictions where no predictions existed previously. Detailed studies of the X-ray production process are now under way in order to obtain accurate information about the angular distribution of the recoil electrons and about various polarization effects that occur in the process. The goal of these studies, supported by the Atomic Energy Commission, is to obtain experimental data which can be used to describe X-radiation under any set of experimental conditions and to check theoretical predictions. Such descriptions are becoming increasingly important because of the wide application of X-rays as a basic tool in modern science and technology.

Nuclear Structure. Research supported by the Atomic Energy Commission has yielded information about the structure of the nucleus. For example, the photoproduction of π° mesons from carbon was found to give a measure of the nuclear matter distribution within the carbon nucleus. The radius of the nuclear matter distribution calculated from these measurements is in good agreement with the radius of the electric charge distribution calculated from electron scattering experiments.

In other work, measurements of the partial cross section (in energy and angle) for the photon induced emission of protons from carbon, leaving the residual boron nucleus in its ground state, indicate considerable photon absorption by quadrupole and higher modes. The measurements will provide a sensitive test of nuclear wave functions. In experiments measuring the photoneutron yields from different nuclei, a correlation was established for the first time between the photoneutron yield and the deformation of the nuclear surface. For a highly deformed nucleus like tantalum, the giant resonance is actually split into two resonances—a fact which has opened up an entirely new approach to the study of intrinsic nuclear quadrupole moments. Correlated measurements, supported by the Air Research and Development Command, showed that the elastic scattering of photons from tantalum can be understood only by considering the tensor nature of the polarizability of a highly deformed nucleus.

Radiation Absorption. Accurate measurements of the total radiation absorption coefficients between 15 and 90 Mev in carbon, oxygen, and aluminum revealed the need for corrections of from 1 to 5 percent in existing pair, production calculations. These measurements, sponsored by the Air Research and Development Command, also provide a sensitive measure of nuclear absorption cross section.

Direct calorimetric measurements of absorbed dose are now possible. A study, which employed a Co^{60} source, gave results in good agreement with the absorbed dose calculated from ionization measurements.

X-ray and Gamma-ray Dosimetry. To provide a better understanding of the processes occurring in photographic film when used for the measurement of radiation, reversal studies were conducted with weak surface developers. The results so far indicate that reversal with X-rays always decreases with increasing exposure rate, as it does with

visible light. Further investigations in the reversal region were made with mixed X-ray exposures leading to different rates of energy absorption in the emulsion.

Silicon solar photocells were investigated in order to test their suitability for dosimetry of X- and gamma-radiation. These photovoltaic cells, when irradiated, produce a photovoltage causing an electric current in an external circuit. As silicon has a smaller absorption of X- and gamma-rays than other semiconductors used in photovoltaic cells, its sensitivity is lower but depends more favorably on the energy of the incident photons. The decrease in sensitivity, due to smaller absorptions, can be easily offset by increasing the sensitive area of the cell.

2.5. Chemistry

The Bureau's program in chemistry includes a wide range of activities in both basic and applied research. Representative activities during the past year in inorganic, analytical, organic, and physical chemistry centered around investigations of analytical methods, development of sensitive criteria for purifying substances and determining their purity, analysis of gas mixtures, automatic high-speed analysis by spectrometric means, studies on mechanisms of electrodeposition and the electrochemical behavior of ion-exchange membranes, determination of chemical constants and the tabulation of scientific data, synthesis of carbohydrates labeled with radioactive atoms, and production and certification of standard samples. These activities were carried out in laboratories that studied organic coatings; organic reactions; preparation, purification, and analysis of materials; electroplating; properties of molecules and electrolytes; gas reactions; surface chemistry; thermochemistry; and spectrochemistry.

Analysis of Small Amounts of Tungsten in Steel. To meet the continual demand for highly accurate methods of analysis and for chemical compounds of unusually high purity, the Bureau conducted numerous projects on purification.

Tungsten in proportions of 2 percent or less is finding increasing application as an alloying element in ferrous metallurgy as it provides improved durability, hardness, and high-temperature properties in steels. Because of tungsten's widespread use, a procedure for detecting its presence and checking for quality control was needed. Therefore the Bureau developed a new photometric method for determining small quantities of tungsten in steels and titanium alloys. This method involves the use of dithiol reagent (1,2-dithiol-4-methylbenzene), which eliminates metal interferences by forming easily isolated metal complexes. Following the removal of these interfering elements, a clear blue tungsten-dithiol complex is formed. This complex is extracted in butyl acetate and its absorbancy is then measured in a photometer to determine the percentage of tungsten present.

Another photometric method—flame photometry—was successfully applied to the determination of sodium, potassium, calcium, and strontium in the presence of other alkali and alkaline-earth ions.

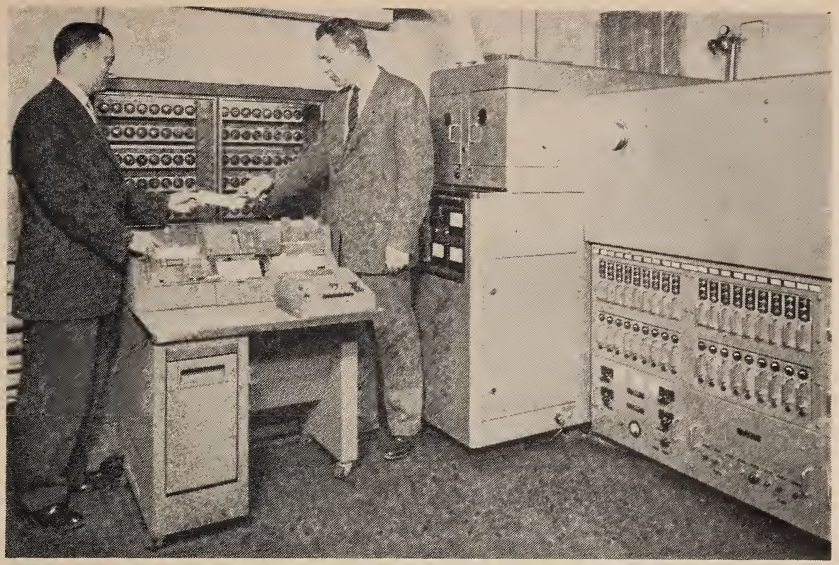
Purification of Titanium Halides. Extensive research on the preparation and purification of various titanium halides was carried out at the request of the Office of Naval Research. The thermodynamic properties of these halides are also being studied in order to evaluate methods for the extraction and refining of titanium. Because titanium has excellent corrosion resistance and a high strength-to-weight ratio, it is considered a promising structural material for aircraft and guided missiles and for applications involving severe corrosive conditions.

To prepare pure titanium trichloride from titanium tetrachloride, a new procedure which eliminates the necessity of sublimation was developed. The process is based on the reduction of $TiCl_4$ in the vapor state by hydrogen. The apparatus is, in effect, made of one large piece of glass with the various components sealed together. No ground joints are used, thus avoiding the interfering reaction of hot $TiCl_4$ with any lubricating grease put on such joints. Then too, by evacuating a sealed system and removing all air and moisture with heat before the addition of the $TiCl_4$, air is prevented from contaminating the starting material. Thus no oxygenated compounds are formed, and the long, drawn-out process of sublimation—which is necessary to remove any interfering oxygenated compounds—is bypassed. Although the conversion yield by this method is fairly low, the recovered $TiCl_4$ can be reused for other runs.

Evaluation of Purity. As part of the program of supplying standard samples of high, known purity, a reliable determination of the degree of contamination is essential. Although this has been accomplished by measuring the change of temperature when samples freeze or melt, the procedure required constant manual control, and results were therefore influenced by the inability to record continuously. Now, automatically controlled equipment has been designed, eliminating most of the observer participation.

Spectrographic Determination of 18 Elements. For rapid spectroscopic determination of 18 elements simultaneously, a unique electronic read-out system was placed in operation. With this system, measurements of the concentrations of elements are made electronically and the results are printed and punched on IBM cards. The cards subsequently are fed into a high-speed computer for statistical analysis of the data. After the sample is inserted, operation of the spectrometer is automatic. The spectral exposure is made for about 30 seconds after which the data of intensity measurements for the 18 elements are read into an electronic storage unit in 5 seconds. Five seconds later, the results are printed and punched on an IBM card. This fully automatic unit—the first of its kind—is being applied to the study of metals and alloys for homogeneity prior to their acceptance as standard sample materials.

Current Integrator. An electrochemical coulometer, which measures amounts of electricity with a precision of 2 parts in 100,000, was developed to integrate variable currents and current pulses. The current is passed through an electrolysis cell where it produces an equivalent



Fully automatic emission spectrometer with punched-card read-out has accelerated homogeneity studies of new standard samples of metals and alloys (page 36).

amount of acid. Then a precisely measured constant current is passed through the cell in the opposite direction and the time required to restore the solution to neutrality is determined. This amount of current, which is readily ascertained, is equivalent to the integral of the original current.

Radioactive Sugars. The basis of organic chemistry is the understanding of the behavior of organic molecules. Because growth in this field is best aided by systematic exploration of general principles and basic reactions rather than by empirical experimentation, isotopically labeled carbohydrates provide a powerful tool for probing the mysteries of biological chemistry. Development of methods for synthesizing C^{14}-labeled sugars and related compounds, sponsored by the Atomic Energy Commission, was extended to tritium-labeled (H^3) compounds. Procedures were developed for the rapid analysis of tritium compounds and for the production of a variety of tritium-labeled carbohydrates.

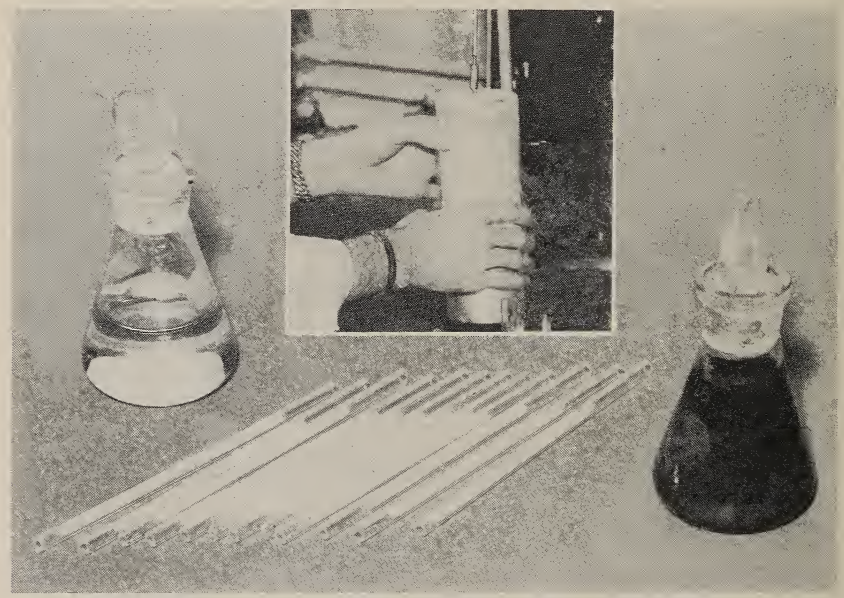
Because branched-chain sugars have been found in antibiotics and a variety of natural products, new sources of these materials are in demand. Certain sugar derivatives were discovered to undergo condensation reactions and to form branched-chain sugars having twice the number of carbon atoms as the parent sugar derivative. A branched-chain 10-carbon sugar derivative was obtained by condensation of 5-aldo-1, 2-isopropylidene-D-xylofuranose. The structure of this unique substance was determined, including the configuration at all asymmetric centers.

Oil-Soluble Metal Standards. The detection of metals in lubricating oils by spectrographic methods provides a simple means for judging engine wear and serves as a guide for maintaining equipment in satis-

factory operating condition. To provide standards for the spectroscopic analysis of petroleum products, the Bureau is developing, under the sponsorship of the American Petroleum Institute, a series of oil-soluble metal analytical standards. About 175 compounds were studied and compounds were selected for use as standards for the determination of 23 elements.

Boron Compounds as Potential Fuels. Boron compounds are of particular interest in the search for new high-energy fuels. Accordingly, experimental and theoretical studies of the thermochemical properties of these materials were made, with the support of the Navy Bureau of Aeronautics. Mass-spectrometric methods were utilized to determine the energies of the chemical bonds between boron and other atoms, and molecular orbital methods were used to calculate ionization energies. In addition, a review of the vapor pressures and dissociation pressures of boron-containing compounds was completed.

Separation of Free Radicals. The possible use of free radicals as concentrated sources of energy is of current interest. Because these substances are normally stable only at very low temperatures, they must be frozen and trapped to be studied. With the support of the Department of Defense, an apparatus which seems promising for the controlled sublimation of molecular species and separation at very low temperatures and under a temperature gradient was designed. (For further information on free radicals, see page 29.)



Compact, portable equipment (insert), used to rapidly collect and analyze small amounts of acetylene dispersed in air (as in smog). Arrow indicates silica gel which adsorbs acetylene. (Other photo.) Flasks of reagent solutions for treating collected air samples. The resultant color is compared with known acetylene concentrations (tubes, center) (page 39).

Instrument for Estimating Night Vision. At the request of the Department of the Army, a device for testing night vision was developed. The instrument utilizes crossed optical polarizers to observe crystals or strained transparent solids. By rotation of the polarizers, the brightness of test objects seen against a dark background can be varied at will and the limit of perception measured. Individuals who can perceive test objects only slightly darker than the background tend to have good night discrimination.

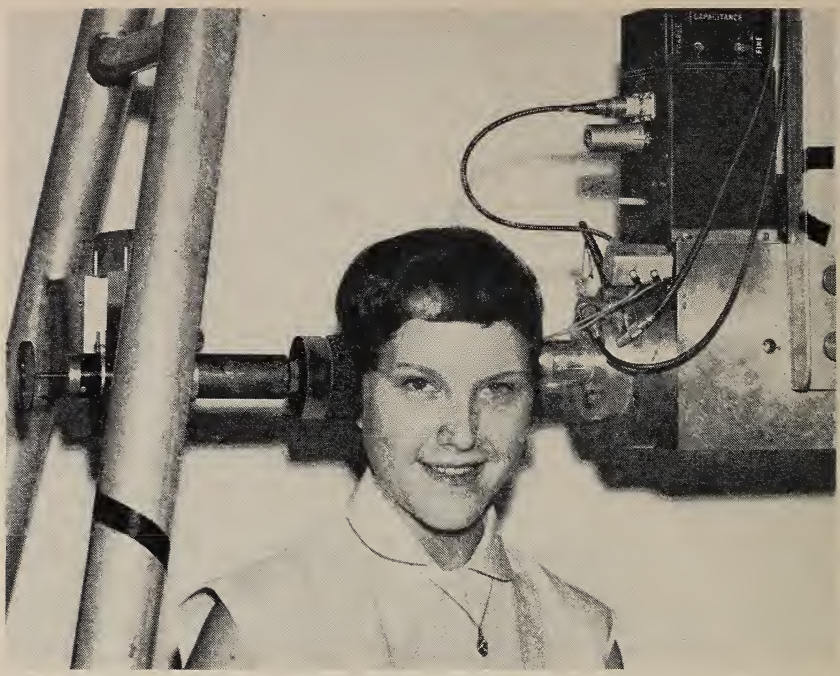
Plasma Jet for Alloy Analysis. The "plasma jet," a new electrical source for exciting the spectra of materials, was developed for the Navy Bureau of Aeronautics. The instrument gets its name from a flamelike jet of ionized gases which appears above the cathode of a specially designed arc. To obtain this gas flame, the solution under study is introduced into the arc which operates on a current of 20 amp. and the vapor produced is carried by streaming helium gas from a constricted channel through a ring-shaped cathode where the flame appears. The very high temperature produced (about 8,000° C) completely volatilizes the solution, decomposes compounds, and excites atoms of all kinds, including helium. This source, which has been applied to the analysis of stainless steel, shows considerable promise for the determination of the major constituents of complex alloys.

Other Chemistry Programs. Other projects studied this year include investigation on the behavior of highly charged colloidal particles; spectrometric identification of trace constituents in complicated gas mixtures (as in smog) for the Department of Health, Education, and Welfare; and determination of the dielectric constant of heavy water from 0° to 100° C. In addition, certification of the *p*H standards, formerly available for the temperature range of 0° to 60° C, was extended to 95° C to meet the requirements of *p*H control in many industrial processes.

2.6. Mechanics

Basic to the Bureau's program in mechanics is the development, improvement, and maintenance of standards, and the development and evaluation of techniques for the measurement of a large variety of mechanical quantities. These include volume capacity, weights and other forces, static pressures, the flow of liquids and gases, vibration amplitudes, and the speed, attenuation, and intensity level of sound. To provide fixed points for comparison and to supplement these basic activities, precise determinations are made of physical constants and properties of materials, such as density, viscosity, and sound-transmission characteristics. In addition, fundamental research is performed in the mechanics of solids and in fluid dynamics.

Acoustic Impedance of the Ear. Establishment of air-conduction threshold standards for hearing requires a knowledge of the acoustic impedance presented by the human ear to an earphone. The problem of ear



Absolute measurement of the threshold of hearing by bone conduction is expected to be of value in the diagnosis of the nature of certain hearing losses (page 40).

impedance measurement hinges on the availability of a physical comparison standard. Although an obvious standard would be an air column, continued measurements and analyses are showing that the behavior of an air column is not completely described by plane-wave theory. As an observed increase in damping with length of column can be explained largely by thermal losses to the column walls, the departures from plane-wave theory appear to be caused by end effects.

Audiometry. To diagnose the nature of a hearing loss, an otologist must know a patient's threshold of hearing by bone conduction, because ability to hear sounds transmitted through the bones of the head is directly related to the sensitivity of the auditory nerve. Accuracy in diagnosis has been hampered by the lack of a standard for normal hearing by bone conduction. Threshold of hearing by bone conduction was therefore measured on an absolute basis for a group of otologically healthy young adults. These results are being used to design a mechanical calibration system for bone-conduction receivers used in hearing measurements.

Vibration Pickups. Recent developments in rocketry, jet propulsion, and high-speed turbines have increased the need for accurate vibration measurements at very high acceleration levels. To meet this need, a method was developed for the Army to calibrate lightweight vibration pickups at acceleration levels above 1,000 *g* over the frequency range

from 500 to above 10,000 cycles per second. By mounting a pickup on one end of a thin aluminum rod, in which the frequencies of the longitudinal modes are much higher than the frequencies of the flexural modes, and by driving the other end with barium titanate vibration exciters, it was found possible to separate the axial resonances from flexural and shear resonances and to obtain good axial motion with large displacements.

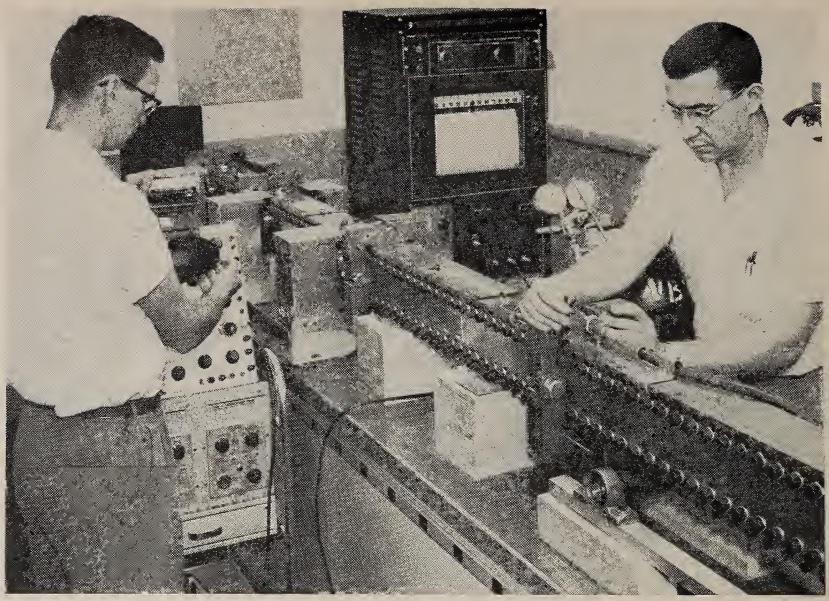
Magnetic Tape Standards. Magnetic tape is used to record data transmitted by guided missiles and satellites during tests, as well as to record data for input to automatic computers. As the usefulness of the recorded information depends on the quality of the tape, standardized tests for selection of magnetic tape are in demand. In studying this matter for the Air Force, it was found that the recording sensitivity of a magnetic tape can be determined from measurements of two magnetic characteristics, the coating thickness, and the length of recording head gap. Assistance is being given to other laboratories in setting up equipment for making these measurements.

Pressure Measurement. Attention was given to the improvement of static and dynamic calibration techniques over the entire measurable pressure range. Under sponsorship of the Air Force, a mercury U-tube standard was designed for calibrating instruments at pressures encountered at high altitudes. In work on dynamic pressure calibrations, sponsored by the Department of Defense, an improved shock tube was developed to provide step pressures up to 1,000 pounds per square inch, and a dynamic calibration device was completed for Aberdeen Proving Ground providing step pressures up to 50,000 pounds per square inch.

Rapidly expanding activity in the area of very high pressures has strongly emphasized the need for a pressure scale based on the physical transformations of pure substances. An initial measurement was made of the pressure at the I-ice-water triple point (about 30,000 psi).

Telemetering Transducers. In the flight testing of guided missiles and aircraft, and in the static testing of propulsion devices for these vehicles, the "weakest link" in the instrumentation has often been the transducer, which senses the pressure, acceleration, or other mechanical quantity being measured. Under the sponsorship of three Department of Defense agencies, the Bureau is carrying on a long-term program aimed at providing additional information on the performance of transducers. The program resulted in the development of testing techniques for transducers and in numerous reports on performance tests of typical transducers used in missile and aircraft testing.

Promotion of Flow by Mixing. Drag is experienced when ships and aircraft move through fluids, such as water and air. Since nature provides turbulent motions which mix the impeded fluids into the outer stream, fluids are kept moving by shaping the body to make the pressure gradient sufficiently small. However, the pressure gradient, or body shape, would require less rigid control if higher rates of mixing than are provided by natural turbulence were obtainable. Under the sponsorship



To improve telemetering transducers and their application to the flight testing of missiles and aircraft, an intensive study of transducer performance characteristics is being conducted. Photo shows a shock tube used to make pressure-sensitivity studies (page 41).

of the Office of Naval Research, the Bureau investigated the mixing problem, exposing the fundamental mechanics of mixing and shedding more light on the relationship between rate of mixing and pressure gradient.

Friction Between Density Currents. Many practically important phenomena involve the movement of superimposed fluids of different densities. These include salt water intrusion into the mouths of rivers and the flow of silt laden water into estuaries or into fresh water reservoirs. In such cases, the movement of the separate fluids depends in part upon the frictional drag between them. The friction at the boundary of a fluid is known only if the flow is laminar, that is, smooth and orderly. However, since one or both of the fluids are often turbulent, an investigation was conducted to determine experimentally the drag which a turbulent fluid exerts upon another fluid. The dependence of friction upon velocity and density in the thin boundary between fresh water and flowing salt water was determined by directly measuring velocity and density variation through the boundary.

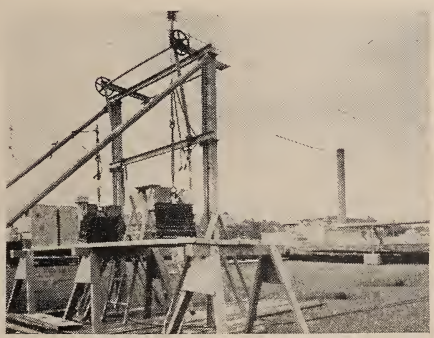
High Strength Aeronautical Fasteners. The restrictions on working space, the requirements of flush construction, and the high loads on modern aircraft have created a need for special fasteners for use in locations which permit access to the head of the fastener only. Under sponsorship of the Navy Bureau of Aeronautics, studies of flat head fasteners provided data and mechanical test methods for fastener specifications.

Creep of Structural Beams. The high speeds which are attained by modern aircraft cause aerodynamic heating in certain critical parts of the structure. Sustained flight under these conditions, which will be possible with atomic-powered craft, may lead to serious creep deformation. Under the sponsorship of the National Advisory Committee for Aeronautics, a program was undertaken to develop design methods for estimating the creep deflections of wing beams subjected to bending.

Suitable methods of analyzing the creep deflections of structural beams were developed around an "elastic followup" technique. Methods of estimating creep deflections which were derived are applicable to a wide variety of built-up beams. Good agreement was obtained between calculated values and the results of creep tests conducted on riveted and extruded I-beams in pure bending and in bending with transverse shear. The analyses are now being applied to tapered multiweb box beams.

Wind-Induced Vibration of Wires. In the rural areas of the United States, wind-induced vibration of telephone and distribution wires damages the wires and increases maintenance costs. The Rural Electrification Administration is sponsoring a test program to study the problem of wind-induced vibrations in an effort to improve the construction of electrical systems and thereby reduce the maintenance costs. Part of this program was to determine the Strouhal number, a dimensionless constant which relates the velocity of the wind and diameter of the wire to the frequency of the forced vibration of the wire. The Strouhal number was measured in a wind tunnel for several circular wires and wires of irregular cross section, leading to a useful approximate formula for the frequency of wind-induced vibration in such wires.

Thermal Stresses in Aircraft Parts. An investigation, sponsored by the Office of Naval Research, provided information on the thermal stresses introduced in aircraft parts by exposure to thermal radiation.



Experimental setup (left) for studying natural wind vibration of telephone wires, which causes a majority of the line failures in the country's wind belt. *Right:* Instruments for making wind-velocity measurements in wind-tunnel tests of the same phenomena (page 43).

Radiation can be an important mode of heat transfer when the temperature of the structure reaches about 1,000° F. The emissivity of the interior surfaces of box beams was varied to determine its effect on temperature distribution, maximum thermal stress, and beam deflection. It was found that, for various beam geometries and heating conditions, increasing the interior surface emissivity of a box beam to blackbody emissivity considerably reduces the temperature gradient at temperatures above 700° to 900° F and the maximum thermal stress and deflection at temperatures above 900° to 1,200° F.

International Density Comparisons. At the invitation of the International Bureau of Weights and Measures, the Bureau took part in an international comparison of density determinations. As part of this comparison, a special cylinder of stainless steel is being circulated among the national standardizing laboratories for an independent density determination of high precision at each laboratory. The average density value obtained at the Bureau agrees with the average of values reported by others within less than 2 parts per million.

Measurement of Jet Engine Temperatures. A continuing program directed toward the improvement of devices for measuring jet engine temperatures is sponsored by the Wright Air Development Center. Because engine temperatures and engine and aircraft speeds are constantly increasing, additional emphasis is placed upon the accuracy of sensor response to sudden changes in the engine. Also, mechanical conditions are more severe in the faster streams of hot exhaust gas in the engines. Thus, improved durability and faster response, two conditions that are inherently incompatible for immersion devices, are desirable. Several resistance-type temperature-sensing elements were examined, and a system for parallel operation of these elements in an engine was analyzed. This system, as are similar systems for use with thermocouples, is designed to permit operation of the temperature measuring and control systems when one or more of the measuring sensors connected in parallel drops out of the circuit because of mechanical failure.

The variation of response with temperature of a thermocouple junction to a sudden change in temperature of the gas in which it is immersed has, until recently, been largely ignored. Because of the increasing requirements for higher accuracy, interest in this variation recently has become greater, and a cooperative program between three industrial laboratories and the Bureau to investigate this phenomenon was undertaken at the request of the Committee on Temperature Measuring Devices of the Society of Automotive Engineers.

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 long, chainlike molecules formed by polymerization. Many of their useful

properties depend upon the size, shape, distribution, and flexibility of their molecules and interaction with other molecules. To advance fundamental knowledge of these industrially important materials and thus to aid in their efficient utilization, the Bureau investigates the mechanisms involved in forming polymers, their constitution, structure, and properties. Studies are also made of the applications of polymeric materials to dental technology.

During the year basic research included investigations of thermal degradation of collagen and plastics, and of the structure and mechanisms of dimensional changes in crystalline fibers. The adsorption of polymers on glass fibers was studied, as well as the molecular constants of polymers. New methods were developed for impact testing leather, and for making torque-speed measurements on high-speed dental drills. Research on properties of materials dealt with problems such as the dimensional stability of map papers, and the radiation resistance of plastic packaging films, and high-temperature resistant fluorine polymers.

Stress-strain Relation for Rubber. The stress-strain relation of a typical pure-gum rubber vulcanizate after a given period of creep can be represented by an empirical equation developed several years ago at the Bureau on the basis of observations of specimens in tension. An examination and analysis of published data on pure-gum vulcanizates showed that the same equation with the same constants also represents data obtained in the compression region with compressions as large as 50 percent, where the relative length is 0.5.

Analysis of Textiles. The expanding array of new and improved textiles accents the need for adequate analytical methods to identify these products. A rapid and convenient technique was developed for identifying the components of very small specimens of finished and coated textiles, and it is also applicable to related materials such as coated papers, adhesives, and plastics. The specimen is fractionated by a series of extractions and the substances present in the fractions are identified from their infrared spectra.

Reference spectra collected for the work include spectra for textile fibers, finishes, coatings, and related materials. This information is automatically recorded on punched cards which permit the mechanical identification of unknown materials from their spectra.

Impact Phenomena in Fibers. The capacity of fibrous materials to withstand high impact stresses and to absorb large amounts of impact energy without rupturing has made them increasingly important to modern industry and national defense. In the Bureau's continuing investigation of the phenomena of strain propagation in impacted fibrous materials, theories leading to analytical expressions for describing the phenomena of strain propagation, reflections, interactions, and attenuation in textile filaments were developed. These phenomena were observed experimentally and evaluated quantitatively with NBS impact testing equipment.

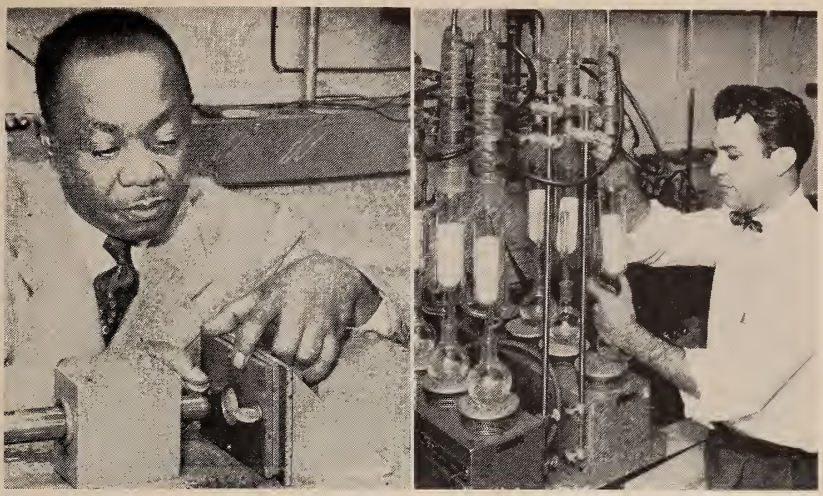
Through the cooperation of the Army Chemical Center, other tests at much higher impact speeds were made for analysis at NBS. Experimental techniques and intricate electronic and microflash equipment developed by the Center were used. The results of these tests not only have practical applications in the design and development of safety lines, seat belts, parachute shroud lines and webbings, cords for tires, and flexible body armor, but they also provide basis information relating to the structure of fibers and the development of fibers and yarns of superior impact properties.

Improved Map Paper. Good dimensional stability is needed in the paper used for multicolored military maps. When such maps are printed by offset lithography, a change in the paper's dimensions, resulting from changes in moisture content between successive impressions with different colors, can cause serious misregistration. Research conducted for the Army Engineer Research and Development laboratories showed that a laminate prepared by bonding two sheets of 2-mil thick map paper to the two sides of a film of polyethylene terephthalate has much lower moisture expansivity, with improved strength properties. Compared with regular military map paper, hygroscopic expansivity was 30 percent less in the machine direction of the laminated paper, and 45 to 70 percent less in the cross direction. Folding endurance was many times greater than that of the regular map paper, while tensile, tearing, and bursting strengths were also increased.

Preservation of Archival Documents. The lamination of archival documents with cellulose acetate film has been practiced for more than 20 years in order to strengthen weak or damaged papers and to protect them against injury from handling. However, as this film was not originally designed for archival purposes, a study was undertaken to develop specifications for cellulose acetate with maximum stability. Sponsors of the program were the Library of Congress, the Army Map Service, the National Archives, and the Virginia State Library.

A laboratory formulation was developed for document laminating film which should be far more durable than the materials previously employed, and specifications have been suggested for use by archival agencies in its procurement. Related studies confirmed and defined the advantages of using tissue paper to reinforce the laminated document, and of neutralizing the acid in documents before lamination to prevent acid deterioration which occurs as the film ages.

Impregnation of Leather. The wear of sole leather was improved 50 percent by impregnation with a blend of elastomers and resins, in a continuing program sponsored by the Navy Bureau of Supplies and Accounts. The treatment is easily applied by immersing tanned, unfilled, unfinished leather in a petroleum solution of polymer blends. The blends consist of an elastomer such as butyl rubber, polybutene, or polyisobutylene, and a resin. The resin is added to maintain the inherent stiffness of the leather and dimensional stability of the soles during wear.



Equipment (left) for testing the strength of leather, its stretch, and tendency to crack. Specimen is being removed from the assembly that clamps it between two plungers, which strike alternately from either side (page 47). At right is apparatus used for extracting and evaluating leather impregnants in efforts to increase the wear of sole leather (page 47).

To insure adequate penetration of the leather matrix, elastomers with a molecular weight under 10,000 should be used.

The improvement in wear was determined in actual service tests with impregnated vegetable-tanned and chrome-retanned soles. The chrome-retanned leather gives longer wear than the vegetable-tanned leather and is a better base material for impregnation. This process is now commercially employed, particularly in the production of boys' shoes.

Impact Test for Leather. In an impact test to evaluate shoe upper leather, a newly-developed machine was used to deliver repeated thrusts to both sides of a specimen until failure occurs. The number of impacts required to produce cracking of the grain and puncture of the leather increases with increase in diameter of the plunger. The load per unit thickness of leather is inversely related to the number of impacts required to produce failure. Examination of the data obtained with the impact tester indicates that resistance to grain cracking, elongation, and puncture can be satisfactorily evaluated.

Straight chrome-tanned leather containing stuffing grease showed higher resistance to puncture than similarly tanned leather containing fat liquor. When both leathers are degreased, their strengths are practically equal. This would suggest that the impact test can also be used to evaluate lubricants in shoe leather. Straight chrome-tanned leather showed much greater resistance to repeated impacting than either chrome syntan-retanned or chrome vegetable-retanned leather. The results obtained for various tannages and for accelerated aging were found to be similar to those obtained in other tests.

High-Temperature Fluorine Polymers. Since most plastic and rubberlike materials fail rapidly at temperatures of several hundred degrees, their use in many types of equipment is restricted. However, some experimental totally-fluorinated aromatic polymers give an indication of better resistance to high temperatures than any organic polymeric material previously known.

A joint program sponsored by the Office of Naval Research, the Navy Bureau of Aeronautics, and the Bureau is underway to discover as many techniques as possible for converting perfluoroaromatic raw materials such as hexafluorobenzene to useful monomers and polymers. New materials that have already been synthesized include pentafluorophenol, pentafluorophenyl polymer, and pentafluorostyrene. Simple ways were also found to prepare, with hexafluorobenzene as a starting material, some crucial intermediates previously known only in small quantities. The preparation of polymers having improved high-temperature properties may now be feasible.

Molecular Constants of Polymeric Materials. As part of a program to improve the methods of determining molecular weights, an absolute photometer was designed and built to measure precisely the light scattered by solutions of polymers. With data from this instrument, the molecular weight and radius as well as characteristic thermodynamic quantities can be determined more reliably than by any method previously reported. Some results show important, previously unknown details of the thermodynamics of solutions under so-called ideal solution conditions. However, with narrow fractions of polystyrene, there is a discrepancy of ± 6 percent between the molecular weights determined by the photometer and by another absolute instrument, the equilibrium ultracentrifuge. Further work is in progress to resolve this discrepancy.

Dimensional Changes in Fibrous Macromolecules. In a fundamental investigation of the physicochemical basis of dimensional changes that occur in systems of fibrous macromolecules, two general types of mechanisms have so far been elucidated. The melting of a highly oriented polymer is almost invariably accompanied by a marked axial contraction and conversely, the crystallization of an oriented polymer results in an increased length. This process, as usually observed, is irreversible unless an equilibrium stress is maintained.

More recently, a second mechanism for developing changes in length was discovered. A highly oriented polymer, cross linked by gamma irradiation, increases in length in the amorphous state on subsequent relaxation. This increase depends on the original orientation and the number of cross linkages introduced. In the case of cross-linked fibrous polyethylene, a 25 percent increase in length in the amorphous state was observed.

When polyethylene fibers cross linked in the prescribed manner are allowed to crystallize from the melt, an increased length manifests itself in the development of a preferential axis for crystallization. Thus an

equilibrium state of oriented crystallization is obtained. On subsequent melting the fiber shrinks about 25 percent and spontaneously reelongates on cooling. This process continues in a cyclic manner without the application of any external force and is a means of converting thermal energy into mechanical work.

These principles should be applicable to crystalline polymers containing reactive functional groups. Also, a system is envisioned that will be capable of converting chemical energy into mechanical work by utilizing an appropriately cross-linked crystalline polymer as the working substance.

Polymer-Glass Adsorption Studies. The adsorption of polyesters from dilute solutions onto glass, silica, and alumina surfaces was investigated. This work is part of a program on the mechanism of reinforcement in glass fiber laminates, jointly sponsored by the Navy Bureau of Aeronautics and the Bureau. The quantity of polymer adsorbed is considerably greater than could be accounted for by a monolayer of polymer molecules lying flat on the surface of the solid; the polymer appears to be deposited in sequences separated by bridges. Polyester adsorption onto glass is irreversible and the temperature dependence is either very small or zero. A large number of sites are available on the solid for bond formation and relatively strong glass-polymer bonds are formed.

Radiation Stability of Plastic Packaging Materials. Plastic films have a potential market as packaging materials for foods which are to be preserved by radiation sterilization and pasteurization. Under the sponsorship of the Army Quartermaster General, an evaluation is being made of the effect of high-energy radiation on various plastic films that may be suitable. Some plastic films, such as polystyrene and polycarbonates, exhibit satisfactory stability when exposed to a high-energy radiation dosage comparable to that required for food preservation.

Stability of Polyvinyl Chloride Plastics. The stability of polyvinyl chloride and its copolymers has been a major problem to the plastics industry because of the polymers' sensitivity to heat, sunlight, and traces of metals. An investigation of the mechanism of degradation of polyvinyl chloride was therefore initiated to provide a basis for the selection of stabilizers on a rational rather than an empirical basis. When polyvinyl chloride was exposed to heat and ultraviolet radiant energy, the gaseous products evolved included hydrogen chloride, water, and benzene. Changes in the chemical structure of the polymer were studied by infrared spectrophotometry. The mechanism of decomposition was found to be a free radical chain reaction with an activation energy of approximately 30 kcal. This study should thus make possible the selection of stabilizers on a rational basis.

Mechanism of Rain Erosion. One problem that has accompanied increase in airplane flight velocities is rain erosion of the radar housing and of the leading surfaces of an airplane. However, a blunt object

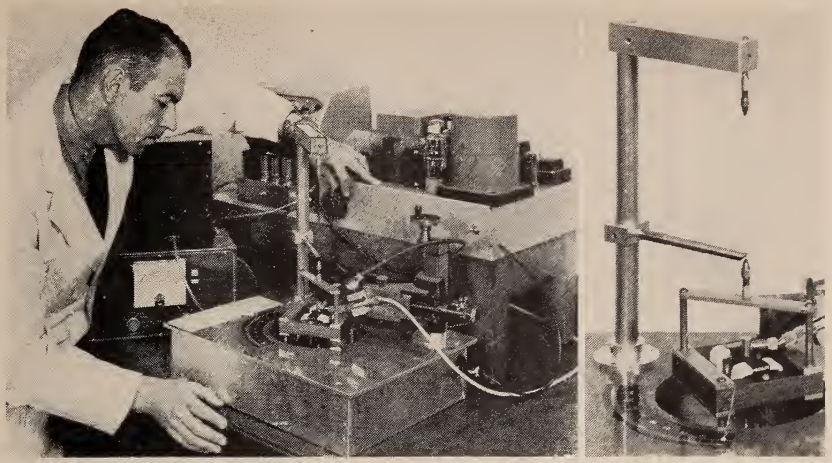
flying at supersonic velocity through air is preceded by a detached shock wave, and a waterdrop should be essentially atomized under the conditions that exist in the zone behind this shock wave. An investigation was made for the Wright Air Development Center to determine whether, within certain limits of random shape and size, and of waterdrop size, this atomization would have time to occur. The results indicate that if the flying object is a sphere having a diameter of 4 feet and if it is moving with a Mach number in the range of 1.3 to 1.7, waterdrops having diameters up to 1.4 mm that enter the zone of detachment will be completely reduced to mist before they impinge on the surface of the sphere.

Vapor Phase Analysis of Polymers by Chromatography. Identification and quantitative determination of the copolymeric constituents of methyl methacrylate polymers cannot be readily accomplished by extractive procedures. The presence of cross-linking agents causes the resulting polymers to be very insoluble in most solvents. So chromatography was used at the Bureau to obtain these data. First the polymer was pyrolyzed at 340° C, and then the vapor phase of the liquid pyrolysate was analyzed by means of a chromatographic column. The presence of 0.2 to 1.0 percent of various comonomers could be detected easily and rapidly. Quantitative estimation of copolymeric components such as methyl acrylate and ethylene dimethacrylate with a precision of ± 1 percent was accomplished by this method.

Low-Angle Diffraction Studies. A special X-ray diffraction camera which can detect periodic spacings of 1000 A (0.1 micron) was used to study the long range periodicity on fibrous polyethylene and in collagen. Polyethylene fibers were shown to contain periods as wide as 480 A; the collagen period was found to be 640 A. Various treatments of polyethylene fibers altered the observed periodic spacing. The results of this work may provide a clue as to the nature of the bond between inorganic salts and long chain polymeric materials.

Speed-Torque Measurements of High Speed Dental Instruments. One of the most significant recent developments in dentistry has been the introduction of handpieces that operate at very high rotational speeds. These instruments have won immediate acceptance from both dentists and patients because of higher cutting efficiency and less annoying vibrations to the patients. The speeds, in some cases as high as 250,000 rpm, have been attained, however, only by sacrificing a high proportion of the torque available with the older handpieces. So a total reevaluation of dental cutting techniques and mechanisms has become necessary. An essential part of such an evaluation must be a method for studying the torque-speed characteristics of the handpieces themselves.

In cooperation with the Air Force, Army, Navy, and Veterans Administration dental services, an apparatus for this purpose was developed that will simultaneously measure speeds up to 300,000 rpm and torques to 30 g cm. In place of the dental bur, the apparatus employs a permanent-magnet cylinder which is braked by means of a synchronous



Equipment designed to make speed-torque measurements of high-speed dental handpieces. The rapidly growing use of such handpieces has necessitated a total re-evaluation of dental cutting techniques and mechanisms (page 50).

external magnetic field. The braking torque is measured as the torsion of a calibrated wire suspension, and the rotational speed is determined from the frequency of the field. The equipment is being used for the evaluation of handpiece designs and to provide background information for studying the cutting mechanism of dental burs.

Denture Reliners. Materials for relining dentures have been available to the dental profession for a number of years and have gained considerable clinical acceptance. A Bureau study of the physical properties of these materials was jointly sponsored by the American Dental Association and the Federal dental services. The materials harden with considerable rise in temperature, and when cured under clinical conditions porous resins are obtained. Because of high plasticizer content, the hardness, indentation and recovery values, and the water solubility are poorer than those for self-curing denture resins. Color stability of the reliners is often unsatisfactory and some relined dentures are very sticky when removed from the mouth. However, flow and detail of the relined denture are adequate, and clinical studies give no significant indication of warpage or dimensional change.

2.8. Metallurgy

Metallurgical research is directed toward a better understanding of the properties of existing metals in order that new or improved metals and alloys may be developed to meet new applications or to give better performance. Studies are made of the effects of treatment, fabrication, and conditions of service on the structure, behavior, and properties of metals and alloys, with considerable emphasis on metals subjected to high temperatures. Information derived from these studies is used to improve the design and operation of jet-propelled aircraft, missiles, and other airborne equipment.

Constitutional Diagrams for Metals. To understand and predict the behavior and utilization of alloys, it is advantageous to have detailed constitutional diagrams that show melting ranges, structural changes occuring at various temperatures, intermetallic compounds, and solubility-temperature relationships. A study was initiated to establish an accurate constitutional diagram for Type 431 stainless steel (16 percent chromium-2 percent nickel). This metal normally can be heat-treated for a combination of high hardness and toughness that makes it greatly desirable for use in the aircraft industry. However, its utility is somewhat restricted because its ductility appears to be highly individualistic from heat to heat, and occasionally a heat of low ductility is produced. The variables of manufacture, chemical composition, and heat treatments, that may cause the change in toughness are not understood, but the constitutional diagram is expected to provide clarifying information.

Commercially Important Alloys. Alloys whose basic compositions include chromium, iron, molybdenum, and nickel are commercially important for use at elevated temperatures. To have a basis for selecting or designing alloys that will retain their strength under prolonged heating, it is necessary to know what solid-state reactions occur. This information is supplied by current investigations in which the composition limits of the reacting phases at the various temperatures are summarized in constitutional diagrams. Examination of several hundred alloys that were heat-treated in the range of 800° to 1,300° C resulted in identifying several phases that had not previously been reported and in determining the temperature and compositional limits of many of the phases in the chromium-nickel, chromium-molybdenum-nickel, nickel-molybdenum, and iron-molybdenum-nickel systems.

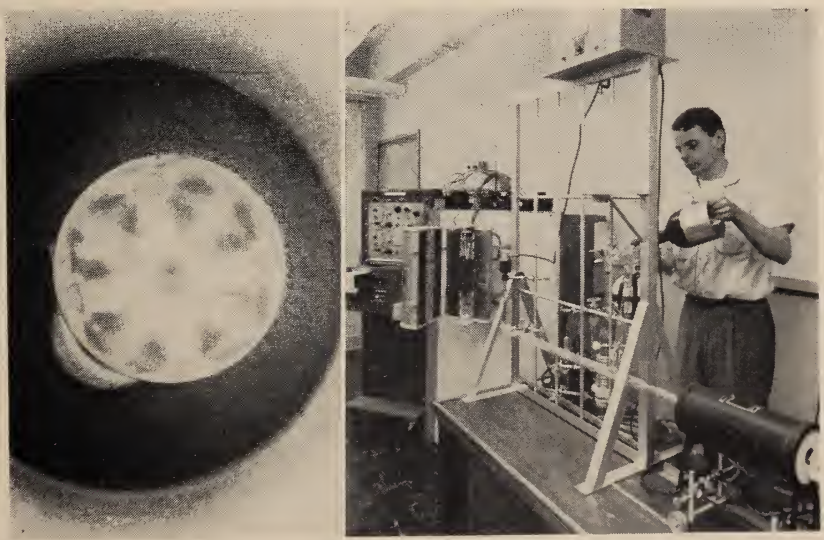
Uranium Alloy Studies. A study of the binary alloys of uranium with the six platinum metals, sponsored by the Atomic Energy Commission, was undertaken to obtain data on compound formation, reaction temperature, and relative solubilities of uranium with these metals. Small additions of the individual platinum metals to uranium produce alloys of lower melting temperatures than uranium itself, but further additions produce intermetallic compounds that may have useful properties. In many cases, the melting points of the compounds are higher than either of the elements from which they are formed. For example, in the uranium-rhodium system, the melting point of a 75 atomic percent rhodium compound is about 2,200° C compared with the melting point of rhodium at 1,966° C. The practical importance of these alloys may be in the development of atomic power, but other uses are being considered because of the relatively high temperatures at which certain of these compounds decompose.

High-Temperature Metals. Steels capable of being fabricated into sheet that retains a high strength-to-weight ratio at temperatures up to 1,000° F are urgently needed for modern aircraft. Investigation of steels capable of structural application in aircraft at tensile strength levels

over 200,000 psi, while at temperatures of 800° to 1,000° F, was conducted for the Navy Bureau of Aeronautics. Thus far, the properties of hot-work die steels of the 5 percent chromium type appear promising in meeting some of these requirements. Accordingly, commercial steels from various manufacturers were procured for an evaluation by tensile and stress rupture tests.

A study to determine the effects of various heat treatments on the mechanical properties of 17 to 7 PH (17-percent chromium, 7-percent nickel, precipitation hardening) stainless steels was continued for Wright Air Development Center. The conditions for heat treating this steel to obtain high strengths in tension at temperatures up to 1,000° F were established. Under appropriate heat treatments, 17 to 7 PH steel develops high strengths at room temperature with sufficient ductility to be suitable for use in aircraft components. However, some data indicate that the steel becomes excessively brittle when exposed for long periods at temperatures of 600° to 800° F. Apparently the change in ductility is affected by time, temperature, and stress. Tests are being conducted to determine whether this is a real phenomenon. If it is, treatments will be attempted to eliminate or ameliorate the effect.

The 17 to 7 PH steels also contain about 1.25 percent of aluminum and small amounts of carbon and nitrogen. How these elements affect the precipitation hardening reaction, the mechanism of the reaction, and the composition of the hardening compound are not definitely known. Metallographic and X-ray examination directed towards the identification of the compound, and tests to evaluate the influence of nitrogen on the mechanical properties of the steel are in progress.



Multicolored pattern (left) formed when a copper single-crystal sphere is corroded in air-saturated distilled water at room temperature. The study of systems involving single crystals is providing a better understanding of the fundamental processes of corrosion. At right is the apparatus used to grow single metal crystals from their vapor (page 55).

The influence of stress, strain rate, temperature, and prior strain history, on the mechanism of creep, flow, and fracture characteristics of high-purity nickel, copper, and two nickel-copper alloys was investigated. It was found that the resistance to creep was materially increased by alloying the component metals. Although experimental results conformed to both the theory of exhaustion and of generation of lattice defects (over limited ranges of temperatures and stresses) during the first stage of creep, none of the existing equations is entirely suited for defining the extension-time relation in each of the three stages of creep.

Under the sponsorship of the Navy Bureau of Aeronautics, a study was initiated of the thermoelastic properties of several metals and alloys to determine modulus-temperature relationship. This study, covering a somewhat broader temperature range than usual, is being made to add to basic information on the properties of metals and alloys, as well as to assist in selecting materials suitable for the fuel metering springs used in modern aircraft engines. These springs are subjected to high and rapidly changing temperatures.

During the year work was undertaken on the design and construction of a soft X-ray spectrometer for obtaining the distribution of occupied electronic levels in metals and alloys in the solid state. As the complete equipment cannot be purchased, it is being built and assembled at the Bureau. Spectrographic data for the solid state by soft X-ray techniques are expected to contribute to a fundamental understanding of alloying, and of the relationship between physical properties and electronic structure. This should lead to the design of special-use alloys, particularly those for high temperature application.

Titanium. An evaluation was made of the effects of variations in stress systems and temperatures on the tensile properties of commercially pure titanium and a titanium alloy containing 4 percent of aluminum and 4 percent of manganese. The study showed that the tensile strength and fracture stress increased and the ductility decreased with either a decrease in temperature over the range of $+100°$ to $-196°$ C or an increase in notch sharpness. The very low ductility obtained with the notched specimens at $-196°$ C was attributed primarily to stress concentrations at the root of the notches. Prestraining unnotched and notched specimens of both materials in tension at $+25°$ C decreased the retained ductility in subsequent tension at $100°$ or $-196°$ C.

Plastic Deformation. Many factors influencing the properties of metals are related to the crystal lattice which can be studied by X-ray diffraction techniques. In the mechanical metallurgy laboratory, work was directed toward obtaining information by these techniques on lattice imperfections and how they are affected by plastic deformation. The results will be of practical as well as theoretical value.

Gage Block Materials Evaluated. A study of material suitable for use in the production of ultraprecise gage blocks was continued. Optimum conditions were established for heat treating and stabilizing several

steels commonly used both for gage blocks and for nitriding types 410 and 302 stainless steels and Nitralloy. Other procedures for producing hard surfaces on gage blocks such as flame and chromium plating, thermospray, chromizing, carbonitriding, and carburizing are being evaluated. Additional material selected and procured for use in the program include alumina, titanium carbide precipitation-hardening stainless, and high-speed tool steel. About 350 gage blocks, ⅜ in. × 1⅜ in. × 2 in., were processed and are under observation for dimensional stability (see page 20). The results obtained in nitriding 410 stainless steel appear exeedingly promising, not only because the gaging surfaces of the blocks are very hard but the blocks themselves can be finished to a high degree of flatness and parallelism. This steel has approximately the same coefficient of expansion as most of the structural steels.

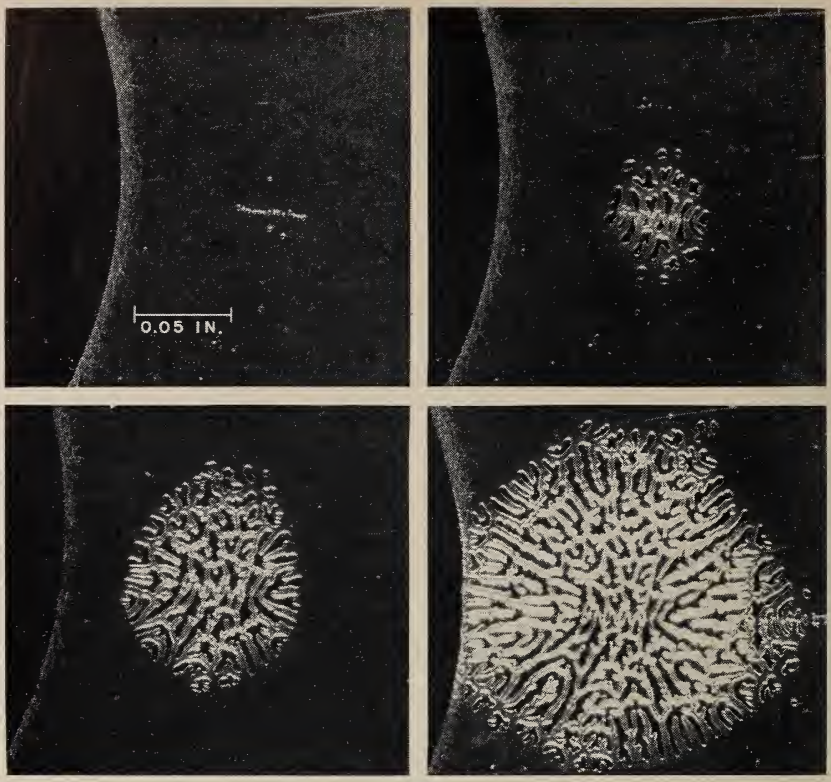
Corrosion. For several years the Corrosion Research Council has partially supported a program of research in basic corrosion processes. In one phase of the work, a study was made of the formation of oxide films on metals in water. It was found that the rate of build-up and composition depended on whether the films were formed in stagnant pure water or in water stirred by bubbling oxygen. The rate of formation was also found to depend on both the crystallographic plane upon which the film was growing and on the oxygen concentration in the water.

Studies of the interactions of free radicals with metallic surfaces at low temperatures were conducted. A reaction takes place at temperatures as low as 4° K when single crystals of copper are exposed to atomic oxygen, but not when exposed to molecular oxygen. This work is part of the free radicals research program supported by the Department of Defense (see p. 26).

In another program partially sponsored by the Corrosion Research Council, the stress corrosion cracking of a magnesium alloy was found to depend not only on the stress applied but also on the strain rate. If the average strain rate exceeds a critical value, the alloy cracks within a few minutes. But if this rate is not exceeded, cracking does not occur during an experiment extending over a 20-hour period.

Experiments on the stress corrosion cracking of stainless steels indicated that the application of anodic currents as small as 0.03 ma/cm^2 can greatly accelerate cracking, but that cracking can be prevented by applying a cathodic current density of 0.04 ma/cm^2. A method was developed for growing single crystals of aluminum and copper of any desired cross-sectional shape and axial orientation within 1 deg. This makes possible the study of the effects of crystal orientation upon metal corrosion and also possibly on other properties of metals.

A study of copper electrodeposited on single crystals of copper revealed that the epitaxial relationships depend on the crystal orientation of the basis metal. On certain crystallographic planes the deposit built up as a continuation of the base structure; on others, as both a continuation and a twinned structure. This study provides information on the bonding



Transparent tape applied to the surface of a metal specimen in which a minute fatigue crack has been induced demonstrates a new effect. As continued cyclic stress is applied, gas evolves in increasing amounts under the tape. The origin of the gas is now being investigated in an effort to shed new light on the processes of metal failure (page 57).

forces of the crystal and should lead to a better understanding of its deterioration during the corrosion process.

Growth of Metal Crystals From Their Vapor. Experiments were performed to find a method for obtaining quantitative data on the growth rate of metal crystals from their vapor. A number of optical techniques were considered and set aside in favor of a thermoelectric method for determining growth rates. Although not yet completely proved, the method appears to be promising. If successful, it will yield data of hitherto unattainable precision and accuracy. It will also allow a critical evaluation of a previous theory of crystal growth which, although generally accepted, has not yet been experimentally proved.

Gases in Metals. Eight steels of the carbon and low-alloy types were certified and made available as standard samples for gases in metals. In addition, a new vacuum-fusion gas analysis unit of modern design was constructed. This unit, currently in operation in studies of techniques for the determination of gases in titanium, will be used in studies of a number of other metals.

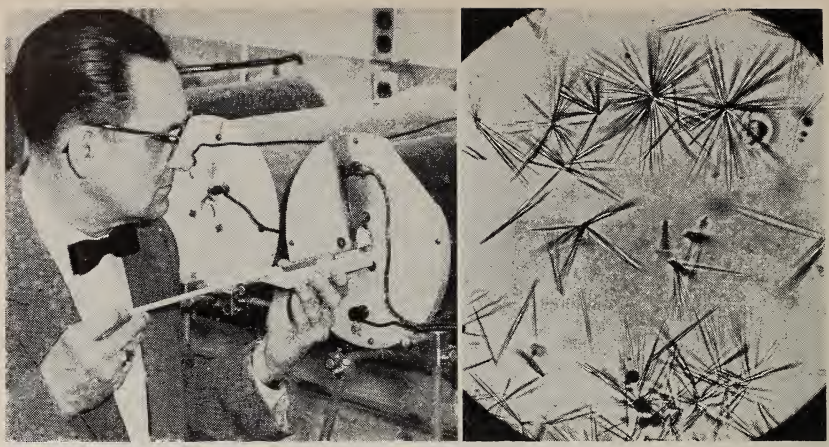
Metal Fatigue Cracks. In a metal fatigue test, transparent tape was applied to the surface of an aluminum alloy specimen in which a minute fatigue crack had been induced by several thousand cycles of stress. When the specimen was then stressed for an additional 1,000 cycles, small bubbles formed under the tape. A series of investigations disclosed that bubbles formed as soon as detectable cracks were present. Even when the cracks were so small they could be seen only with a microscope under special lighting, the bubbles were large enough to be readily seen with the unaided eye. However, in additional experiments it was found that the bubbles could not be produced with some metals. It therefore appears that the phenomenon may be due to surface reactions, but further studies must be made before the mechanism of the effect can be fully explained.

2.9. Mineral Products

The Bureau conducts both fundamental and applied research on a wide variety of inorganic nonmetallic materials. The primary objective of this work is the accumulation of basic data on the general properties, constants, and behavior of these materials as an aid to mineral industries in the production of glasses, refractories, porcelains, pottery, enamels, cermets, and cements. Much of the research during the past year, however, related to the high-temperature properties of these materials. This is due to the increasing need of fundamental knowledge to further research in aeronautical fields such as high-speed flight, and in power sources utilizing new high-energy fuels or atomic energy.

Ferroelectric Materials. Ferroelectric oxides, of which barium titanate may be considered the prototype, have found wide applications as accelerometers, as dielectrics in capacitors, as memory devices for electronic computers, and as transducers in ultrasonic generators. Because there are still many problems in the application of these materials, the Bureau conducted a basic investigation on the relationship between the fundamental structure and the ferroelectric properties of $BaTiO_3$.

Ferroelectric crystals are generally subdivided into minute regions called domains. Although each domain is uniformly polarized along one crystal axis, the direction of this axis varies from one domain to the next. However, some of the most important applications of ferroelectric materials require that the domain axes be more or less alined along one preferred direction in the specimen. This has been accomplished by two procedures. In both, a d-c field controls the orientation—the stronger the field, the more efficient the alinement process. Thus, it is necessary to know the maximum, or "breakdown," field that the material can stand. Since previous measurements indicated only that the breakdown field generally decreased with increasing temperature, detailed measurements were made during the past year on ceramic $BaTiO_3$ over a wide temperature range to gather more information. These data showed not only the general negative temperature coefficient, but also well-defined minima at



Specimen holder and electric furnace used in determining the liquidus temperature and rate of crystal growth in glasses. Liquidus and crystal growth data provide a basis for structural interpretation. *Right:* Micrograph of crystals in glass (page 61).

the ferroelectric transitions at −90°, 0°, and 120° C. Having minima at these points is important for two reasons. First, the depth of the minimum at 0° C shows that the efficiency of the domain alinement process at this temperature cannot be as high as expected on the basis of the older breakdown data. And second, the very existence of the minima indicates that the previously accepted mechanism of simple thermal breakdown is not completely correct and must be modified.

Low-Temperature X-ray Crystallography. To obtain previously unrecorded X-ray diffraction patterns of many low temperature phases, equipment was designed for rapid electronic recordings of data from polycrystalline specimens at temperatures down to 4 deg above absolute zero. In this project, sponsored by the Department of the Army, some new phases were discovered (such as a low-temperature form of ammonia), and basic information was added on the structures of solid ozone, nitrogen, and ammonia.

With the low temperature apparatus, samples can be frozen directly from a vapor whose flow rate can be controlled. In this way, low-temperature glasses—that is, any solid lacking long-range order—were made of water, hydrogen peroxide, ammonia, ammonium azide, hydrazoic acid, and oxygen. However, even those vapors that tend to be frozen into crystalline solids show crystal imperfections. This can be overcome by annealing the solids to form more perfect crystal aggregates.

Phase Equilibrium Studies. Phase equilibrium studies—which are important in the understanding of various ceramic and metallurgical processes, such as glass formation, and electronic-component fabrication—are concerned with the variables of temperature, pressure, and over-all composition governing the composition of the individual coexisting phases. Because germania (GeO_2) is similar to silica (SiO_2) in that it is a glass

former and has the same cation-oxygen ratio and tetrahedral-oxygen coordination, comparison studies of MgO-GeO_2 and MgO-SiO_2 were made. Marked parallelism was noted between the systems in immiscibility, polymorphism, and compound formation. However, a new compound, $4MgO \cdot GeO_2$, which is not observed in the silicate system, was found. This compound is of interest in the formation of commercial phosphors, which are used for such diverse applications as luminous paints, high-speed X-ray films, radar screens, and television tubes.

Phase diagram investigations are also being conducted on the BaO-B_2O_3-SiO_2 system. Within a large compositional range in this system it was observed that two liquids are formed at complete melting, although the usual one-liquid region is found at sufficiently high temperatures. In relation to this, the shape of the two-liquid : one-liquid boundary was determined.

Ceramic Dielectrics. Ceramic systems are assuming an ever increasing importance as essential components of electronic circuits because of their ruggedness, compactness, and temperature stability. Investigating new ceramic compositions in rarer oxide systems, the Bureau found that some compositions of the four-component system, lead oxide-niobium pentoxide, zirconium dioxide-titanium dioxide (PbO-Nb_2O_5, ZrO_2-TiO_2) have promising piezoelectric properties. Studies on PbO-Nb_2O_5 were completed, showing that the desirable high-temperature ferroelectric polymorph of $PbNb_2O_6$ can be stabilized by small additions of ZrO_2 or TiO_2. To study further the crystallography of high-temperature transformations, a systematic X-ray study was made of compounds in the beryllium oxide- and strontium oxide-niobium pentoxide (BeO- and SrO-Nb_2O_5) systems, as well as in the corresponding tantalum oxide (Ta_2O_5) systems.

In the calcium oxide-titanium dioxide (CaO-TiO_2) system (another dielectric system of interest) a new compound of the composition $4CaO \cdot 3TiO_2$ was discovered, which led to revision of the existing phase diagram.

New Data on Silicates and Related Compounds. An understanding of the nature of the forces between atoms and molecules in compounds is necessary for efficient utilization and modification of existing materials in specific technological applications. One method of investigating these forces is by studying the bond properties by infrared analysis. A pressure cell made from a type II diamond, which is characterized by a low absorption spectra band in the 8 to 10 micron region, was completed for obtaining infrared data on solids subjected to high pressures and elevated temperatures. With the infrared spectrometer, data were obtained on silica and germania oxides, both of which exist in several polymorphic forms. The study showed that a new dense form of silica (coesite) was built up of the same silicon-oxygen tetrahedra found in other forms of silica, except that the tetrahedra are more closely packed. Similar studies on a series of garnets and hydrogarnets yielded new information on the relation of the hydrogen in hydrogarnets.

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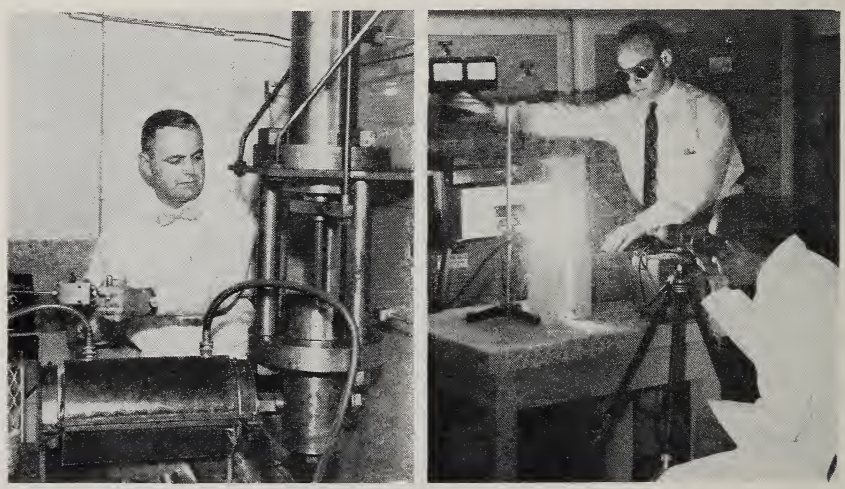
Crystal Structure of Inorganic Materials. The atomic configuration of a compound must be known before the various physical and chemical properties of the material can be understood. One of the most powerful methods of determining the atomic positions of complex compounds is that of single crystal X-ray diffraction. Since this technique was previously limited because of the time-consuming computations required, the Bureau's electronic computer was recently programed to calculate electron density maps for any of the 230 crystallographic space groups.

Standard X-ray Diffraction Patterns. In cooperation with the Joint Committee for Chemical Analysis by Powder Diffraction Methods, a continuing program for the preparation of standard X-ray powder diffraction is being carried out for the Powder Data File. These data are widely used in research and industry as a rapid and accurate method of identifying crystalline phases. During the past year 54 standard patterns were published, replacing 40 cards in the File, and adding data on 24 new compounds. The eighth volume of NBS Circular 539 (Standard X-ray Diffraction Powder Patterns) is in press.

Because many of the powder samples are unstable in the ordinary atmosphere, they must be protected when transferred from a conditioned dry box to the X-ray diffractometer, and during exposure to X-rays. To eliminate this interference, a controlled-atmosphere specimen holder was designed. This cell consists of a spherical metal chamber with a transparent plastic window to permit X-ray penetration. In assembly, the sample is mounted in the center of the cell and the cell is bolted shut. Because of the simple operation, the cell can be conveniently assembled directly in the dry box and then moved to the diffractometer.



The demand for improved high-temperature materials has put special emphasis on the study of the properties of materials at high temperatures. Typical NBS studies include the melting behavior of ceramics (right), and the effects of high temperatures and high pressures on crystallization (left).

Radiation Control for Rockets and Satellites. Radiation is the only mechanism of heat transfer to or from a satellite or other vehicle traveling in outer space; hence the energy absorbed and radiated by the outer skin material will control the heat balance and the equilibrium temperature achieved by such a vehicle. This control is essential to ensure satisfactory operation of the electronic components of current satellites, and will be even more critical for the manned space vehicle of the future. Data on heat radiation or emittance properties are thus urgently needed not only on materials for vehicles in outer space but also on materials for aircraft and missile components operating within the atmosphere.

For these reasons equipment was designed for the Army Ballistic Missile Agency to evaluate total hemispherical emittance by modifying the hot filament method. Data were obtained over the temperature range 100° to 1,100° C on the total hemisphere emittance of three alloys of interest to the current rocket program at the Redstone Arsenal. Equipment was also designed for the evaluation of normal spectral emittance of coated and uncoated metal specimens over the temperature range from 350° C to slightly below the melting point of the alloy, and over the wavelength range 0.3 to 40 microns.

Mechanism of Ceramic-Metal Adhesion. Although strong bonds between ceramic materials and metals are essential for the successful manufacture of such diverse products as electronic tubes, fluorescent lights, and porcelain-enameled architectural panels, no widely accepted theory to explain the bonding mechanism has been established.

Experiments performed at the Bureau several years ago showed a correlation between roughness of interface and adherence of porcelain enamels to steel. When similar enamels were applied to stainless steel, however, a good bond was sometimes observed without any detectable roughening of the stainless-steel surface.

In recent experiments, a relatively simple ceramic-metal system was studied in an attempt to discover some of the basic factors responsible for bonding. Small gold pellets were melted on polished silica plaques in a furnace with varying oxygen content. After the samples were cooled to room temperature, the bond strengths were determined by measuring the force required to shear the pellet from the silica surface. Results showed that bonding occurred only when oxygen was present, and that bond development was independent of the degree of wetting.

A second type of test using radioactive gold (Au^{198}) as a tracer showed that bonding occurred only when gold diffused into the silica lattice. Electron micrographs indicated that a good bond could develop without appreciable roughening of the interface.

Glass Transition Temperatures. In studying or using glass-forming materials, it is necessary to define a transformation temperature above which the material is considered an undercooled liquid and below which it is considered a glass. Since the transformation from an undercooled liquid

Gold pellets fused on silica plaques in a high-temperature furnace are used to study the strength of ceramic-metal bonds. When the pellet was sheared from the silica surface (right), fracture occurred in the glass rather than at the interface, showing good bond strength (page 61).

to glass is probably controlled kinetically rather than thermodynamically, the value of the transformation temperature for an material will vary slightly. Because the accuracy with which a scientifically useful value of this temperature can be defined is of scientific importance, an investigation was started on various glass-forming materials representative of the vitreous state in general.

Current measurements are on mixtures of calcium nitrate and potassium nitrate. The glass transformation temperatures are determined as the temperature at which the slope of the volume-temperature plot changes when the material reverts from the undercooled to the glassy condition or vice versa. This temperature is determined for various rates of cooling or heating.

Chemical Analysis of Cements. X-ray fluorescence methods—which give in a few minutes results comparable to those requiring hours to obtain by other analytical methods—were adapted for determining the major constituents of portland cement. Studies were made on the suitability of various analyzing crystals and detectors as well as on the effectiveness of pulse-height discrimination and helium paths for detection of calcium, silicon, iron, aluminum, manganese, magnesium, and sulfur. The method may prove to be a valuable tool for routine production-control testing.

Coatings for Supersonic Vehicles. Vehicles traveling at supersonic speeds within the atmosphere are subject to severe heating from atmospheric friction. Because high temperatures are detrimental to essential metallic components, the heat must be disposed of without allowing the components to become excessively hot. One solution to this problem is to provide coatings that will withstand high temperature, have low thermal conductivities, and have a high capacity to radiate the heat generated in them. At the request of the National Advisory Committee for Aero-

nautics, a new type of coating was developed by the Bureau to meet these requirements. This coating was prepared by mixing inert ceramic fillers with an aqueous solution of monoaluminum phosphate. Hardening and moisture stability, requirements necessary for airframe materials and assembly procedures, were achieved by curing for 2 hours at 400° F or for ½ hour at 600° F.

Refractory Castables. Because refractory castables are suitable for use over a wide range of temperatures, they are being utilized in a variety of installations including ballistic missile take-off pads and jet warmup aprons. These castables consist essentially of a mixture of a heat-resistant aggregate and a hydraulic aluminous cement—which becomes resistant to temperature changes when combined with water, cured, and dried. At ordinary temperatures the hydraulic bond of the cement holds the castable in a rigid shape. As the castable is heated, the hydraulic bond gradually changes to a ceramic bond, with a consequent change in mechanical properties. To better understand the mechanisms involved in these changes, an investigation of the physical and chemical properties of aluminous cement and its components was undertaken during the past year.

From the data obtained in this study a schematic diagram was constructed to illustrate the major changes in mineralogical composition which probably occur during the hydration and subsequent heating of aluminous cements. Comparison of this diagram with corresponding transverse strength, dynamic modulus of elasticity, and thermal expansion values showed that a definite correlation existed between the mineralogical composition and these mechanical properties.

Standard Glass for Measurement of Physical Properties. Standard glasses that can be used for calibrating instruments which measure viscosity, surface tension, or other properties of glasses at elevated temperatures are needed by research laboratories. Also needed is a series of simple two- and three-component glasses that can be used for studying the structure and constitution of glass. For these reasons, measurements on the properties of soda-lime-silica glass, which will be the first of the standard glasses, is under way and measurements of viscosity in an intermediate temperature range have been made. In addition, apparatus suitable for precise measurements up to 1,450° C was constructed.

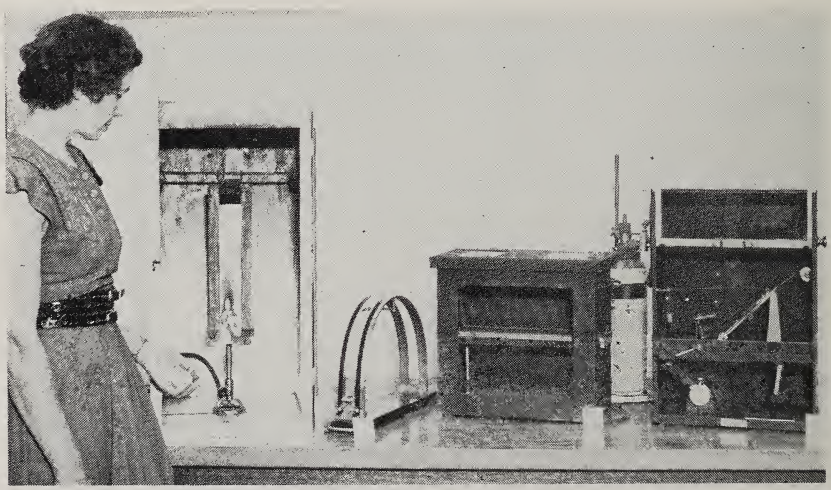
2.10. Building Technology

The Bureau conducts research in the fields of chemistry, physics, and engineering to assist the building industry in making advantageous use of scientific knowledge and techniques. It also assists other Government agencies in solving special technical building problems. Research emphasis is directed toward increasing knowledge about the factors affecting the performance of buildings, their facilities and equipment, the behavior of structures under various conditions, and the nature of the physical

processes that result in changes in materials in different environments. Much of the data are used in the development of specifications and standards prepared by technical organizations, and in manuals of design.

During the year significant improvements were made in the precision of measurements of the thermal conductivity of metals over the range −150° to 750° C; a new technique was developed for determining the self-ignition properties of materials; substantial progress was made in developing methods of testing and new design criteria for underground insulated pipe; further progress was made in developing methods for separating asphalts into their components and in applying chromatographic and spectrometric techniques to studies of the chemical and physical processes of asphalt deterioration; and a contribution was made to a better understanding of the mechanisms of diagonal tension failures of reinforced concrete structures.

Fire Hazards of Common Combustible Materials. Because of the complexity of the behavior of fires and the lack of understanding of the mechanisms of either the growth or the inhibition of fires, only arbitrary methods for measuring the fire hazard properties of materials have been available. However, significant progress was made during the past year in measuring the ignition properties of solids and liquids by means of an adiabatic furnace. The kinetic reaction constants measured in this manner can be used for predicting the size of pile and the ambient temperature which may be considered safe for the storage of combustible material over prolonged periods. Such information is of value not only to manufacturers and others concerned with transporting and stockpiling ordinary materials, but could help determine safe conditions for storing rocket fuels and explosives.



Four devices for measuring and evaluating fabric flammability are shown left to right: Vertical test for flame resistance, British semicircular test, horizontal flame spread test, and inclined flammability test (page 64).

Fire Retardants for Fabrics. A study of the effectiveness of five fire-retardant treatments for fabrics was completed, and the methods used for measuring retardancy were reconsidered.

Fabrics studied included cotton and rayon textiles of various weaves and color. Although they provided a considerable range in finish and weight, four of the five fabric samples were considered well suited for fire-retardant treatments. Of the seven different treatments applied to the fabrics, all tended to stiffen the fabrics, some slightly, others severely. A simple water-soluble treatment was as effective a fire retardant as any, but other treatments tended to retain their effectiveness better after laundering. The data disclosed not only a lack of concordance between the results of flame resistance tests made by different methods but also the need for research to develop better methods to measure the fire hazard properties of fabrics.

Standards for Refrigerated Trailers. A method for determining the cooling load of refrigerated trailers is currently under study in a program sponsored by the Truck-Trailer Manufacturers' Association, the U. S. Department of Agriculture, and the Quartermaster Research and Engineering Command. The objective is to develop a standard laboratory rating method that can be applied to refrigerated semitrailers under simulated road conditions. At present no standards exist for rating truck and trailer bodies for heat transfer, moisture gain, and air leakage, nor

Specially equipped tractor used to develop standard test methods for determining the heat transfer and air-moisture leakage of refrigerated trailers **(page 65).**

for rating the refrigerating units that cool them. Insulated bodies and refrigerating units are matched largely by empirical rules even though this type of transportation represents a one-hundred-million-dollar a year industry.

The importance of air leakage and moisture transfer on a total cooling load was shown by comparative laboratory and road tests. The pathways and mechanisms of air and moisture movement appeared to be controlled principally by the air pressure pattern produced around the body when in motion. The proposed rating procedure consists of a laboratory measurement of the steady state heat transfer rate of a trailer, determined while the interior is maintained at 0° F, the ambient conditions are 100° F dry bulb temperature and 50 percent relative humidity, and with a static air pressure on the nose of the trailer simulating the ram air pressure at a road speed of 50 mph.

Underground Pipe Insulation. For the past several years the Bureau has been studying methods for insulating underground steam and hot water distribution systems under the sponsorship of the Office of the Chief of Engineers, the Bureau of Yards and Docks, and the Air Force. The investigation is intended to provide data on the insulating properties, water permeance, expansion characteristics, and chemical and mechanical stability of insulating materials and on the principles of simultaneous heat and moisture transfer in insulating materials and soils under simulated service conditions. Although this project is not yet completed, sufficient data and information have been gathered to serve as a basis for tentative criteria to design a good protective system for underground heat distribution piping. These criteria were used by various Federal agencies as the basis for writing new specifications that will be essentially uniform in their requirements.

Conductive Flooring in Danger Areas. Sparks resulting from the accumulation of static electricity constitute a danger when explosive vapors are present. An effective means of mitigating this hazard lies in keeping the electrical resistance between objects in the hazardous location so low that dangerous sparking potentials are never attained. Most objects normally rest or move upon the floor and therefore can be electrically connected by way of the floor if it has sufficient electrical conductance.

In cooperation with agencies of the Department of Defense, all types of conductive flooring materials recommended for use in hospital operating suites were evaluated in the laboratory and in the field. This included investigating instruments and methods pertinent to the testing of conductive flooring. A report on electrical and nonelectrical properties, and a proposed purchase specification were prepared for eight types of electrically conductive flooring materials.

Degradation of Asphalt. In the course of the Bureau's studies of the mechanism of asphalt degradation this year, asphalts were separated into their components and the components were weathered separately

and in different combinations. Changes due to weathering were observed by infrared spectrometric and other techniques, and a technique was developed for taking infrared spectra of whole asphalts, using films from 1 to 2 mils in thickness.

The effect of a number of antioxidants on the weight losses and durabilities of asphalts exposed to accelerated weathering was determined, and a study of the relationship between the physical properties and component distribution of an asphalt during the blowing operation showed that the softening point and asphaltene content increased linearly with the time of blowing. Other work indicated that of two asphalts having essentially the same physical characteristics, the one with the lower asphaltene content had the greater durability on exposure to the weather.

Strains in Reinforced Concrete Beams Having Diagonal Cracks. In cooperation with the American Iron and Steel Institute, beams of unusually small ratios of span to depth were investigated when loaded to cause failures by diagonal tension. Numerous measurements of strains showed that, after the formation of the typical diagonal cracks, the maximum longitudinal compressive strains occurred between the extreme fiber and the neutral surface rather than at the extreme fiber as predicted by theory. This result implies distortions of sections that were originally plane. The strains also indicate that longitudinal reinforcement of large bars resists a significant part of the external shear after the formation of a diagonal crack. However, the shearing force in the bars decreased rapidly as the load approached the maximum, and the evidence available indicates that the shearing resistance is not of practical significance except for beams of unusually small ratio of span to depth.

Drying Shrinkage of Concrete Masonry Units. To develop an improved, rapid method of determining the drying shrinkage of concrete masonry that indicates the potential shrinkage under service conditions, a study was made of the shrinkage characteristics of concrete units. Tests on autoclaved and low-pressure cured blocks of several different aggregates showed that the shrinkage may be determined rapidly at room temperature by the use of thin laminas removed from concrete units at right angles to the face shell. The shrinkage of the thin laminas correlates well with that of the control specimens of full-size blocks under the same exposure conditions.

Moisture in Insulated Roof Constructions. Moisture in the insulation of insulated roof deck constructions reduces their insulating value considerably, causing heating and air conditioning loads which exceed design estimates based on dry materials. Moisture may exist in roof insulation, either because it was present initially when the roofing was applied, or because it had entered through leaks in the roofing. In an investigation for the Department of Defense, specimens of typical roof constructions were exposed to simulated winter and summer daily solar heating. The results show little tendency for the moisture to be expelled. However, some types of construction that allow vapor flow through the

An improved method for determining the drying shrinkage of concrete masonry is being studied. The shrinkage of a thin lamina (left) was found to correlate well at a relative humidity of 30 percent with that of the full-sized blocks (right), and can be measured in a much shorter time (page 67).

undersurface of the structures recovered their insulating values markedly during a summer test exposure condition, even when the initial moisture content was high. The investigation is therefore being directed toward development of information on designs and factors which promote the self-drying of roofs in service.

Thermal Conductivity of Metals. To satisfy requests from Defense Agencies and industrial laboratories for accurate measurements of the thermal conductivity of metals over a wide temperature range, the Bureau's existing apparatus was modified to permit measurements at temperatures from −150° to 750° C. At the same time, the apparatus and procedure were modified to permit calculations of the final results from observed data by means of the IBM 704 computer. These changes have significantly increased the precision of the measurements while reducing substantially the time required to make them.

Capacity of Horizontal Plumbing Drains. Experiments were conducted to determine the flow capacities of nominally horizontal drains under conditions of surging flow, such as actually occur in plumbing drains in service. The findings provide a basis, useful to design engineers and code writers, for significant changes in design procedure which can result in appreciable savings of materials and labor in plumbing installations.

2.11. Applied Mathematics

The Bureau maintains a central applied mathematics facility which conducts basic and applied research and renders advisory services in various mathematical fields. The services of the applied mathematics facility are available both to the Bureau's technical staff and to other government agencies. Equipped with modern computing aids, including high-speed digital computers, the facility has played a significant supporting role in the Bureau's research and development program. The work covers a wide range of investigations and applications in engineering and the physical sciences. In addition, an increasing share of the Bureau's mathematical effort is devoted to applying digital computers to problems of the type encountered in business management and operation, sometimes referred to as "data processing" problems.

During the past year, the applied mathematics facility placed research emphasis on statistical and numerical analysis and mathematical physics. In addition to consulting services in applied mathematics, including mathematical statistics, extensive attention was given to problem formulation and analysis to determine and, if necessary, develop numerical methods for the solution of problems on automatic and nonautomatic computing machines.

Approximation Theory. The numerical integration of periodic and analytic functions was compared by means of the trapezoidal rule and the Gaussian rule. It was discovered that the efficiency of one rule over the other depends strongly upon the singular behavior of the integrand in the complex plane. Therefore criteria were developed for determining which rule is the more efficient for a given integrand. In addition, preliminary theoretical studies were undertaken of the relative accuracies of polynomial approximation and rational approximation to a given analytic function. A digital computer code which permits calculations of the best (Chebyshev) polynomial approximation to a given function resulted from this work.

Studies were also made of a method of summability recently proposed by Lototskii. An attempt is under way to generalize Lototskii's results and to determine possible areas of application to numerical analysis.

Matrix Code Studies. In a program for testing matrix codes, sponsored by the David Taylor Model Basin, the precision of inverting matrices is being correlated with their p-condition number. A collection of a dozen representative matrices with a large spread of p-condition numbers was subjected to a variety of codes on various computing machines throughout the country. A comparative study was made of the results and significant information was obtained about the correlation. The same program will be carried out with codes for eigenvalues and eigenvectors. Under the sponsorship of the Office of Naval Research, further results were obtained on the location in the complex plane of the eigenvalues of matrices, and extensive research was conducted in other mathematical topics applicable to numerical analysis.

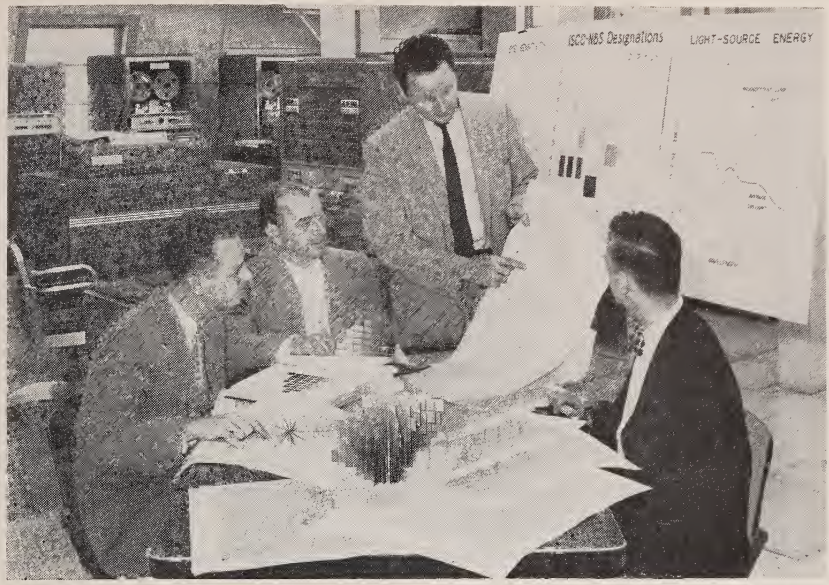
Eigenvalue Theory for Differential Operators. In eigenvalue theory for differential operators, significant progress was made, both theoretically and numerically. Application of Aronszjan's theory of bounds to symmetric operators with a perturbation term was carried out and the method was used to find lower bounds for simply excited and bound energy levels of helium and lithium. Numerical estimates are being obtained with a computer code which evaluates the integrals that intervene.

Mathematical Tables. Work was begun on the preparation of the *Handbook of Mathematical Functions* with the support of the National Science Foundation. The volume is designed to cover the entire field of special functions and will contain methematical properties, graphs, and comprehensive tables. Each chapter—devoted to a special function—lists in detail the mathematical properties important in computation and includes a section on numerical methods to illustrate the use and extension of the mathematical tables. Graphs are provided to describe the analytic behavior of the functions. Also included in each chapter are pertinent definite and indefinite integrals, infinite series, inequalities, differences, and differential equations, together with a list of references to primary sources.

As a result of the Bureau's program of computing mathematical tables of wide-spread interest and importance to the physical, chemical, and engineering sciences, tabulation of the exponential integrals of complex arguments was published, a table of natural logarithms for arguments for 5 to 10 decimal places was revised, and compilations of Airy integrals and Sievert's integrals reached their final stages.

Digital Computation. The availability of a modern electronic computer (the IBM 704) has contributed to a considerable growth in the Bureau's computation program. For example, spectrum analysis computations were reprogramed in a more extensive form and established as a routine problem, and crystal structure calculations were modified to include a complete program for three-dimensional Fourier series summations. Other projects also placed on a routine production basis include the evaluation of thermodynamic functions, optical ray tracing, thermometer calibrations, electron penetration, computations for colorimetric problems, thermodynamic properties of gases, calculations for d-spacings, nuclear scattering of photons, and crystal structure calculations. Additional problems programed include the study of a magnetic field from a local source in a thin ferro-magnetic sheet, computation of hydraulic elements for circular pipe sections, determination of viscoelastic properties of materials, calculations of the response function in the measurement of the energy spectrum of rays, and the NBS payroll calculations.

Reliability Studies. Research on statistical aspects of the reliability of components and assemblies led to the formulation of mathematical models for the analysis of experiments on the aging of components. Methods for estimating the pertinent parameters in these experiments were worked out. This work, which is applicable to a variety of aging



Automatic reduction of spectral reflectance data into colorimetric and Munsell terms by high-speed digital computer has accelerated the work in colorimetry and photometry (pages 17, 70).

studies, formalizes and improves methods of analysis that have previously been based on intuitive grounds. A method for making multifactor studies in life-testing programs was evolved for use in studies where the experimenter can preset certain environmental factors affecting performance. Investigation of mathematical models to describe interdependence of components continued, with particular attention given to the resulting needs for new data on failure and reliability.

Experiment Design. The use of factorial designs has now become widely accepted as an efficient way for carrying out experiments involving many different factors. However, one of the main difficulties with factorial designs is that the number of measurements required may be large and in some cases prohibitive. Another disadvantage is that in many experimental situations it is not practical to plan an entire experimental program in advance. Instead, the program is restricted to a small experiment which serves as a guide to further work. This condition is especially true when measurements are made singly or in small groups, in such a way that the experimental results become known sequentially as they are taken. There are presently available catalogs of the 2^n series and the 3^n series, but not of the 2^m 3^n mixed series. Therefore, a method involving the direct product of matrices was developed for the analysis and for use in construction of fractional replicates of the 2^m 3^n mixed series designs. This method greatly simplifies the formation of the normal equations for the design and reduces the analysis to manageable proportions. With this new development, the construction of a catalog of such designs was begun under the sponsorship of the Bureau of Ships.

Continuum Mechanics. In fluid-mechanics research for the Office of Naval Research, the Stokes flow problem was solved for several axisymmetric bodies not hitherto considered, and certain new theorems in the theory of Stokes flow were proved. An exact solution of the problem of the unsteady water wave in a straight channel of arbitrary slope was given; previously, only numerical solutions for this type of problem have been available. A particular case worked out in detail specified a wave produced by the sudden release of a triangular wedge of water (the dam-break problem).

Work in elasticity for the Air Research and Development Command was for the most part concentrated on the theory of plates and shells. Work on the bending and stretching of corrugated diaphragms was completed. This analysis may be considered the most accurate available on this subject and has important applications in the field of instrumentation. A study of the bending of elastic plates of variable thickness was started; in particular, the circular plate with variable axially symmetric lateral load is under consideration.

Theory of Orbits. In connection with the Office of Basic Instrumentation, a study of the influence of the "rotation wind" on the inclination of the orbit of a satellite was instituted. This investigation may be broadened into a more elaborate study of the transition from an elliptic to a ballistic missile orbit.

2.12. Data Processing Systems

The Bureau's program in data processing systems includes research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. The Bureau serves Government as a central agency for providing comprehensive and readily available information in both the development and application of high-speed automatic data processing systems. As a result, a great number of requests are received from other Government agencies for assistance and advice relative to their data processing problems in engineering, management, and operations research, as well as control systems and simulation. These advisory activities strengthen the Bureau's basic computer program, which ranges from research in components, circuits, systems, and simulation to advanced work in new computer applications.

SEAC as a Research Facility. The experimental modification, operation, and maintenance of SEAC has been a continuing responsibility. Since it was reoriented from a scheduled scientific computational facility to a research and development tool for new computer systems and specialized areas of application, the memory has been expanded to 2,048 words to facilitate try-outs of larger-volume data-processing problems. During the past year, provision was made for parallel input-output with alphanumerical representation, and for handling information from the analog computer. A high-speed photoelectric paper tape reader and punch were incorporated in the system. Testing of the versatile high-

speed multichannel magnetic tape system for parallel input and output is in process.

Analog Computers. The analog computer is an additional facility for the solution of problems in connection with the Bureau's scientific programs and also an important part of the simulation facility for solving various problems in simulation of physical systems. It was augmented by two new GEDA function generators and one 6-amplifier summing unit. For the large X–Y plotter, an rf pickup was procured, simplified modal conversion was arranged, and a sampled-data smoother was designed and constructed.

Pilot Electronic Data Processor. The system design plans for the new NBS Pilot Electronic Data Processor are now virtually completed, and the engineering necessary for its physical construction is under way. This general-purpose system is suited to the processing of digital information at very high speed, and when completed is to be utilized for experimental investigations on a wide variety of large-scale problems of special importance to the Government.

To enable the machine to be used as a research tool for such varied purposes, the system was designed to include a number of different characteristics that are not ordinarily associated with one machine, such as high computation rate, flexibility of communication with the outside, and a wide variety of internal processing operations. The system contains three independently operating computers, each of which is specially adapted for performing certain special classes of operations that frequently occur in large-scale data-processing applications. The system thus provides a working model of an integrated multiple-computer network.

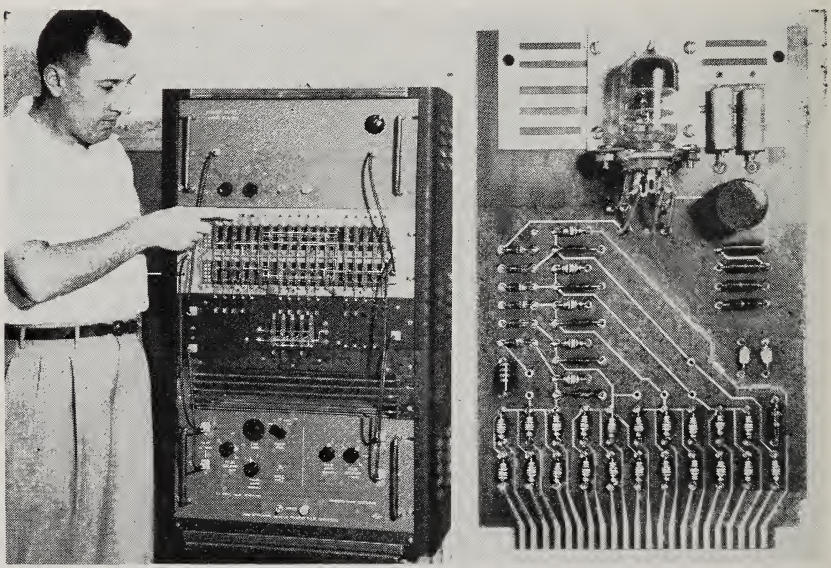
Components and Techniques. Under the sponsorship of the Air Force Cambridge Research Center, instruments were constructed to perform measurements on samples of new switching transistors; transistorized read, write, and control circuits for magnetic tape input-output searching systems were developed, and the transistorized diode-capacitor memory was tested. In addition, work on the d-c stability and drive capabilities of an Eccles-Jordan transistor flip-flop, and on the development of a high-speed or-inverter circuit was completed. Studies were made on the measurement and equivalent circuit characterization of diffused transistors at very high frequencies and large signals to establish a basis for predicting accurately the performance of high-speed switching circuits. Samples of new types of switching transistors and related components were procured and tested. Characteristics of these commercially available transistors were then coded and punched into cards to facilitate selecting those types satisfying given specifications.

A trapped-flux memory using evaporated superconducting films was studied. In addition to basic studies in superconductivity, photo-resist techniques in forming tiny intricate masks for multilayer evaporations were investigated. Work continued on the study of evaporated ferromagnetic films for uses as elements in a coincident current memory array.

Under the sponsorship of the Office of Naval Research, studies were made on transistor nor-circuit design, the design of a parallel adder with nor-circuits, and some aspects of the theory of asynchronous circuits.

Transistor-Magnetic Core Circuitry. The transistor-magnetic core circuitry, developed under the sponsorship of the Department of Defense, was refined and completed during the year. Circuits were specifically designed to perform the logical and switching functions of the central portion of a digital computer. Three basic packages, for gating, pulse repeating, and complementing, were designed to perform all required computing functions, and with these modules a small system was designed for testing the over-all operating margin of an array of the packages. The results to date have shown highly reliable operation.

Rapid Selector. Under the joint sponsorship of the Patent Office and the Bureau of Ships, the rapid selector, originally designed by Yale University, was completely redesigned using computing techniques. This development is intended to retrieve rapidly information from massive files of correspondence, drawings, patents, and similar matter which has been transferred to 35-mm film. Its optical and mechanical systems were improved and the detecting and related electronic interrogating system was redesigned. As a realistic testing ground for the device, a master film using articles from the NBS *Technical News Bulletin* series was prepared using a high-efficiency coding system. The present laboratory prototype is being tested to determine the reliability of the modified circuitry.



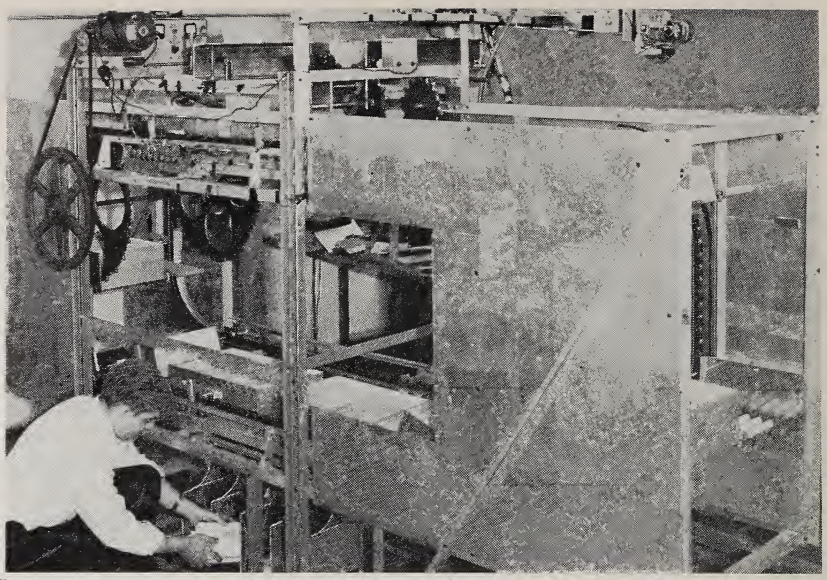
Among the advances made in computer components and techniques (page 75) were a computer shift register that utilizes the NBS diode-amplifier technique, left, and a low-power plug-in tube, right.

Digital Systems Research. Research on the problem of using an existing computer to work out the design details for a new and more advanced computer has reached the point where a large-scale practical test can now be run. A complete procedure was formulated for mechanizing the work of converting system design plans into printed tables that specify the exact point-to-point wiring interconnections and other detailed data needed for constructing an actual machine. To provide a rigorous practical test of this procedure, it is currently being employed to convert the system design plans of the new NBS Pilot Electronic Data Processor into fabrication data for constructing the new machine.

An investigation of the problem of harnessing several computers into a network of machines is now under way to try to meet the extreme requirements in computing speed and data storage that many important future computer applications will demand. Since such requirements are beyond the capabilities of any single machine using currently available technology, methods must be developed for organizing several machines to work cooperatively on a common task. The initial investigation was directed toward evaluating the efficiency of several schemes by which the independent computers in the network can share a common workload. Various models were devised for simulating the behavior of pairs of computers working together and exchanging information, and their relative operating efficiencies were calculated. A number of automatic control schemes were devised for solving the problem of interlocking a pair of computers, and one of these schemes was chosen for use in the system of the NBS Pilot Electronic Data Processor.

Advanced Computer Systems. Technical advice and assistance were provided to the Aberdeen Proving Ground's Ballistic Research Laboratories on the design of the BRL digital computing and data-processing installation. Specifications were formulated for various multi-purpose calculating and processing units in the BRL system, and detailed logical diagrams were devised. Assistance was also given on the specification and procurement of component packages and high-speed magnetic-core memory units.

Man-Machine Systems Simulation. The simulator facility for research on man-machine systems, begun in 1957, was completed and a test problem was performed. The machine simulates the interactions between electronic control systems and a team of human operators. Sponsored by the Wright Air Development Center, this prototype includes a digital computer (SEAC) and an analog computer, linked with display and control equipment which permits human beings to be coupled into the system. In the facility the analog computer performs such tasks as accepting continuous control information, solving complex dynamic equations in real time, and activating conventional display devices. The digital computer controls the experiment, generates open loop data, calculates with high precision, handles variables requiring large dynamic range, makes logical decisions, and statistically analyzes experimental



In a continuing program to aid the Post Office with its mechanization problems, a laboratory prototype machine (above) for high-speed sorting of letter mail was developed under the Bureau's technical supervision. A preproduction model is now under construction (page 77).

results. As an example of a high-performance sampled-data system involving human operators as components in a control loop, the ground-controlled interceptor problem was chosen for the first studies.

Data from the prototype machine form the basis for determining the feasibility and estimating the cost of a more elaborate laboratory installation. This type of facility will permit both operational and dynamic analyses of complex and expensive systems involving human beings in control loops, such as those used for interdiction and interception, missile assignment and guidance, and air traffic control.

Aircraft Flight-Loads Data Processing. Under the sponsorship of the Navy Bureau of Aeronautics, a study was initiated to establish detailed plans for a computing facility to automatically edit, reduce, and process flightload data collected from military aircraft in normal flight operations. The objective of this data processing is to provide information for structural design and safety criteria based on maneuvers of operational aircraft during the various types of service missions.

Data Processing Applications. In connection with encouraging maximally efficient application of automatic data processing techniques to the massive information handling problems encountered in Government operations, feasibility analyses were made of generic problems common to such agencies. Typical problems under study included file maintenance, stores accounting, capital equipment depreciation accounting, and report generation. In addition, problems of data preparation and input were investigated and a survey of the art of automatic character recognition was completed.

Under the sponsorship of the Public Housing Administration, programs were developed for the IBM 704 Computer to check the eligibility reports of occupants of 400,000 units of low-rent housing.

The first phase of a study of the Naval Aircraft Operating Program and the effects of program changes upon maintenance supply support was completed for the Navy Bureau of Supplies and Accounts. This first phase was an examination of the aircraft inventory, the aircraft program operations which cause changes in inventory due to program and to extraneous causes, and the maintenance and supply support expressed as a function of an operating program.

Continuing research in collaboration with the U. S. Patent Office for the mechanization of patent search operations has resulted in an expanded and improved program for comprehensive search of chemical patent literature. In addition a search program was developed and is being refined for general search, with emphasis on mechanical arts. Modifications to make SEAC a more effective searching tool are nearing completion. A survey of recent advances in techniques applicable to the development of automatic machine techniques to aid in searching technical literature was initiated in the following four areas: (1) Information sources, (2) communication theory and information processing, (3) mathematical logic and abstract algebra, and (4) automatic and artificial intelligence. The findings of the survey will provide the nucleus of an information center whose major objective is to make such scientific information generally available within Government.

Under the sponsorship of the Department of Defense, work was initiated to develop star counting techniques, utilizing automatic scanning of photographic data and computer processing. Following studies of the reliability of the scanning equipment, modifications were made in the apparatus, the logical requirements for an iterative operation for counting the number of stars in a field were developed, and a trial program was written.

Processing First-Class Mail. The operations analyses of mail handling in post offices have continued with the concurrent development of elements of an automatic mail sorting system under the sponsorship of the Post Office Department. Analyses of the distribution of outgoing mail for typical large cities and of the physical characteristics of letter-size mail were made. Address coding plans were developed and tested on an electronic computer to determine duplications among 38,000 Post Office names. Data on incoming mail operations are also being assembled for analysis.

The development contract for laboratory prototype elements of a proposed mail sorting system was completed midyear, and contract negotiations were concluded by the Post Office Department for the development and construction of a preproduction model of a complete system, under the Bureau's technical supervision. This equipment is

under construction and will soon make possible operational tests under actual working conditions.

Contracts for developing improved sorting equipment elements and for a cost analysis of a proposed electronic directory were also negotiated, and technical analyses were made of several proposals submitted by industrial concerns.

Six machines which simulate mail coding stations were completed by an outside contractor using the Bureau's design. With the technical assistance and expert advice of staff members of the Bureau these were put into use for keyboard-code-operator experiments in the Washington Post Office. A series of human engineering tests, supervised by a contractor competent in psychological studies, are in progress to provide data for determining equipment parameters when these machines are operated by differently qualified personnel. (Other aspects of the mail-handling problem are discussed on p. 155.)

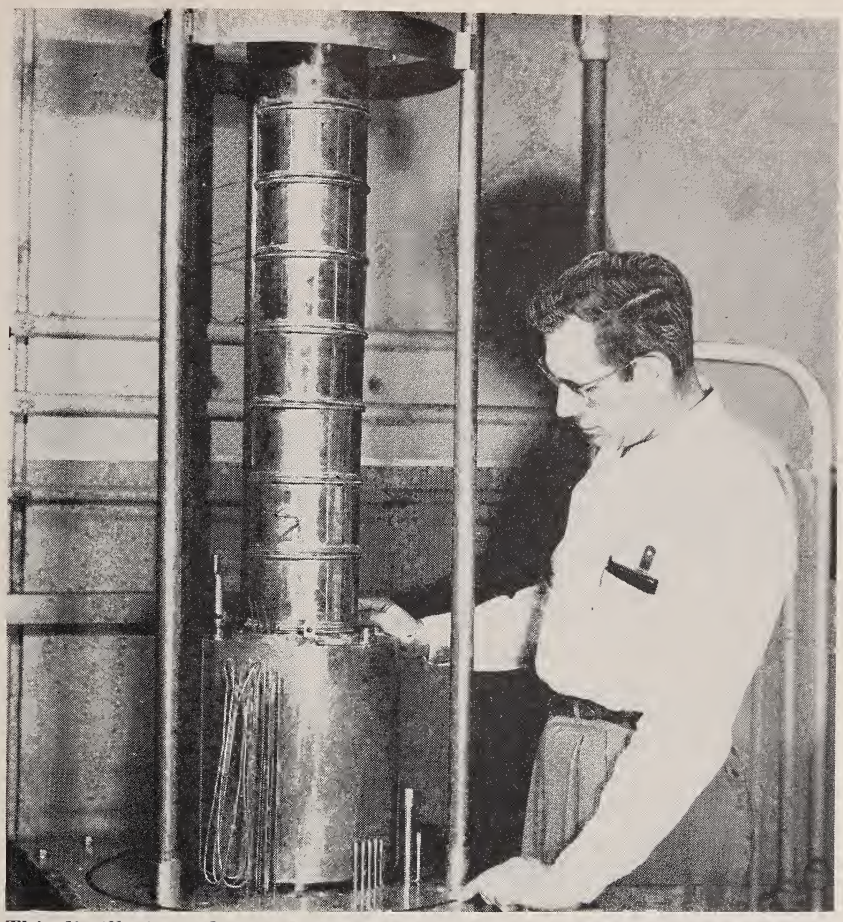
2.13. Cryogenic Engineering

The Bureau's cryogenic engineering program, located at the Boulder laboratories, is designed to provide information for the practical application of very low temperatures to both Government and industry faced with problems in this rapidly growing specialized field.

To carry out these objectives research is conducted on the properties of materials at low temperatures, on cryogenic processes, and on cryogenic equipment. The demand for advisory services by both industry and other government agencies has greatly increased as a result of rapidly accelerated programs dealing with long range missiles and space vehicles. All vehicles that are now in service and most of those planned utilize low-temperature liquids as propellants. A noteworthy example is the nuclear powered rocket now under development which will be propelled by liquid hydrogen.

Low Temperature Liquids. The Bureau conducted investigations into the use of liquid oxygen in a missile tank concentrating on instrumentation for the accurate determination of the amount of liquid oxygen aboard during standby, miscellaneous heat transfer problems connected with transferring the liquid oxygen to the missile, the generation of electrostatic charge during transfer, and the effect of violent vibrations on the liquid oxygen.

Other work included the design of cryogenic equipment, such as the helium liquefier which was put into operation during the past year. The liquefier is providing enough liquid helium to meet all the present requirements of the Boulder laboratories as well as 45 to 50 liters per week for use in free radical research at the Washington laboratories. Another piece of apparatus completed is a distillation column used to study the feasibility of separating deuterium from ordinary hydrogen. This distillation column is expected to provide valuable data to designers of large-scale equipment for producing deuterium or heavy water.



This distillation column, designed to investigate the separation of deuterium from ordinary hydrogen, is expected to provide valuable data for designers of large-scale equipment for producing heavy water (page 78).

Cryogenic Engineering Data. To make generally available the techniques of cryogenics to engineers and other research workers, a book on the subject of cryogenic engineering is under preparation. In a further effort to meet the demand for technical information a Cryogenic Engineering Data Center was established. The center is compiling an organized index of published literature applicable to the cryogenic engineering field.

Flow of Liquefied Gases. Single-phase liquefied gas flow studies consisted of theoretical analyses aimed at providing a basis for designing long transfer systems in which single-phase fluid flow could be maintained. Two-phase flow work was confined to experiments planned to provide a basis for the design of transfer systems in which both liquid and vapor phases are present. This work showed that the pressure drop in steady, two-phase, single-component fluid flow can be predicted from the Lockhart and Martinelli correlation if simple corrections are made to account for changes in the axial component of momentum.

Both theoretical and experimental work was performed to evaluate the behavior of sharp-edged orifices as flow meters for liquefied gases. The experimental work indicates that these devices can be used with confidence with cryogenic liquids as long as pure liquid enters the device—a limitation common to all volumetric flow meters. The theoretical work was designed to predict the discharge coefficients which were obtained empirically before. Results obtained thus far appear to account for previously unexplained observations.

Storage of Liquefied Gases. Several innovations in the design of mobile containers for liquefied gases were incorporated in a liquid oxygen container for the Wright Air Development Center. This container has a predicted heat leak which may be as little as one-quarter that of present containers for similar applications. Its successful storage ability results from such design considerations as the utilization of the load-bearing qualities of evacuated powder insulation and the use of plastic materials for support members.

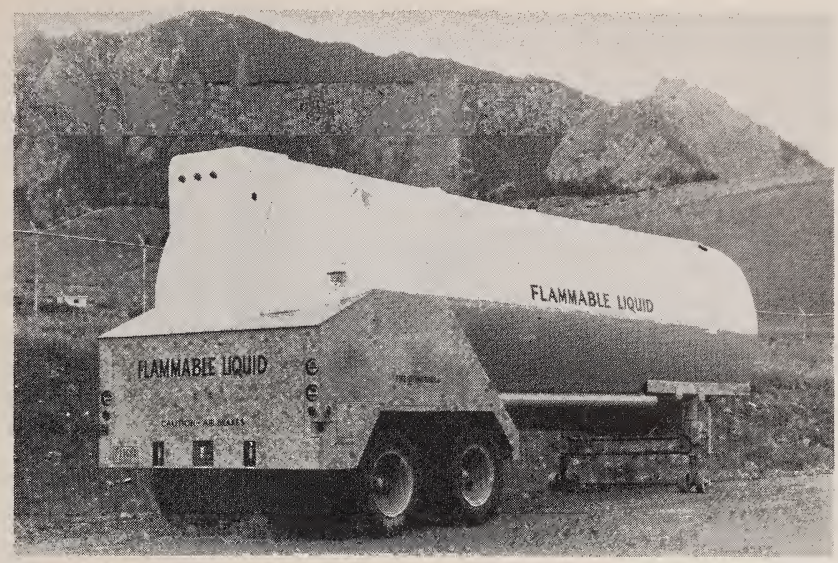
A cryostat, developed for the Air Force Cambridge Research Center, maintains a superconducting resonator at liquid helium temperature for over 40 days without service or maintenance of any kind. One of the novel features of this cryostat is a mechanism which permits the tuning at any time of the resonating cavity from outside the cryostat.

Experimental work during the development of vacuum-insulated transfer lines for liquid nitrogen demonstrated the feasibility of using "condensing-type" vacuum insulation. The advantage of this system is that vacuum-insulated equipment may have long shelf life even though it contains leaks which would ruin conventional vacuum (Dewar) insulation. This work was undertaken with the support of the Rocket Engine Test Station, Edwards Air Force Base, Calif.

Hydrogen Refrigerator for Bubble Chamber. For the past 3 years assistance has been given to the University of California Radiation Laboratory in the development of liquid hydrogen bubble chambers. Liquid hydrogen refrigeration is required for continuous operation of the bubble chamber. During the past year an 1,800-watt hydrogen refrigerator was built in accordance with basic NBS designs. It will soon be assembled as part of the bubble chamber unit at UCRL.

From this work resulted a new procedure for use in the design of high-pressure heat exchangers of the type usually employed in low-temperature processes. An effort was made to balance the flow and therefore increase the efficiency in a given heat transfer area. Results of refrigerator performance tests gave initial verification to the new design procedures.

Helium Liquefaction. In giving assistance to the Navy Bureau of Aeronautics in its plan for the liquefaction and distribution of helium, the best designs possible were made of liquid helium containers in sizes ranging from light, transportable units to large road-transportable trailers and rail tank cars. Weight and no-loss storage time were the primary considerations of these design optimizations. Studies of helium gas



The transport of large quantities of cryogenic fluids is of increasing importance. This 6,000-gallon transport vessel for liquid parahydrogen is four times larger than any previous unit (page 80).

liquefaction processes that were made during past years are now being used by the sponsor and by the U. S. Bureau of Mines in the procurement of liquefaction facilities.

Low Temperature Properties of Materials. It is well known that certain of the austenitic stainless steels (300 series) partially transform to martensite on chilling, especially if they have been cold-worked. Because of the widespread use of these steels in cryogenic equipment, it was desirable to study an unexplored aspect of this transformation, namely its slow continued occurrence during long exposure to a constant low temperature. Magnetic analysis is being used to investigate the occurrence of such changes.

In the course of the Bureau's program of measuring mechanical and thermal properties useful in low-temperature engineering and research, determinations of the ultimate, tensile, yield, and impact strengths of a group of commercial magnesium alloys were made. These measurements indicate that these alloys have only limited special uses in cryogenics because of their low impact strengths. Investigations of a relatively new aluminum alloy of promising characteristics showed that deformation at slow strain rates occurs by repeated sudden yielding. Ultimate and tensile strength, shear modulus, and Young's modulus were measured on a group of plastic foams. These properties together with the thermal expansion coefficient are sufficient to determine the ability of bonded foam insulations to withstand thermal stress.

The thermal conductivities of two copper-silver alloys were measured. These, with the high-purity copper measured earlier, formed an alloy

series with graded silver content. Separation of the ideal and defect thermal resistivities for each sample showed a new effect, the existence of a residual term representable as a cross product of the two resistivity components, as was predicted theoretically by Sondheimer.

Tentative temperature-emf reference tables for gold-cobalt versus copper, gold-cobalt versus silver-gold, and copper versus constantan thermocouples were derived from experimental measurements down to to 4° K. These thermocouples are important as practical low-temperature thermometers of moderate accuracy.

Gas Liquefaction. This was a record year in the production of liquefied gases. Nearly 200,000 liters of 90 to 95 percent parahydrogen were liquefied, and over a million liters of liquid nitrogen and 2,500 liters of liquid helium were produced. In addition, some 65,000 standard cubic feet of pure hydrogen gas and about 200,000 cubic feet of pure nitrogen gas were produced for both laboratory and off-site use. Cryogenic fluids were furnished to Bureau laboratories for applied research and engineering development, to other government agencies and their contractors in the area, and to private companies and institutions.

The general practice of recovering hydrogen gas evaporated during storage, handling, and on-site use of the liquid netted almost three million cubic feet of gas for re-use in liquefaction. This nearly equalled the amount of electrolytic gas purchased, and made possible some of the large runs that would otherwise have exceeded local available supply. Gas recovery from off-site use will be considered if substantial increase in requirements materialize. This practice also reduces operating costs, since in large production, the cost of the gas is a major item of liquefaction cost.

2.14. Radio Propagation

The Central Radio Propagation Laboratory has primary responsibility within the nation for collecting, analyzing, and disseminating radio propagation data and information of value to such diversified fields as air and sea navigation, frequency allocation, and worldwide communications. To carry out this responsibility, the Laboratory conducts research on the fundamental nature of radio waves, the basic theories of radio-wave propagation, and the characteristics of radio energy under widely varying conditions. A network of field stations is operated from the Arctic to the tropics, and data are exchanged with other laboratories throughout the world. The work in radio propagation includes both physics and engineering studies. During the year, a considerable amount of work was performed under the auspices of the International Geophysical Year.

Radio Propagation Physics

The radio propagation physics program is concerned with radio-wave propagation over long distances by means of the ionized regions of the earth's outer atmosphere. The program includes (1) basic research on

Radio propagation data are gathered at field stations throughout the world. Above, an NBS team observing low-frequency field intensities on the Arctic tundra near Thule, Greenland (page 82).

upper atmosphere physics, on the formation and disturbances of the ionosphere, and on the interaction of radio waves with the ionization; (2) study of the characteristics of specific propagation mechanisms such as ionospheric reflection, ionospheric scattering, and guided-mode propagation; and (3) regular public service as in the prediction of long-term changes in useful frequencies for communication, in the warning of short-term disturbances to communication, and in the collection and distribution of ionospheric and solar data on a national and international basis.

Radio Waves from Lightning Discharges. Lightning flashes constitute a powerful and nearly constant source of radio waves over a wide range of frequencies in the radio spectrum. Their complex, transient nature and their random occurrence have made it very difficult to study them effectively with ordinary equipment. Under Air Force sponsorship, specially designed broadband equipment (1 to 200 kc), coupled to two crossed vertical loop antennas and a vertical monopole, was installed at Boulder, Colo., Salt Lake City, Utah, Palo Alto, Calif. and Maui, Hawaii. These locations form a chain covering a distance of 3,200 miles. The equipment records the detailed waveform and polarization of the electromagnetic pulses from lightning flashes. Such records make possible the calculation of radio wave attenuation values from the pulses as a function of radiofrequency and propagation distance.

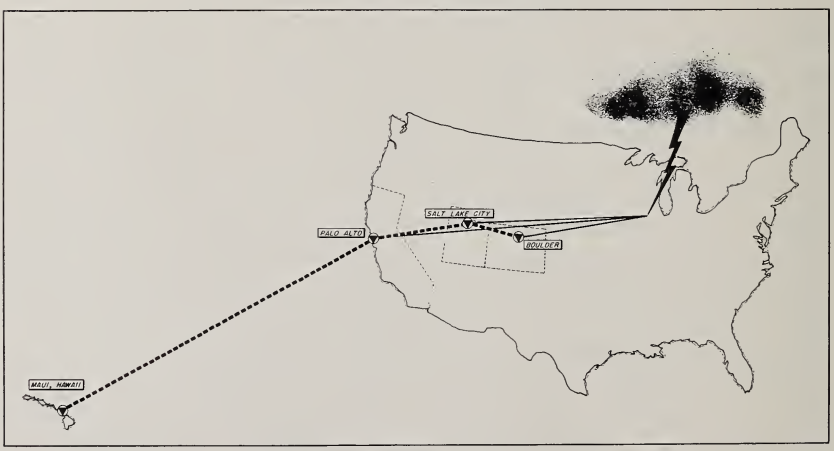
Meteor Studies. Long distance radio communication is possible by use of signals scattered from trails of ionization left by burning meteors as they plunge into the upper atmosphere. The Bureau, for the Department of Defense, instituted a program to obtain statistics on the variation of meteor burst signals by studying burst propagation over three oblique test paths in the United States and Alaska. Digital

recording techniques are being employed to amass the enormous quantity of statistics required. Most of the instrumentation and preliminary testing is completed.

Airglow Observations. In a program supported jointly by the Bureau and the U. S. National Committee of the IGY, bi-refringent filter photometers, located on Fritz Peak in Colorado and in the Black Hills of South Dakota, scanned the night sky to detect emission at 5577 A from oxygen atoms in the vicinity of the *E*-region of the upper atmosphere. These observations confirmed the fact that the 5577 A emission occurs from a height of 100 km and that the night sky contains large patches or cells of airglow emission. For the first time these cells were mapped in detail concerning their extent and movement. A typical airglow cell for 12 nights of study had a diameter of approximately 2,500 km, a diameter not far different from the great cyclonic motions in the troposphere. The airglow cells appear to be moving through the upper atmosphere with a transitional velocity of about 100 m/sec and a rotational period of about 5 hours. The upper atmosphere appears to undergo very strong dynamic motions of large cyclonic types.

Radio Propagation Engineering

The radio propagation engineering program is concerned with the more efficient use of the radiofrequency spectrum. This objective can be attained only to the degree that the nature of radio-wave propagation and the characteristics and the effects of radio noise and interference upon various signals are understood both qualitatively and quantitatively. The quantitative understanding of radio-wave propagation and the characteristics of radio noise requires the collection of statistical samples of



Chain of stations used in a study of the radio waves originating in lightning flashes. Broadband receiving equipment is used to record the signals in a study of the attenuation of low- and very-low-frequency radio waves (page 83).

data appropriate for the description of observed phenomena. It also requires the development of adequate methods for the prediction from these samples of the statistical characteristics of the various radio-wave propagation and noise variables required in engineering applications. The work is directed toward a basic understanding of radio-wave propagation, radio noise and signal-to-noise problems.

Radio Meteorology. During the past year a new Radio Meteorology Section was established. Methods were developed for describing the average refractivity of the atmosphere profile, from the surface upwards, in terms of surface values which can easily be derived from measurements regularly made at all weather stations. This model atmosphere will make possible the prediction of the diurnal, seasonal, and geographical changes of these average refractivity profiles throughout the world. The work led to a description of the bending of the radio waves in terms of the model atmosphere, and to predicting the transmission loss in ground wave, ionospheric wave, and tropospheric scatter propagation. By relating the surface value to a reduced-to-sea-level values, an improved method was developed for predicting the surface value at any point in the world.

Tropospheric Forward Scatter. The formula for predicting the transmission loss expected on tropospheric forward scatter circuits was improved by using the new model radio refractivity atmosphere. More accurate predictions are now possible at the lower frequencies (in the range from 10 to 200 Mc), for very high or very low antennas, and for very large or very small values of the surface refractivity.

Ionospheric Propagation in the Range 10 to 1,000 kc. New theoretical methods for predicting ionospheric propagation in the range 10 to 1,000 kc were developed. These techniques allow for tropospheric bending, a new approach to the space wave radiation from dipoles over a spherical, finitely conducting earth, and focusing from a rough ionosphere.

Below 20 kc the formulas are based on the wave guide mode theory. These formulas were used to predict an optimum frequency of the order of 20 kc for a worldwide radio standard frequency broadcast system.

Radio Modulation Studies. Further progress was made in the development of methods for determining the information bearing capabilities of forward scatter circuits. In this connection, a method for the spectrum analysis of the fading on such circuits was developed and tested.

Measurement of Television Service Area. An improved method of measurement that is expected to lead to a better estimate of the areas of television service was proposed to replace the old method. In this method sample measurements are taken at fixed locations around the transmitter. These locations are established in a systematic manner so that all terrain types are equally likely and the data represent a random sample from the area. In most cases the measurements consist of a single observation of field strength except when time variations are involved. In these instances they represent a short recording of field strength from which the

Equipment for measuring microwave energy transmitted through a parallel-wire grid. The known properties of the grid provide a reference for use in studying radio attenuation in various materials (page 89).

distribution with time can be estimated. A sample set of observations would be taken at a constant radius with sufficient separation to eliminate serial correlation between successive observations. The distribution obtained can be used to estimate the percentage of locations at that distance which receive service in the several grades. By joining together several such estimates made at different distances, an estimate can then be made of the total area around the transmitter for each grade of service.

International Geophysical Year

During the year a considerable part of the Bureau's radio propagation physics program was devoted to the International Geophysical Year—an internationally coordinated program of worldwide synoptic geophysical

observations. These observations are particularly significant in understanding the interaction of radio waves with the ionosphere since such phenomena as ionospheric disturbances, radio noise, solar flare effects, magnetic storms, and aurora and airglow activity are interrelated on a worldwide basis.

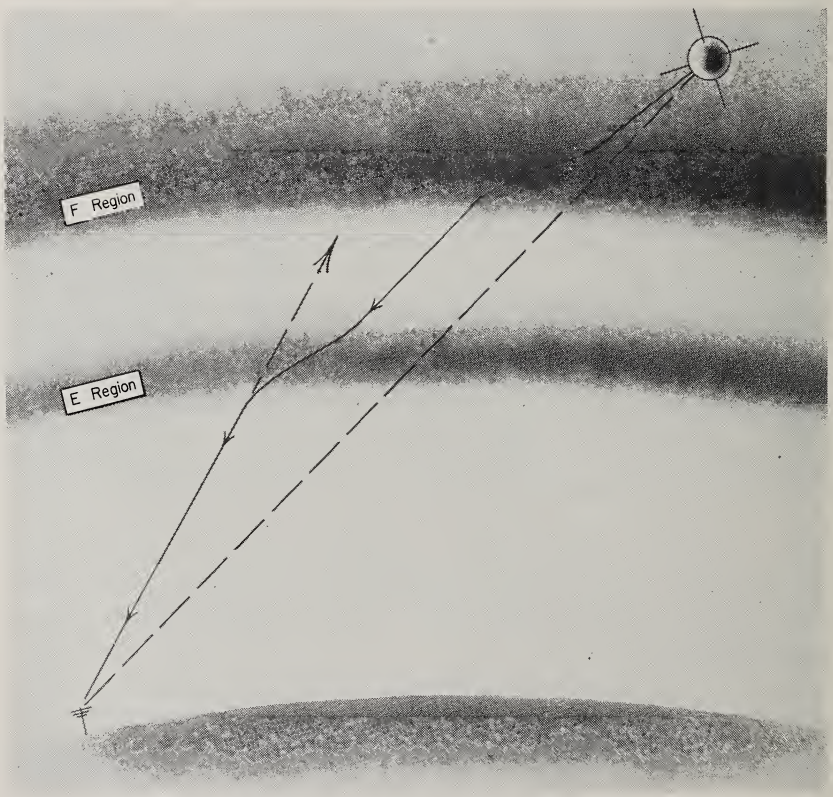
IGY World Alerts. The special communications circuits for the IGY observations, set up during the previous year, were put into formal operation. The Bureau's radio forecasting center at Fort Belvoir, Va., is the communications center of the worldwide IGY program. This World Warning Agency makes the final decisions designating the IGY Alerts and Special World Intervals which are flashed in a few hours to IGY stations throughout the world. Thus the many experiments and observations which must be timed with respect to activity on the sun can be synchronized. Here are gathered from all over the world telegraphic summary reports concerning solar flares, geomagnetic and ionospheric conditions, and opinions of expected terrestrial consequences of solar activity. The IGY warnings declared by the Fort Belvoir staff are sent out over the most extensive communication network ever established for scientific purposes. During the year six significant terrestrial disturbances were successfully forecast and stations were alerted 26 times for unusual solar activity.

New Data on the Ionosphere. The ionospheric vertical sounding program was considerably expanded in order to provide equipment for a number of new stations established in the western hemisphere, particularly in South America, and to implement a pioneering effort in ionospheric observations in Antarctica, where five stations were operated directly by the United States and a sixth cooperatively with New Zealand. New C–4 ionosondes were placed at most of these stations, or older equipment modified and modernized. Data from these stations were collected at the IGY World Data Center A for the Airglow and the Ionosphere, located in the Boulder, Colo., Laboratories. Although analysis of the data is still in process, results to date from the station at the geographic South Pole show that an appreciable electron density persists in the *F*-region of the ionosphere during the prolonged absence of sunlight in the Antarctic winter. Also, a significant diurnal variation of the *F*-region ionization was observed during both the polar winter and summer; this result indicates some degree of terrestrial geomagnetic influence on the ionization.

Observations on Soviet Satellites. Immediately after receiving information that a Soviet earth-satellite had been successfully launched on 4 October 1957, a program was initiated to set up radio interferometers and observe transmissions at 20 and 40 Mc. These interferometers remained in operation for the lifetime of the radio transmissions from Sputniks alpha and beta, and many successful observations were made. The data were reduced immediately for orbital information and passed on to the Naval Research Laboratory. The data are being analyzed further

to sort out such effects as the Faraday rotation of the plane of polarization due to the nonisotropic properties of the ionosphere in the Earth's magnetic field. Toward the end of the year, new permanent interferometers were set up to receive at 20 and 40 Mc to prepare for observations on satellites transmitting on these frequencies in the future.

Propagation Near the Magnetic Equator. Along the west coast of South America, straddling the earth's geomagnetic equator, a network of transmitting and receiving stations at 50 Mc in Chile, Peru, Ecuador, Argentina, Brazil, and Panama was operated to study the special forms of oblique incidence ionospheric scattering that occur in this region. Discovered so far are a form of scattered signals correlating closely with the vertical incidence echoes known as "spread-*F*," and a scattered signal giving detailed information on the two closely related equatorial phenomena, the equatorial electrojet and the equatorial sporadic-*E*. The equatorial electrojet is a strong concentrated ring of current surrounding the earth in the ionosphere in the vicinity of the magnetic equator.



A new technique for studying the upper atmosphere evolved from satellite observations. Radio waves do not necessarily travel in a straight line to the earth. Their path depends to a great extent upon the distribution of electrons in the ionosphere, and can be used as an indication of this distribution **(page 87).**

2.15. Radio Standards

The Bureau is endeavoring to adapt its program to the ever-growing need for new and improved electronic measurement standards. This program consists mainly of basic research and development on national standards for fundamental electrical quantities, measurement techniques, and properties of materials from audiofrequencies through the highest attainable microwave frequencies. These activities include a calibration service and radio broadcasts of the United States primary standard of frequency and time intervals.

Attenuation. Developing of improved techniques and instrumentation for accurately measuring and standardizing attenuation at all required radiofrequencies was continued. Radiofrequency and microwave attenuators are used in signal generators, receivers, field-strength meters, power meters, alinement of radar transmitters and receivers, and many other applications. To insure the proper performance and accuracy of these instruments the top standardizing laboratories in industry, military and other government agencies need transfer standards checked against an adequate national standard.

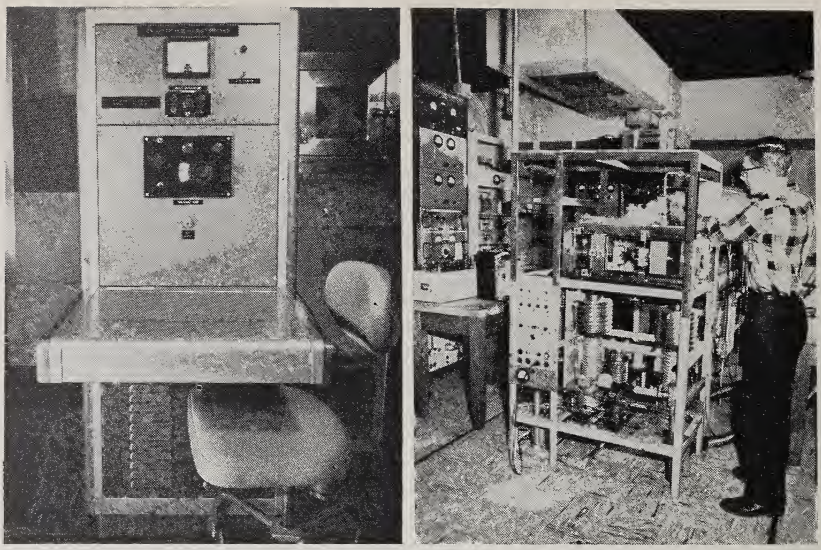
Field-Strength. The planning, layout, construction, procurement, installation, and performance testing of low- and high-frequency field-strength attenuation and linearity consoles for the Electronic Calibration Center were essentially completed. Six crystal-controlled low-noise receiver converters for 400 and 500 Mc were also completed for the Center.

An experimental microwave antenna-gain measuring system was constructed, and an experimental microwave absorbing enclosure was constructed and its properties partially evaluated. Some waveguide horns were investigated for possible use as standards of horn gain.

National standardization in this field is very important in the growth and control of all types of communications systems, including AM, FM, and TV broadcasting. Increasing use of the microwave frequencies now requires an extension of standards into that range.

Frequency. Accurate frequency and time interval standards are of recognized national importance to research, development, operation, and manufacture by private and government organizations. The accuracy requirements in frequency standards have increased by a factor of 10, or more, per decade for the last 30 years, and the national primary frequency and time interval standard has continually been kept ahead by at least one order until now; recent trends in research and engineering indicate that it will become more and more difficult to keep one order ahead of commercially available frequency standards.

The Bureau's atomic frequency and time standards were improved during the year. A second ammonia beam spectrometer (maser) was put into operation. The relative stability of the two masers was shown to be about 2 parts in 100 billion. With more careful thermal control and better voltage stability it is expected that a stability of 1 part in 1,000



Improved power standards installed during the year included this standard calorimetric wattmeter (left) (page 91). *Right:* The second ammonia beam spectrometer (maser) was put into operation as part of the Bureau's program to improve its atomic standards of time and frequency (page 89).

billion may be attained for a long period. A frequency comparison chain was constructed for comparing the frequency of the ammonia emission with the cesium frequency standard.

The causes and possible reduction of short-time instabilities in oscillators and frequency multipliers were investigated. Two new oscillators at 5 and 10 Mc were developed, which showed a major improvement in stability. Under the sponsorship of the Department of the Army, the stability and aging rate of quartz crystals at low temperatures were determined; measurements were made at 4° and at 77° K.

To operate quartz crystals at very low temperatures, a more precise temperature-control device was developed in the form of a proportional type electronic oven placed in a liquid nitrogen Dewar.

To measure more accurately the magnitude of short-time instabilities of oscillators and frequency multipliers, a new decade frequency multiplier was developed that makes possible a frequency comparison precision of 1 part in 100 billion or better in 1 second or less.

Impedance. The development of national impedance standards has become more important to the country's welfare as the manufacture of radiofrequency impedance components has grown to be one of our major industries. Accurate impedance measurements are also basic in the measurement of attenuation, power, voltage, field-strength and other quantities.

Measurements on a new 20 micromicrofarad variable standard capacitor showed that its effective capacity can be calculated from its dimensions to 300 Mc within 0.1 percent accuracy. A 2 $\mu\mu$f variable capacitor which

will act as a national reference standard to 300 Mc was also designed and partially constructed. The NBS coaxial connector, recently adopted for use in all accurate impedance measurements up to 300 Mc, was modified to permit quicker fastening and more accurate machining.

At microwave frequencies new techniques were developed for making more accurate impedance measurements. Two new type microwave impedance standards (half-round obstacles in rectangular waveguides) were constructed; measurements of their performance agreed within 0.05 percent of the theoretical tabulated values. A method was devised to measure the reflection coefficient of short circuits. An ultra-stable klystron power supply was placed in operation and a system developed for water-cooling low-power klystrons, resulting in a stable high-gain microwave receiver.

Noise and Interference. Noise, which includes any type of random fluctuation, sets the ultimate limit to the successful detection or reception of information. In many cases, such as in radio astronomy or in observations of high temperature plasmas, the actual derived information is itself of a noisy character, and must be compared with a standard of noise power in order to take on quantitative meaning. Thus noise standards are fundamental to developing and evaluating the performance of radio and microwave devices, and are fundamental as a basis for making numerous physical measurements.

Techniques for measuring the spectral intensity of both random and impulse noise were investigated mathematically and experimentally in the frequency range from 50 kc to 50 Mc. Improvements were made in the sensitivity of an X-band comparison radiometer.

Under the sponsorship of the Navy Bureau of Ships, a program was initiated to develop an improved standard method of measuring conducted spurious power outputs of radio transmitters at frequencies from 14 kc to 1,000 Mc and carrier power output levels to 1,000 watts. A study was made of the characteristics of a receiver to be used in measuring the spurious output of the transmitters; the range of spurious harmonic output levels of one type of transmitter was determined. From these two studies the required interim characteristics of special filters to be used in the measurements were determined.

Power. A set of national primary power standards for use up to 300 Mc was completed and is now in use. These include the 0- to 100-milliwatt thermistor bridge, the 1-milliwatt to 10-watt bolometer bridge, and the 200-milliwatt to 20-watt dry, static calorimeter. The over-all accuracy of these standards is 0.5 percent which is marked improvement over previous accuracy and ranges.

A number of general purpose rf generators were constructed; all employed a special automatic rf level control. Two 10 db attenuator pads capable of dissipating 100 watts of power were constructed to extend the range of the power bridges and calorimeters.

Evaluation of a microwave microcalorimeter was completed and the

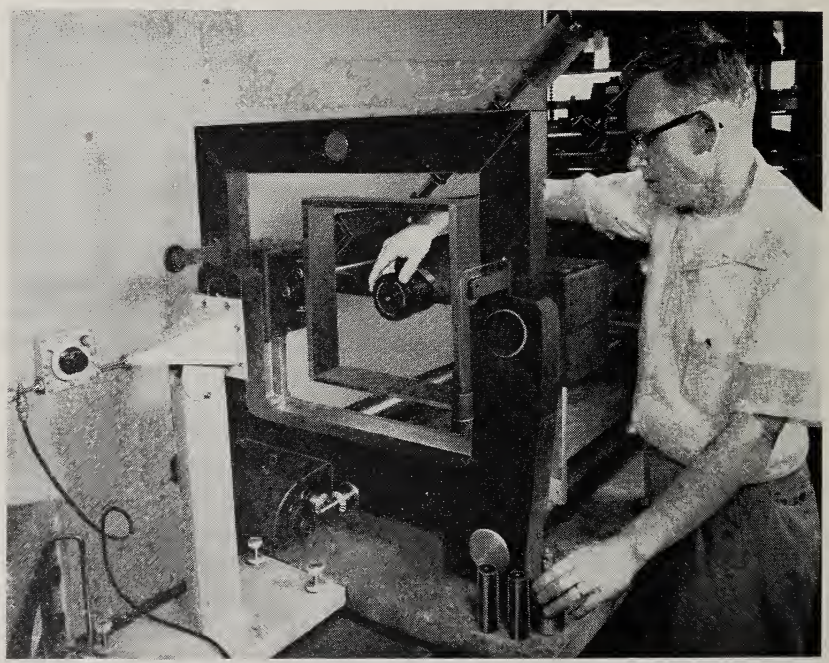
instrument placed in operation. It is used to determine the effective efficiency of bolometer mounts within an accuracy of 0.3 percent. A new method of measuring bolometer mount efficiency, based on the impedance technique, was devised to provide improved accuracy and simplified operation.

Voltage and Current. Consoles for calibrating radiofrequency voltmeters were completed, tested, and placed in service in the Electronic Calibration Center. They cover eight frequencies from 30 kc to 100 Mc. Construction on a console for higher frequencies is in progress.

An experimental study of the behavior of conical condensers showed that their wide range of capacity agreed with theoretical predictions. Comparative maps of a two-dimensional field and, for the first time, of an axial-symmetry field for the conical case were constructed to verify certain theoretical work.

Development continued on the new type attenuator-thermoelement (AT) voltmeters. A new balanced two-thermistor mount was designed and constructed. This was used to compare balanced rf micropotentiometers with the single thermistor bridge while sources of error were studied in the balanced devices.

A 60 ampere, 1 Mc source was constructed for a special calibration service.



Model of millimeter-wave interferometer being used to investigate applications to the measurement of the velocity of light, to metrology, and to dielectrometry (page 94).

Dielectric Measurements. Various improvements, added to the automatic cavity used for dielectric measurements, included a latching system, meter circuit, and a memory drum. All helped reduce operator time.

At microwave frequencies the theory and practice of making dielectric measurements in a special resonator were improved. Loss tangents as low as 5×10^{-5} can be measured by this method. The theory was extended to include a magnetic as well as a dielectric constant, and experimental evaluations of errors were made. Improvement was also made on a method of microwave dielectric measurement using a special resonator with a centered sample rod. This method was successfully used to measure the dielectric properties of ceramics up to a temperature of 500° C. It also provides good sensitivity in measuring low losses.

A theoretical analysis of the loss measuring capabilities of sealed cavity resonators for compressed gas dielectric measurements was completed.

Magnetic Materials. A ballistic galvanometer was set in operation for obtaining static hysteresis loops. A dielectric sample holder was adopted for determining dimensional resonance phenomena in ferrites. The frequency range of the reversible permeability permeameter was increased. Construction was completed on two instruments for complex permeability measurements; one was a variable length cavity for the 300 to 6,000 Mc range and the second, a coaxial variable length transmission line for the 1 to 50 Mc range. Under the sponsorship of the Navy Bureau of Ships, studies were made of the tensor permeability of ferrites.

Conductivity of Materials. Preliminary investigations were made on the Hall effect at radiofrequencies and on cyclotron resonance in semiconductors. Equipment was installed and microwave resonant cavities were constructed for the purpose of studying the gyrotropic effects experimentally.

Work in this field was undertaken to make fundamental studies of the complex conductivity and related phenomena of conducting and semiconducting materials at high frequencies. The studies include investigation of conduction gyrotropic phenomena at radiofrequencies and of the plasma behavior of fluid and solid materials.

Microwave Spectroscopy of Gases. The analysis of the microwave spectral data for gases and beams was virtually completed.

To provide better mathematical procedures for use in the Bureau, new methods for numerical integration and for obtaining interpolation functions from computations or measurements at optimally spaced points were developed. These methods often reduce computation by a large factor and may reduce calibration and other measurement time by a third.

In addition to providing a compendium of precise spectroscopic and molecular data useful in many branches of science and industry, the microwave spectral tables will provide reference and working frequency

standards. Analysis of the dielectric constant and adsorption data permits reliable estimates of such data for pressures, temperatures, and even materials for which such data are unavailable.

Millimeter Wave Research. A microwave interferometer and associated instrumentation to operate at a wavelength of 6 mm was developed for application to velocity of light measurements, to metrology, and to dielectrometry. Electromagnetic horn radiators with matched dielectric lenses, having stable radiating apertures of dimensions 60 and 30 cm square, were constructed. Radiation pattern measurements showed that these horns give well collimated beams in agreement with theory. Calculations showed that the diffraction correction would be around 2 parts in 10^5 for the aperture sizes and field distributions envisaged.

Excellent fringes were obtained in an experimental model of the Michelson interferometer, and the advantages of inserting attenuation in the free space arm to eliminate multiple reflections were demonstrated. Some work on the design of a millimeter-wave Fabry-Perot interferometer was completed, with particular reference to the problem of reflector design. A pilot model of this interferometer is under construction.

A higher mode cavity was developed for measuring the refractive index of gases at 6 mm. Also a Pound IF system of frequency stabilization was made and a klystron, operating at frequencies around 50,000 Mc, was locked to a cavity resonator for long periods.

2.16. Basic Instrumentation

Research and development in basic instrumentation during the past year was carried on under the support of the Office of Naval Research, the Atomic Energy Commission, and the Office of Scientific Research of the Air Research and Development Command. The principal emphasis, throughout the program, was on the fundamentals of measurement and control, and on the development of the science of instrumentation. Preference was shown to those research projects that seemed likely to have broad utility in measurement or in extending significantly the range, reliability, or sensitivity of some general class of instruments. Also given primary consideration were theoretical and experimental studies of problems common to many instruments—drift, lag, and unsteadiness, for example—or of the limits of performance inherent in various types of instruments. Besides the basic research and development in instrumentation, major work during the past year included the operation of an instrumentation reference service and the research and development of information retrieval systems.

Instrumentation Reference Service. References to instrumentation literature were selected, analyzed, coded, and recorded by punching into the special punched-card index system. One set of punched cards constituting an index of 18,000 instrumentation references was completed and was placed in routine use for information retrieval in providing consultation service. Indexing work continued on the second set of index

cards. The card system and other sources of information were used in answering a large number of inquiries from the Bureau and from other government agencies and their contractors.

Various areas of instrumentation were surveyed including thickness measurements, measurements of free-air temperature and aircraft true airspeed and groundspeed, and recording methods.

Information Retrieval Systems. Development of methods for replicating the index card set referred to above was undertaken to permit distribution of the collection on an experimental basis. A number of techniques are feasible. A printing technique appears most promising and is being actively pursued. Design of electromechanical devices to increase efficiency and speed of information retrieval with the special card system reached an advanced stage and construction was started.

Great interest has been shown by other government agencies, by private industry, and by other institutions in the information retrieval developments thus far achieved. A large number of requests for information have been answered, consultations on information problems have been provided, and working drawings of devices thus far developed have been made available to potential manufacturers and users.

Basic Instrumentation Research. Research has included investigation of linearization of capacitive-probe measurement of displacements, investigation of photoconductive devices, development of simple and reliable methods for counting holes in punched cards, investigation of limitations in microphotographic copying and reading, and development of automatic data-processing techniques.

3. Calibration, Testing, and Standard Samples

Rapid developments in both civilian and military technology, and particularly in the missiles and satellite programs have brought an unprecedented demand for new and more accurate standards of measurement. This demand has led to the establishment by the military agencies and their contractors of rather elaborate systems of laboratories. The national standards of measurement at NBS may be considered as occupying a position at the apex of a giant pyramid. Successive echelons of reference and working standards serve to relate the national standards to the measuring instruments required for the successful operation of the extremely complex equipment at the launching pads or on planes, shipboard, or in fortifications.

This rapidly increasing demand for standards has been reflected in all fields of calibration, particularly in electrical instruments. During the year over 4,000 electrical and magnetic standards were calibrated, involving over 25,000 determinations, an increase of 50 percent over the preceding year. This reflects both the tendency to use electrical methods and instruments to measure non-electrical quantities and also the establishment throughout the Nation of an ever-increasing number of electrical standardizing laboratories.

Nomenclature of Standards

A uniform nomenclature for standards of measurement has assumed increased importance because of the growing use of standards in modern technological development. To meet this need a nomenclature has been developed as a substitute for the loose and imprecise terminology now in use.

Standards are classified into categories under this system, the first category being the prototype category which includes the arbitrary and independent standards of length, mass, time, and temperature on which our measuring practices are based. The other standards, defined in terms of the prototypes, are classified in derived, calibration, and instrument categories. A fifth category, called standard materials, includes pure chemicals and other materials which are not defined in terms of standards of the prototype category. The items which the Bureau has been supplying under the standard sample program fall into the categories of calibration standards or standard materials.

Within each category the standards are ranked as national standards, national reference standards, and national working standards. It is suggested that standardizing laboratories cooperating with the Bureau rank their standards within each category as laboratory reference standards and laboratory working standards.

New Calibration Facilities and Equipment

To meet the ever increasing needs of science, industry, and the Government, the Bureau is constantly developing new calibration facilities which contribute to higher accuracy and new and improved standards. These range from small items of laboratory equipment to installations the size of the new Calibration Center at Boulder, Colo.

Electronic Calibration Center. Construction of equipment for the Center formed a major part of the year's activities. Instrumentation for d-c and low-frequency calibrations was almost completed, and about half of the planned instrumentation for high frequency and microwave calibrations. Reports of this work are included under appropriate subject headings in section 2.15 (page 89). The rate of completion was limited by the availability of funds and trained personnel and in some cases by the lack of primary standards upon which to base a calibration service. Numerous types of standards were calibrated for industry and all branches of the armed services during the latter half of the fiscal year.

Calibrations performed in the low-frequency region fall into six general categories: Resistors and resistance apparatus, inductors and capacitors, standard cells, indicating instruments, potential and current transformers, and miscellaneous, including ratio devices. In the high-frequency region, equipment is being installed to calibrate voltage, power, attenuation, field strength, and impedance standards. In the microwave region (above 300 Mc), facilities for the measurement of power, impedance, attenuation, and frequency are being constructed.

As the facilities described above were completed and put into service, the Center handled an increasing volume of the calibration services. The need for the low-frequency calibration service offered by the Center was amply confirmed by the extent to which this service was utilized. In addition to the services provided to the Armed Forces (the original request that the low frequency service be offered in Boulder was made by the Air Force), numerous calibrations were made for industrial organizations located in the West.

Standard Radio Broadcasts. The national primary standard of frequency and time interval is maintained at the NBS Boulder Laboratories. A commercial atomic frequency standard along with data from the NBS cesium resonator made it possible to commence in December 1957 regular determination and publication of WWV corrections in terms of the NBS atomic frequency standard.

As a step in the further improvement of the stability and precision of the broadcasts from WWV and WWVH, two new commercial oscillators were procured and one placed at each station. Tests indicated that the stability of the one at WWV was 2 to 3 times better than that of the best oscillator previously in use.

The experimental standard frequency broadcast (KK2XEI located at Boulder, Colo.) at 60 kc, begun in 1956, was continued during the year. This provided a standard frequency, at receiving points in the United States, which in 1 to 3 hours' measuring time is 1 or 2 orders better than that provided by WWV. However, the low radiated power on 60 kc (20 to 40 watts) was a deterrent to its wide use because of the difficulties in reception at distant points. Because many research organizations need the higher accuracies afforded in 60 kc, considerable planning work was done toward establishing a high power, standard frequency broadcast station near Boulder in band 4 (3 to 30 kc) which will provide high quality signals in the United States and over the rest of the world.

The addition of equipment to broadcast special signals for IGY was made at WWV and WWVH during the year. This service was added because the NBS stations are well known and extensively used throughout the world.

The radio-broadcast technical services are widely used by scientific, industrial, and governmental agencies and laboratories as well as by many airlines, steamship companies, the armed services, missile research laboratories and contractors, IGY personnel, satellite tracking stations, schools and universities, numerous individuals, and many foreign countries. They are of importance to all types of radio broadcasting activities such as communications, television, radar, air and ground navigation systems, guided missiles, antimissile missiles, and ballistic missiles.

Standard Capacitors. The accuracy needed by industry in the calibration of standard capacitors has recently been increasing so rapidly that the Bureau has at times been unable to meet this need. Recently the design and construction of an experimental bridge was completed, pro-

viding greatly increased accuracy of capacitance measurements. A bridge of this type will soon be built for use in the calibration of capacitance standards.

Automation of End Standard Calibration. Master end standards, or gage blocks, are calibrated by the Bureau for other government agencies and for industrial and scientific laboratories. By this means the Bureau extends its length standards throughout the country and makes it possible for industry to produce, in different factories, precision parts which are interchangeable.

During the past fiscal year the Bureau calibrated over 4,500 end standards. This large workload has made it profitable to investigate the applications of semi-automatic methods of calibration. A large portion of these calibrations are made by mechanical comparison with master end standards rather than by measurement by the use of lightwaves. For the calibration by comparison procedure the observer records the original observations on punched cards. After this has been done, automatic programed computing equipment applies all corrections and ultimately types out the report. This not only accelerates the work but it eliminates many sources of error and much tedious checking.

Periodically the original punched cards prepared by the observer are subjected to a different program by the computing machine which tests the consistency of the results obtained by the comparison of a given gage submitted for test with the different Bureau master gages. This affords a check on the correctness of the calibrations of the Bureau gages with a minimum of additional work. An extension of a similar method to the gages that are measured directly in terms of lightwaves is planned.

Dead-Weight Testing Machine. The Bureau is designing a 300,000-lb. dead-weight machine which will serve to provide high precision calibration service for many current industrial and military requirements. Modern missile and rockets systems depend on the development of thrusts in excess of those which can now be measured directly against standards calibrated in existing dead-weight machines. An accurate determination of the rocket thrust and also of the missile load is extremely critical at the early launching stages of a missile flight.

Based on its design experience with the 300,000-lb machine, the Bureau plans to design and construct a 1,000,000-lb dead-weight machine which will meet some of the very special and urgent calibration requirements now in existence and those expected to develop in the near future.

Since 1927 the Bureau has provided a calibration service for force measurement devices which are used for such varied purposes as weighing the contents of tanks, bins and hoppers, measuring the thrust forces of jet and rocket engines, and serving as load-sensitive devices in the automatic control of machinery. A dead-weight machine of 120,000-lb capacity was installed in 1927 and was augmented in 1931 by nine 1,000-lb weights, increasing its capacity to 111,000 lbs and providing test loads by 1,000-lb increments instead of 10,000-lb increments.

Calibration Services

The Bureau's calibration services are a natural outgrowth of its custody of the national standards of physical measurement. Through these services, the national standards are extended, with the required degree of accuracy, throughout commerce, industry, and the military establishments. The growing demand for calibration services indicates the importance to science of precise measurement, the dependence of industry upon accurate calibration services, and the increasing complexity of our technology, in which measurement plays a more vital role every year.

Recognizing the importance of this problem to modern aircraft and missile reliability, the Defense agencies have individually initiated programs for the careful and continuous monitoring of all their instruments which control the reliability of the components in their weapons systems. Collectively they have asked the Bureau to provide an up-to-date and continuing calibration service for their individual standard control instruments. These priority calibrations have necessitated an augmentation of the Bureau staff in these areas. In the calibration of force-measuring devices in connection with the missile program, the workload in some instances has required a two-shift operation.

In such diverse areas as electronics, optics, acoustics, thermodynamics, and atomic and radiation physics, the volume of calibrations performed by the Bureau, in number of items, and in dollar value, showed a considerable rise over the previous year (table 1). Dynamometers, load cells and transducers, aircraft weighing kits, proving rings, Amsler boxes, vibration pickups, and hardness test blocks were among the many items calibrated.

Most large scale weighing is done on railway track scales. The Bureau calibrates these scales through the use of 80,000 lbs. of highly accurate weights carried in each of two test cars. Seventeen of the eighteen master scales of the country were calibrated, and 148 commercial type railway scales were tested. On the Bureau master scale 39 railway scale test cars were standardized and 3 such cars, which could not be moved to a master scale, were standardized in the field by comparison with NBS standards. Two hundred sixty-two large test weights, some of which were destined for missiles projects, totaling some 203,000 lbs., were tested and adjusted to nominal values.

Services Discontinued. The calibration of viscometers by the Bureau was discontinued effective January 1, 1958. This service has been requested very rarely during the past several years, and the instruments in question can be calibrated by the users with the NBS or American Petroleum Institute viscosity standards. Calibration by the user is just as accurate as are his determinations of unknowns, and offers the advantage that certain systematic errors might tend to cancel out if both the calibrating liquid and the unknown are used by the same operator under the same conditions. All those who requested this service during the previous 4 years were contacted before this service was discontinued, and no substantial objection was encountered.

TABLE 1. *Testing and calibration*

Areas of Bureau activities	Representative items	Public		Government		Totals	
		No. of items	Value	No. of items	Value	No. of items	Value
Electricity and Electronics	Electrical instruments, standard cells, resistance, reactance and capacitance standards, d-c to 30 kc.	7,989	$97,464.58	3,034	$39,330.00	11,023	$136,794.58
Optics and Metrology	Light and color standards, photographic lenses, gage blocks and other length standards, refractive index standards, sieves.	23,490	73,844.47	2,771	28,004.55	26,261	101,849.02
Heat	Resistance and liquid-in-glass thermometers, thermocouples, pyrometers.	9,752	84,048.55	766	16,881.00	10,518	100,929.55
Atomic and Radiation Physics	Neutron sources and instruments, X-ray and gamma-ray protective materials and instruments, gamma-ray sources; alpha-ray sources, radioactive materials.	798	17,024.00	301	12,428.90	1,099	29,452.90
Chemistry	Thickness of electrodeposited coatings	143	7,849.50	2	20.00	145	7,869.50
Mechanics	Acoustic instruments, proving rings, load cells, dynamometers, pressure standards, mass standards, track scales, capacity standards, water current meters.	26,710	147,133.02	3,214	53,414.45	29,924	200,547.47
Building Technology	Thermal conductivity, insulating materials	32	1,859.00	28	11,007.00	60	12,866.00
Radio	Electrical and electronic instruments and standards in radio, ultra-high frequency and microwave ranges.	492	10,581.83	16	1,031.50	508	*11,613.33
Total		69,406	439,804.95	10,132	162,117.50	79,538	601,922.35

*This figure does not include a considerable amount of work done by special arrangement with the Armed Services.

Testing Services

While the calibration services of the Bureau are rendered for all who require them in Government and public alike, the testing services are available only to other Federal agencies except when the Bureau has facilities not available elsewhere or when it is called upon to act as a referee.

Testing in quantity is restricted to a few items—notably lamps and cement; with these the Bureau's tests control a large part of the procurement for the Federal Government, and as indicated in table 2 they represent the largest dollar volume of test fees. The samples of lamps inspected represented over 4,500,000 individual lamps, of which 5 percent were rejected on initial inspection at the factories and about 1 percent more on subsequent life test at the Bureau. The cement inspected and tested represented 13,686,361 barrels, for major Federal construction projects.

Other tests included a great number and diversity of items under government procurement ranging from conveyor belting to ball-point pens, from feathers and down to road building materials. These tests were made in the main for other Federal agencies that either lacked laboratory facilities or else required facilities available only at the Bureau.

In connection with the maintenance of the List of Certified Dental Materials of the American Dental Association, Research Associates supported by the ADA tested a total of 131 items of dental materials for compliance with ADA specifications. The materials tested included amalgam alloys, dental mercuries, zinc phosphate cements, silicate cements, and agar type hydro-colloidal impression material. Five items had not been previously certified. The association, through the Journal of the American Dental Association, made available to practicing dentists a certified list of 317 items of dental materials.

Standard Samples

Thirty-eight new standard samples were developed during the year, bringing the total number of samples available to science and industry to well over 600. Approximately 55,523 standard samples, having a fee value of $241,554, were issued by the Bureau. A summary of the standard samples program by area of activity is given in the accompanying table.

Fourteen samples of phosphors were made available as standard samples for the first time. These were selected in cooperation with representatives of the industry, users, the Electrochemical Society, and NBS for industrial and research use in controlling the quality of phosphors and the development of improved phosphors for radar screens, television sets, and radioactivity counters and detectors. The main concern in the development of the samples was to provide material with uniform characteristics to serve as a basis of comparison with other phosphors.

TABLE 2. *Standard Samples*

Areas of activities	Description of samples	Public		Government		Totals	
		No. of samples	Value	No. of samples	Value	No. of samples	Value
Electricity and Electronics	Dry cells, hearing aid batteries, storage batteries	------	----- ----	645	$7,437.00	645	$7,437.00
Optics and Metrology	Lamps	------	----------	4,992	54,000.00	4,992	54,000.00
Atomic and Radiation Physics	Radioactive materials	------	----------	489	16,835.00	489	16,835.00
Chemistry	Paints and other surface coatings, detergents, reagent chemicals.	--- --	----------	509	16,751.25	509	16,751.25
Mechanics	Mechanical devices, furniture	------	----------	968	12,190.50	968	12,190.50
Organic and Fibrous Materials	Paper, textiles, rubber, leather, and plastic products	442	$32,003.50	5,863	66,045.47	6,305	98,048.97
Metallurgy	Metals and alloys	------	----------	65	16,017.00	65	16,017.00
Mineral Products	Cement, concrete and concreting materials, ceramic products.	185	6,513.45	39,826	789,868.21	40,001	796,381.66
Building Technology	Building materials, elevators, air filters, fire extinguishers, heating and air conditioning equipment.	6	12,317.38	633	29,526.40	639	41,843.78
Totals		633	50,834.33	53,990	1,008,670.83	54,623	1,059,505.16

TABLE 3. *Standard Samples Issued*

Area of activities	Descriptions of samples	Public		Government			
				Federal		State	
		No. of samples	Value	No. of samples	Value	No. of samples	Value
Optics and Metrology	Resolution test charts	4,106	$821.20	355	$71.00	1	$0.20
	Photometric standards	110	1,930.00	18	561.00	------	------
	Spectrophotometric standards	60	3,885.00	------	------	------	------
	Color temperature standards	24	570.00	4	90.00	------	------
	Reflectance standards	199	1,969.00	------	------	------	------
	Opacity standards	108	2,168.00	4	64.00	------	------
	Signal glass limit standards	97	3,830.00	4	168.00	------	------
	Gloss standards	135	1,364.00	11	114.00	------	------
	Haze standards	14	140.00	------	------	------	------
Heat	Viscosity oils	788	12,563.00	73	1,095.00	16	223.00
	Thermal radiation standards	21	840.00	9	360.00	------	------
Atomic and Radiation Physics	Radioactive standards	379	6,267.00	248	4,226.00	80	1,360.00
	Meggers lamp (length std)	3	450.00	8	1,200.00	4	600.00
Chemistry	Paint pigments	60	180.00	------	------	------	------
	Sucrose and dextrose	265	993.75	37	138.75	51	191.25
	Composition	19,005	83,033.25	1,126	4,806.00	475	1,825.25
	Spectrographic	3,208	20,248.00	341	2,158.00	97	638.00
	Hydrocarbon	311	8,316.00	58	1,600.00	28	901.00
	Labeled carbohydrates	8,347	10,118.50	5,774	6,994.00	------	------
	Methane fuel gas samples	47	2,425.00	------	------	------	------
	Benzoic acid thermometric cells	6	860.00	------	------	------	------
	Thickness samples for electroplated coatings	2,007	20,070.00	------	------	------	------
Organic and Fibrous Materials	Standard fading samples	527	4,617.00	22	204.00	3	32.00
	Rubber	4,439	17,507.05	43	258.45	------	------
	Phosphor reference samples	127	381.00	------	------	------	------
Metallurgy	Gas analysis samples	18	180.00	2	20.00	8	80.00
Mineral Products	Cement	1,961	4,902.50	65	162.50	137	342.50
Building Technology	Limestone slabs	49	441.00	------	------	------	------
Total		46,421	211,070.25	8,202	24,290.70	900	6,193.20

The second year of a 3-year program for the production of spectrometric standard samples has been completed. Sixteen new spectrographic standards (8 compositions in two sizes) of ingot iron and low alloy steel were issued with provisional certificates of analysis covering 17 elements. This is the first set of standards designed especially to provide calibration for all of the elements encountered in the analysis of iron and steel, including carbon, phosphorus, the common metals, and several unusual elements such as zirconium, tantalum, germanium, and titanium. Work continued on the preparation, testing, and analysis of 27 standards of high-temperature alloys, 27 titanium alloys, 6 zirconium-base alloys, 2 copper-base alloys, and 1 nickel oxide.

Also, six new standard samples of certified composition were prepared: 3 lithium ores, 2 alumina refractories, and 1 titanium alloy. Twelve renewals of exhausted standards were also prepared. These included 4 steels, 1 iron, 1 nickel-base alloy, 2 copper-base alloys, 3 chemicals, and 1 melting-point aluminum.

Two new samples, one of which is the first natural rubber sample issued as a standard were added to the list of standard samples of rubber compounding ingredients during the year, making a total of 17 samples. Two of the existing samples were exhausted and replenished during the year.

The sample of natural rubber is the culmination of approximately 8 years of effort in cooperation with technical committees, rubber growers, and manufacturers. When studies to improve natural rubber testing were resumed at the Bureau in 1948, it was recognized that a standard sample was needed as a yardstick for standardization of testing in rubber laboratories throughout the world. The new natural rubber sample fills this requirement.

Inter-Laboratory Reference Sample Program

Tests of properties of materials are usually somewhat empirical in nature. The results obtained are therefore particularly sensitive to the condition of test equipment and deviations from prescribed laboratory procedures In an attempt to assist testing laboratories in identifying factors which may adversely affect their results, the use of a standard reference sample program is being explored. It is thought that standard reference samples regularly distributed to testing laboratories may enable each to measure its performance against those obtained by the balance of the industry, and to judge when equipment or procedures require repair or modification. Also, data from such a program are useful in the determination of methods which require refinement to make greater reproducibility possible.

Portland cement testing has been chosen as an area in which the benefits of such a reference sample program can be evaluated. Pairs of samples are sent bi-monthly to 103 laboratories which have indicated an interest in such a program. Data are distributed to the participants in a graphi-

cal form which, without involved statistical procedures, permits evaluation of the test method and evaluation of an individual laboratory. More formal statistical analysis involving extensive computation is also being conducted. There is already evidence, after only two pairs of samples, that some improvement has resulted in laboratory performance.

In addition to the portland cement program, assistance in the maintenance and improvement of standardized testing for government laboratories was provided through the paint reference sample program. Seventeen laboratories participated in the examination of two samples. Nine different properties were evaluable for each point. The examination of the data revealed that some of the best procedures should be reviewed and more carefully specified. Apparently some of the procedures are vulnerable to individual interpretation causing a lack of accordance among the results from the 17 laboratories.

4. Cooperative Activities

Throughout its long history, the Bureau has carried on extensive cooperative and consultative activities with other agencies of government on local, state, and Federal levels, as well as with broad segments of the nation's scientific, industrial, and commercial communities. The increasing importance of international trade, and the dependence of technological progress upon the exchange of scientific data among the nations of the world have tended to extend this cooperation into the international sphere.

The activities range from research projects on the properties of materials to the development of nationally and internationally recognized standards and practices.

In general, the relationship between the Bureau and the cooperating organization follows this pattern: the Bureau contributes by providing methods of testing, data on properties of materials, and standards of measurement; the sponsoring society or agency provides other technical data and promulgates the finished documents in the form of codes or specifications.

Some indication of the trend toward the coordination of standardization work among all interested national organizations and laboratories is the increasing amount of foreign travel by members of the Bureau staff. About 70 members of the Bureau staff went to Europe to participate on behalf of the United States in technical meetings of the International Organization for Standards and the various other international scientific commissions and unions.

One of the more important meetings in the western hemisphere occurred at Rio de Janeiro, Brazil, September 1957. The Associate Director for Engineering served as Chairman of the United States Delegation to the Inter-American Meeting of Experts on Standards of the Inter-American Economic and Social Council, Organization of American States.

At the request of the Australian Government, the Bureau's Director served on a committee to study the programs and organization of the Australian National Standards Laboratory. He spent the months of October and November 1957, in completing this assignment. Recommendations for the long-range strengthening of Australian standards activities were made and are now being implemented.

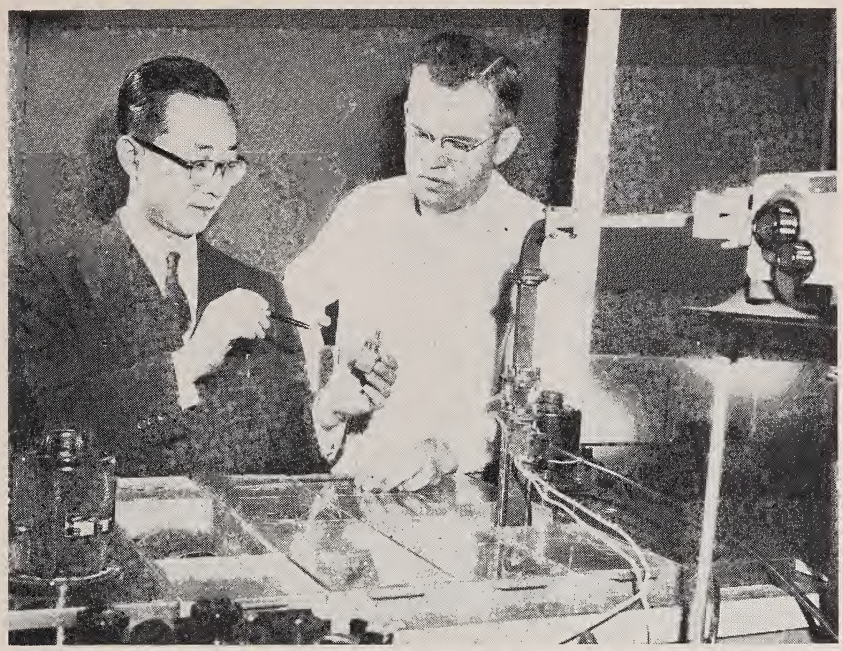
Specifications and Test Methods for Government and Industry

At the request of the General Services Administration the Bureau is responsible for the preparation and maintenance of Federal Purchase Specifications covering a wide range of materials and products. In addition, the Bureau reviews hundreds of proposed specifications both for GSA and other agencies to determine their suitability for use by the Federal Government.

The development of test methods is one of the statutory functions of the Bureau. For Federal Specifications, the Bureau attempts to develop methods that will be applicable to groups or classes of products or materials rather than methods covering a single item. To eliminate unnecessary or undesirable variation, general methods for similar products have been grouped together and made available in the form of test method standards. Suitable and uniform tests for a product are assured in a product specification by making appropriate reference to these standards. The Bureau is in a position to make an important contribution in this entire area by its active participation in the work of technical societies, industrial organizations, and standardization groups. Thus, Federal Purchase Specifications can be coordinated with those of industry, and full advantage can be taken of new developments and improved manufacturing processes. Coordination does not necessarily make Federal Specifications identical with those of industry because purchasing methods of the Government differ markedly from those of industry.

The Bureau accepted assignment for 106 commodity specifications, 30 material specifications, and 8 test method standards in the field of organic and fibrous materials alone. The development and revision of methods of test for various properties of these materials was carried forward. Also, assistance was given to government users of linoleum floor covering, who were engaged in developing standard methods for measuring specular reflectance for these products.

The Bureau has long worked closely with the American Society for Testing Materials. In the past year cooperation was given ASTM Committees in the publication of Method of Color Specification by the Munsell System, in the evaluation of the haze and color properties of clear and diffusing plastic materials, and in the development of a proposed standard method for the measurement of turbidity of industrial waters. Also for ASTM Committees, the Bureau worked on such varied projects as a test method to determine the resistance of plastic to scratch-



International agreement on the standards of physical measurement is receiving increased emphasis. Above, preparations are made for the intercomparison of the Japanese and American standards of microwave power at the NBS Boulder Laboratories (page 108).

ing, a proposed revision of the method for determining the resistance of rubber to abrasion, the revision of their Tentative Method of Test for Tensile Properties of Plastics, a specification for glass fabric reinforced resin laminates, and the preparation of official abbreviations for long chemical names for various types of plastics. Also, one of the staff members served as chairman of a task group of ASTM to write a test method for determining the weight of coating on aluminum-coated sheet and wire.

Another scientific society with which the Bureau has had close association is the American Standards Association. Last year, an NBS Handbook, "Safe Design and Use of Industrial Beta-Ray Sources," was prepared under the sponsorship of the Bureau by the Subcommittee on Sealed Beta-Ray Sources of American Standards Association Z54 Sectional Committee, whose purpose is to formulate safety codes in which basic standards and other appropriate data are applied to industrial radiation protection problems. In addition, the Bureau sponsored or cosponsored 13 other ASA projects.

Standards research was also done in cooperation with organizations such as the American Chemical Society, the Electrochemical Society, the Optical Society of America, the EIA Joint Electron Tube Engineering Council, the Society of the Plastics Industry, the Inter-Society Color Council, and the Signal Section Committee of the Association of American Railroads.

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International Activities

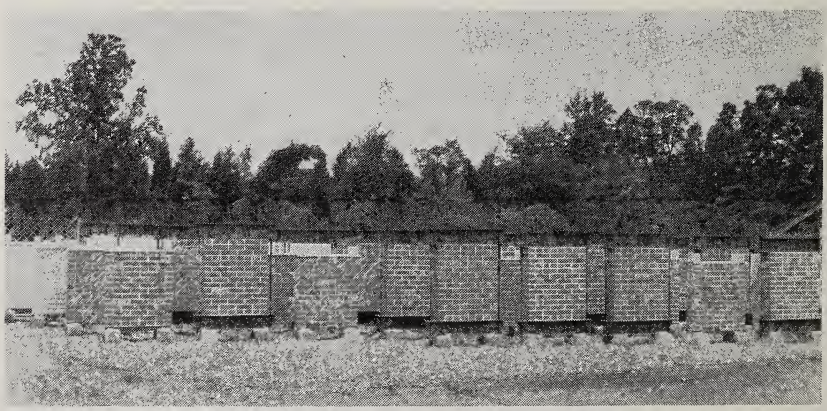
The Bureau contributes to the establishment of internationally recognized standards and practices through cooperation with international standardization and professional groups. Prominent among these groups is the International Organization for Standardization. A staff member served as Chairman of the Seventh Meeting of ISO/TC/61 on Plastics held in Burgenstock, Switzerland, and a member also was leader of the U. S. Delegation to the meeting of ISO/TC/45 on rubber held in Zürich, Switzerland.

The Advisory Committee on Thermometry held three sessions at the International Bureau of Weights and Measures at Sèvres, near Paris, France. Two members of NBS were sent to attend and to visit laboratories in Europe in preparation for these sessions.

To ascertain the degree of reliability of thermal methods for the assay of chemical purity, the International Union of Pure and Applied Chemistry requested at its Paris meeting in 1957 that the Bureau undertake a comparative study of results obtained in the many laboratories that employ this method of assay. This is the first time that a thorough comparison of the results obtained in different laboratories by this important method has been made.

The 12th meeting of the International Commission for Uniform Methods of Sugar Analysis was held at the Bureau in June. Approximately 98 delegates and observers from 20 countries were in attendance.

Meeting in the United States for the first time since 1927, the International Scientific Radio Union (URSI) held its 12th general assembly in Boulder, Colo., from August 22 through September 5. More than 500 delegates from 26 countries responded to the invitation of the U. S. A. National Committee of URSI and the National Academy of Sciences.



Field test of the dimensional stability of brick walls constructed with mortars containing various dolomitic limes. The results are being correlated with those of a laboratory autoclave expansion test of the lime constituent to determine the suitability of the autoclave test for masonry lime specifications. This program is carried on in cooperation with the National Lime Association, **(page 110).**

The scientists met to exchange technical information, coordinate international research efforts, and recommend future projects. The international intercomparison of microwave power standards recommended by Commission I of URSI, was inaugurated by comparing a bolometer mount provided by Japan with the Bureau's standard.

Five members of the staff participated in the following capacities in the work of the International Commission on Illumination: Secretary of U. S. National Committee, Chairman of International Working Committee on Colorimetry, Chairman of Papers Committee and of U. S. Committee on Photopic and Scotopic Vision, Chairman of U. S. Committee on Colors of Signal Lights, and Chairman of U. S. Committee on Aviation Ground Lighting.

The Bureau cooperated with the International Association of Testing and Research Laboratories for Materials and Structures in compiling and reviewing technical information on materials for prestressed reinforced concrete structures.

For more than three decades NBS has provided major support for both national and international groups concerned with radiation protection. It serves as sponsor for, and currently holds the chairmanship of, both the National Committee on Radiation Protection and Measurements (NCRP) and the ASA Z54 Committee on Industrial Uses of Radiation.

The Bureau continued its training services to the International Cooperation Administration, the United Nations, and other federally recognized organizations interested in its research and testing programs. Arrangements were completed for a number of individual trainees, guest workers and research fellows to work in NBS laboratories.

Teams of specialists have come from several nations. Among these were specialists in refrigeration, textiles, purchasing, industrial technology, physical measurement, and education. Conferences and visits to our research laboratories were followed by question and discussion sessions. These were profitable to the teams as well as to the Bureau experts.

In one outstanding example, trainees from the Central Glass and Ceramic Research Institute, Calcutta, India, successfully produced optical glass at that Institute upon their return. The Minister of Scientific and Cultural Affairs described this as the Institute's "crowning achievement", and the Director of the Institute expressed his thanks to the Bureau for the assistance and information given the trainees, which enabled them to design, fabricate, and successfully operate the plant.

Other international organizations in which the Bureau participated include the International Union for Theoretical and Applied Mechanics, the International Institute of Refrigeration, the International Council for Building Research Studies and Documentation, and the European Productivity Agency.

Cooperative Research With Industry

The Bureau's Research Associate Plan, a cooperative program with American industry, has resulted in many significant developments in science and technology. Under this plan, technical, industrial, and commercial organizations can support work at the Bureau on projects that are of special interest to them, yet are of sufficient general interest to justify use of government facilities. These projects must also be important from the standpoint of the Nation's sum total of technological knowledge. Supporting industries donate both funds and personnel for the projects. At the present time, 10 groups are supporting research associates at NBS in the following areas:

Sponsor	*Field of Activity*
American Dental Association	Dental research and testing.
American Electroplaters Society	Research on electroplated coatings.
American Society for Testing Materials	Cement reference laboratory.
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.
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.

An important and similar area of cooperation between the Bureau and industry is the program authorized in 1950 by Public Law 619 under which the Bureau is authorized to accept funds for the purpose of furthering its work. This arrangement permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public.

During the past year 18 projects were supported by gifts from 31 organizations as follows:

Donor	*Field of Activity*
American Dental Trade Association	Standards for color of dental equipment.
American Iron and Steel Institute	Standard samples of ferrous metals, steel research.
American Iron and Steel Institute	Bond tests on high yield point reinforcing bars.
American Petroleum Institute	Metal-organic analytical standards.
Brown and Sharpe Manufacturing Company	Precision Gage Block Program.
CBS Television	Television Field Strength Studies.
Corrosion Research Council of the Engineering Foundation.	Reactions at Metal Surfaces and Stress Corrosion.
Dearborn Gage Company	Precision Gage Block Program.
Do-All Company	Precision Gage Block Program.
E. I. du Pont de Nemours & Company, Inc	Precision Gage Block Program.
Edward Orton Ceramic Foundation	Research in clays.

Donor	*Field of Activity*
Fonda Gage Company, Inc.	Precision Gage Block Program.
General Electric Company	Precision Gage Block Program.
Georgetown University	Physiological Research.
Greenfield Tap and Die Corporation	Precision Gage Block Program.
Hughes Aircraft	Precision Gage Block Program.
IBM Corporation	Precision Gage Block Program.
International Nickel Company	Effect of Nickel on Thermal Conductivity of Steel.
International Nickel Company	Revision of "Nickel and its Alloys."
Link Aviation, Inc	Precision Gage Block Program.
National Lime Association	Hydration of Lime.
New Departure, GMC	Precision Gage Block Program.
Owens-Corning Fiberglas Corp	Design Values for Reinforced Plastics
Pratt and Whitney Company	Precision Gage Block Program.
The Sheffield Corporation	Precision Gage Block Program.
Sugar Research Council	Indices of Solutions of Invert Sugars.
Taft-Peirce Foundation	Precision Gage Block Program.
Timken Roller Bearing Company	Precision Gage Block Program.
UNESCO	Ionization Chamber.
The Van Keuren Company	Precision Gage Block Program.
Welding Research Council	Stress-corrosion cracking of stainless steel.
Anonymous	Ether peroxides.
Anonymous	Phenomena of crystallization.

Free Radicals Research. Close cooperation between the Bureau and industry also is maintained in the three-year program of basic research on the properties of solids containing trapped free radicals which was undertaken for the Department of Defense in October 1956. During the past year considerable progress was made in unraveling the problems connected with this field. The program which is being carried out in various sections of the Bureau represents a coordinated effort by scientists from Government, industrial, and university laboratories to determine the properties of a new class of materials in as short a time as possible.

During the past year approximately 30 senior investigators were actively engaged in the program. Of this group approximately half are scientists on loan from industrial laboratories. Others are on leave from or associated with universities. These scientists are applying a wide variety of physical and chemical techniques, both experimental and theoretical, in an effort to determine the properties of the solids which contain appreciable quantities of trapped reactive species. One way of classifying the many diverse activities in progress is in terms of three broad categories of activity. The first category involves a considerable effort on methods of production of radicals for stabilization. The second category, which represents the largest effort, is that devoted to the characterization of the solids containing trapped radicals, and the third category consists of experiments in progress designed to develop information concerning the use of radicals, or of solids containing radicals, in chemical processes.

Weights and Measures

The Bureau's Office of Weights and Measures carries on a broad program of cooperation with officers of the States, Commonwealths, and Territories of the United States, who are responsible for the regulatory control of commercial weighing and measuring devices and practices within their jurisdictions. The range of these services is extensive, including consultation on model weights and measures statutes, rules, and regulations, the design of accurate physical standards of length, mass, and capacity, effective procedures for testing commercial weighing and measuring devices, specially designed testing equipment, plans for systematic and effective quantity checking of prepackaged merchandise, administrative procedures, specifications and tolerances for commercial devices, training schools for weights and measures officers, and visual aids for technical training.

During the year a field study on methods of commercial filling of consumer storage tanks for liquefied petroleum gas was completed, and the results were made available to the weights and measures officials and to the industry through the National Conference on Weights and Measures. Testing equipment, based on a prototype prover developed by the Bureau, is now available commercially for proving the accuracy of LP gas meters. This equipment is being placed in service by industry and by the States for accuracy control.

Although weights and measures officials have for years checked prepackaged commodities for accuracy of the quantity declarations required on such packages, the procedures for these operations have been nonuniform, and in many cases theoretically unsound. A thorough study was made during the year to develop a standard procedure that could be recommended to weights and measures officials. This study was distributed for comment, as a proposed procedure.

Under a continuing project of reconditioning, when necessary, State standards submitted to the Bureau for reverification, a number of mass and volumetric standards have been put into acceptable condition and certified.

During the year the motion picture "Assignment—Weights and Measures" was released. Presented by the National Conference on Weights and Measures through the cooperation of the Bureau, the film tells the story of how weights and measures supervision affects the average American family. A total of 16 prints were purchased by officials and schools, and 83 loans were made. Over 82 loans of the other two weights and measures films, "A True Standard" and "Testing Mass Standards by Substitution," were made to schools, civic organizations, service clubs, businesses, industries, and scientific and technical societies.

During the year the assembly of books, public documents, and other publications was begun, which will eventually be a completely indexed weights and measures archival and reference library for the NBS staff as well as for students and researchers in this field.

At the request of the National Conference on Weights and Measures, effort is being devoted to the development of new physical standards of weights and measures for the States—standards that are more accurate, more constant, and more durable. In 1836 and in 1866, the Congress provided the States with reference standards that became the basis for nationwide uniformity. Since then, through obsolescence and some individual purchases, nonuniformity in the physical characteristics of the standards has developed among the States. The Bureau's current efforts will provide a sound basis for repeating the Nineteenth Century actions which would bring about complete uniformity among the States in the area of weights and measures reference standards.

A practical contribution was made toward uniformity in field testing procedures for weighing and measuring devices by the expansion of the "training school" project started several years ago. Bureau personnel assisted State officers in the planning and conduct of such schools, and gave lectures and demonstrations in about 18 separate jurisdictions.

Traditionally, the National Conference on Weights and Measures has been one of the principal means of promoting uniformity and raising performance standards in weights and measures administration in the United States. Sponsored by the Bureau, the 43d Annual Conference was held in Washington, D. C., during the year. Thirty-nine states, Hawaii, Puerto Rico, and the District of Columbia were officially represented at this 5-day meeting by 213 delegates out of a total registered attendance of 424.

Education Program

The broad educational program at the Bureau provides an opportunity for the scientific staff to further their education and increase their opportunities to take on added responsibilities.

The NBS Graduate School Program is divided into courses classed as NBS out-of-hours, NBS in-hours, and NBS-university sponsored out-of-hours courses. The program is flexible to meet the varied and changing needs of the research staff. Research workers from other Government agencies may enroll in the NBS classes if the knowledge gained will assist them in their official duties. Since the establishment of the educational program in 1908, over 13,000 registrations have been recorded, and more than 260 graduate degrees have been awarded by 40 different universities, partly on the basis of credits obtained, or the thesis work carried on, under the Bureau program. During the past year there were 1,265 registrations in 46 courses offered at the Washington and Boulder laboratories.

A summer Junior Scientist-Engineer program is open to the qualified scientific student with possibilities for a future career at the Bureau. It consists of orientations, training assignments, and discussions with advisors from the technical divisions. During the past year, approximately 165 students from schools throughout the country participated in this program.

Postdoctoral Resident Research Associateships recommended by the National Academy of Sciences-National Research Council are tenable at the National Bureau of Standards, one of two laboratories in the United States which provide this opportunity. Young scientists at the Ph. D. level participate in basic research in the physical and mathematical sciences. This is the fourth year of the program and the Bureau has 8 associates; 3 in chemistry, 3 in physics, and 2 in mathematics.

The educational program also includes a series of seminars, colloquia, and lectures. The seminars and colloquia are of a specialized nature and are devoted to detailed discussions. The weekly Scientific Staff Meetings are of a more general nature. They are open to all members of the professional staff at the Bureau and are also regularly attended by scientific personnel from neighboring laboratories. Designed to keep Bureau personnel abreast of current developments in the various fields, these lectures are given by members of the staff and by scientists from universities and other laboratories in the United States and abroad. Lectures by members of the Bureau staff include a yearly report to the staff by the Director, lectures on current research of broad general interest to other members of the staff, reports by staff members on international meetings, and reports from fellowship scientists on research work at other institutions in this country and abroad. About two-thirds of the program is devoted to lectures by guest scientists.

A course of lectures by specialists in their respective fields on the establishment and maintenance of standards of measurement was coordinated by a staff member. This course attempted to fill a need for spreading more widely through the scientific staff information about the principles, instruments, and techniques involved in the very accurate experiments required for standards work.

5. Appendixes

5.1. Organization of the National Bureau of Standards*

ALLEN V. ASTIN, *Director*

Associate Director for Physics
ROBERT D. HUNTOON

Associate Director for Engineering
ARCHIBALD T. MCPHERSON

Associate Director for Chemistry
EDWARD WICHERS

Associate Director for Planning
IRL C. SCHOONOVER, Acting

Associate Director for Administration
ROBERT S. WALLEIGH

Associate Director for the Boulder Laboratories
FREDERICK W. BROWN

Director Emeritus
LYMAN J. BRIGGS

Assistants to the Director

HENRY BIRNBAUM and C. N. COATES

Consultants to the Director

L. F. CURTISS, A. G. MCNISH, and C. H. PAGE

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY AND ELECTRONICS, F. B. SILSBEE, *Chief*

Resistance and Reactance, J. L. THOMAS
Electron Devices, C. P. MARSDEN, Jr.
Electrical Instruments, F. M. DEFANDORF
Magnetic Measurements, I. L. COOTER
Dielectrics, J. D. HOFFMAN
Engineering Electronics, G. SHAPIRO
Electronic Instrumentation, C. STANSBURY
Electrochemistry, W. J. HAMER

OPTICS AND METROLOGY, I. C. GARDNER, *Chief*
D. B. JUDD, *Assistant Chief*

Photometry and Colorimetry, L. E. BARBROW
Optical Instruments, F. E. WASHER
Photographic Technology, C. S. MCCAMY
Length, L. V. JUDSON
Engineering Metrology, I. H. FULLMER

HEAT, C. M. HERZFELD, *Chief*

Temperature Physics, J. F. SWINDELLS
Thermodynamics, C. W. BECKETT
Cryogenic Physics, R. P. HUDSON
Rheology, R. S. MARVIN
Engine Fuels, F. L. HOWARD
Free Radicals Research, H. P. BROIDA

ATOMIC AND RADIATION PHYSICS, L. S. TAYLOR, *Chief*
Atomic Physics Laboratory

Spectroscopy, B. F. SCRIBNER, *Acting*
Radiometry, E. K. PYLER
Mass Spectrometry, F. L. MOHLER
Solid State Physics, H. P. R. FREDERIKSE
Electron Physics, L. L. MARTON
Atomic Physics, L. M. BRANSCOMB

*As of September 1, 1958.

Radiation Physics Laboratory, H. O. Wyckoff, *Chief*

Neutron Physics, R. S. Caswell
Radiation Theory, U. Fano
Radioactivity, W. B. Mann
X-rays, H. O. Wyckoff
High Energy Radiation, H. W. Koch
Nucleonic Instrumentation, L. Costrell
Radiological Equipment, S. W. Smith

CHEMISTRY, E. Wichers, *Acting Chief*
R. G. Bates, *Assistant Chief*

Organic Coatings, P. T. Howard
Surface Chemistry, W. W. Walton
Organic Chemistry, H. S. Isbell
Analytical Chemistry, H. A. Bright
Inorganic Chemistry, R. Gilchrist
Electrodeposition, A. Brenner
Molecular Structure and Properties of Gases, F. Buckley
Physical Chemistry, R. G. Bates
Thermochemistry, E. J. Prosen
Spectrochemistry, B. F. Scribner
Pure Substances, C. P. Saylor

MECHANICS, W. Ramberg, *Chief*
B. L. Wilson, *Assistant Chief*

Sound, R. K. Cook
Mechanical Instruments, E. C. Lloyd
Fluid Mechanics, G. B. Schubauer
Engineering Mechanics, B. L. Wilson
Mass and Scale, H. S. Peiser
Capacity, Density, and Fluid Meters, C. T. Collett, *Acting*
Combustion Controls, F. R. Caldwell

ORGANIC AND FIBROUS MATERIALS, G. M. Kline, *Chief*
W. D. Appel, *Assistant 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. P. Bekkedahl
Plastics, F. W. Reinhart
Dental Research, W. T. Sweeney

METALLURGY, J. I. Hoffman, *Chief*
T. G. Digges, *Assistant Chief*

Thermal Metallury, T. G. Digges
Chemical Metallurgy, L. L. Wyman
Mechanical Metallurgy, J. A. Bennett
Corrosion, G. A. Ellinger
Metal Physics, L. M. Kushner

MINERAL PRODUCTS, I. C. Schoonover, *Chief*
C. H. Hahner, *Assistant Chief*

Engineering Ceramics, M. D. Burdick
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*
H. R. Snoke, *Assistant Chief*

Structural Engineering, D. Watstein
Fire Protection, A. F. Robertson
Air Conditioning, Heating, and Refrigeration, P. R. Achenbach
Floor, Roof, and Wall Coverings, H. R. Snoke
Codes and Safety Standards, J. A. Dickinson
Heat Transfer, H. E. Robinson

APPLIED MATHEMATICS, E. W. Cannon, *Chief*
F. L. Alt, *Assistant Chief*

Numerical Analysis, P. J. Davis
Computation, E. W. Cannon, *Acting*
Statistical Engineering, C. Eisenhart
Mathematical Physics, R. F. Dressler

DATA PROCESSING SYSTEMS, S. N. Alexander, *Chief*

SEAC Engineering Group, P. D. Shupe, Jr.
Components and Techniques, R. D. Elbourn
Digital Circuitry, S. Greenwald
Digital Systems, A. L. Liener
Analog Systems, H. K. Skramstad
Applications Engineering, S. N. Alexander, *Acting*

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, H. E. Hardaway
Personnel, G. R. Porter
Administrative Services, H. P. Dalzell
Shops, F. P. Brown
Supply, G. B. Kefover
Management Planning, Ivan Asay
Budget, N. L. Christeller
Internal Audit, J. P. Menzer
Plant, H. Graham

BOULDER LABORATORIES, F. W. Brown, *Director*

Boulder, Colorado

CRYOGENIC ENGINEERING, R. B. Scott, *Chief*

Assistant Chief, B. W. Birmingham
Cryogenic Equipment, R. B. Jacobs
Cryogenic Processes, B. W. Birmingham
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, E. K. Smith
Regular Propagation Services, W. B. Chadwick
Sun-Earth Relationships, Alan Shapley
VHF Research, K. L. Bowles, *Acting*
Ionospheric Communication Systems, R. C. Kirby, *Acting*

RADIO PROPAGATION ENGINEERING,* K. A. Norton, *Chief*

Assistant Chief for Research and Development, J. W. Herbstreit, Jr.
Assistant Chief for Engineering, Logistics, and Technical Administration, K. O. Hornberg
Data Reduction Instrumentation, W. E. Johnson
Modulation Systems, A. D. Watt
Navigation Systems, G. Hefley
Radio Noise, W. Q. Crichlow
Tropospheric Measurements, C. F. Peterson
Tropospheric Analysis, P. L. Rice
Radio Systems Application Engineering, R. S. Kirby
Radio-Meteorology, B. R. Bean

RADIO STANDARDS, W. D. George, *Acting Chief*

Asst. Chief for Radio Frequencies, W. D. George
Asst. Chief for Microwave Frequencies, D. M. Kerns
High Frequency Electrical Standards, M. C. Selby
Radio Broadcast Service, A. H. Morgan
High Frequency Impedance Standards, J. L. Dalke
Electronic Calibration Center, H. W. Lance
Microwave Physics, J. M. Richardson
Microwave Circuit Standards, R. W. Beatty

ADMINISTRATIVE DIVISION, S. W. J. Welch

*The above two divisions comprise the Central Radio Propagation Laboratory.

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

Lamp Inspector, Brookline 46, Mass.
Visual Landing Aids Field Lab., Arcata, Calif.
Master Railway Track Scale Depot, Clearing, Ill.

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

Cheyenne Mt. Field Station, Colorado Springs, Colo.
Radio Transmitting Station WWV, Beltsville, Md.

Radio Propagation Field Stations
- Anchorage Alaska
- Barrow, Alaska
- Carthage, Ill.
- Fort Belvoir, Va.
- Gunbarrell Hill, Longmont, Colo.
- Long Branch, Ill.
- Margarita, Panama, Canal Zone
- San Juan, P. R.
- Sterling, Va.

Radio Noise Recording Stations
- Bill, Wyo.
- Front Royal, Va.
- Kauai, Hawaii

5.2. Fiscal Data on NBS Program

PROGRAM AND SOURCE OF FINANCING	Obligations Incurred (in thousands of dollars)		
SUPPORTED BY NBS APPROPRIATIONS			
Operating Program:			
Expenses		$9,723.5	
Construction and Facilities Programs:			
Plant and Equipment	$470.2		
Construction of Facilities	3.1		
		473.3	
Total NBS Appropriations			$10,196.8
SUPPORTED BY OTHER FUNDS			
Research and Development Programs:			
Department of Defense and AEC	13,265.1		
Other Agencies	3,167.5		
Non-Governmental Sources	168.4		
		16,601.0	
Calibrations and Standard Samples		1,137.8	
Reimbursable Administrative Services		1,222.7	
Total, Supported by Other Funds			18,961.5
Total Program			29,158.3

5.3. Advisory Committees

STATUTORY VISITING COMMITTEE

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

Dr. M. J. Kelly, President, Bell Telephone Laboratories, Inc. (1962), Chairman
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)
Professor F. Seitz, University of Illinois (1961)

Technical Advisory Committees

[Designated by leading scientific and technical societies to advise NBS Director in specific technical areas. Members listed served during fiscal year 1958.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Dr. Ralph Brown, Millburn, N. J.
Dr. C. G. Suits, General Electric Company
Mr. Robert C. Sprague, Sprague Electric Company
Dr. J. A. Hutcheson, Westinghouse Electric Corporation
Mr. H. P. Corwith, Western Union Telegraph Company
Professor W. A. Lewis, Jr., Illinois Institute of Technology

INSTITUTE OF RADIO ENGINEERS

Professor Henry G. Booker, Cornell University
Mr. Stuart L. Bailey, Jansky & Bailey
Professor E. C. Jordon, University of Illinois
Professor A. H. Waynick, Pennsylvania State University
Professor J. B. Wiesner, Massachusetts Institute of Technology
Dr. H. W. Wells, Carnegie Institution of Washington

AMERICAN INSTITUTE OF PHYSICS

Professor R. B. Lindsay, Brown University
Professor D. M. Dennison, University of Michigan
Dean R. A. Sawyer, University of Michigan
Professor Mark W. Zemansky, City College of New York
Professor A. O. C. Nier, University of Minnesota
Dr. H. M. Parker, General Electric Company
Dr. Otto Oldenberg, Harvard University
Professor John Strong, Johns Hopkins University
Professor Henry A. Fairbank, Yale University
Professor H. F. Olson, Radio Corporation of America
Professor J. W. M. DuMond, California Institute of Technology
Professor J. E. Mayer, University of Chicago
Professor John Bardeen, University of Illinois
Professor P. Kusch, Columbia University

CONFERENCE ORGANIZATION FOR MATHEMATICAL SCIENCES

Professor A. H. Taub, University of Illinois
Dean Mina Rees, Hunter College
Professor Philip M. Morse, Massachusetts Institute of Technology
Professor David Blackwell, University of California
Professor Mark Kac, Cornell University
Dr. E. U. Condon, Washington University

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

Mr. Clarence E. Sims, Battelle Memorial Institute
Dr. Maxwell Gensamer, Columbia University
Dr. E. C. Smith, Republic Steel Corporation
Dr. Cyril S. Smith, University of Chicago
Dr. Albert J. Phillips, American Smelting & Refining Company
Dr. Clarence Zener, Westinghouse Electric Corporation

AMERICAN CHEMICAL SOCIETY

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

AMERICAN CERAMIC SOCIETY

Dr. A. C. Siefert, Owens-Corning Glass Corporation
Mr. Paul V. Johnson, Structural Clay Products Research Foundation
Dean Elburt Osborn, Pennsylvania State University
Mr. Harry W. Thiemecke, Homer Laughlin China Company
Mr. H. N. Kraner, Bethlehem Steel Company
Mr. Raymond C. Reese, Toledo, Ohio
Mr. John T. Roberts, Glen Ellyn, Ill.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Dean 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

AMERICAN SOCIETY OF CIVIL ENGINEERS

Dr. G. H. Hickox, Engineer Research and Development Laboratories, Fort Belvoir, Va.
Dr. A. T. Ippen, Massachusetts Institute of Technology
Mr. Raymond C. Reese, Toledo, Ohio

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

Mr. Charles M. Fuller, Sealer of Weights and Measures, Los Angeles, California
Mr. Seth T. Shaw, Safeway Stores, Inc.
Mr. C. J. McCaffrey, Ralph N. Brodie Company, Inc.
Mr. W. A. Scheurer, Exact Weight Scale Company
Mr. Roland Meek, State Board of Health, Indianapolis, Indiana
Professor L. J. Gordon, Director, Weights and Measures Research Center, Denison University

AMERICAN STANDARDS ASSOCIATION

Mr. H. Thomas Hallowell, Jr., Standard Pressed Steel Company
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

Dr. K. B. Woods, Purdue University, West Lafayette, Indiana
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 1958.

RECIPIENT	HONOR	SOURCE
Alexander, S. N.	Award	Washington Academy of Sciences.
Austin, A. V.	Honorary Doctor of Science Degree	George Washington University.
	Election to Membership	American Philosophical Society.
		American Academy of Arts and Sciences.
Beckett, C. W.	Ludwig Mond Prize for Paper	Institution of Mechanical Engineers of London.
Brenner, Abner	Richards Memorial Lecturer	The Electrochemical Society.
	Heussner Award for Paper	American Electroplaters' Society.
Brode, W. R.	Elected President	American Association for the Advancement of Science.
de Minjer, C. H.	Heussner Award for Paper	American Electroplaters' Society.
Eisenhart, Churchill	Rockefeller Public Service Award	Administered by Princeton Univ. as a national trust.
Elbourn, R. D.	Award	Washington Academy of Sciences.
Gross, D.	Richard L. Templin Award	American Society for Testing Materials.
Gardner, I. C.	Elected President	Optical Society of America.
Harvey, Kenneth B.	Fellowship grant to the Univ. of Amsterdam	National Research Council of Canada.
Herbstreit, Jack W.	Fellowship Award	Institute of Radio Engineers.
Hoffman, James I.	Gold Medal Alumni Award	Franklin & Marshall College.
Huntoon, R. D.	Achievement Award	Alumni Association of Iowa State Teachers College.
	Alumni Recognition Award	American University.
Leaderman, Herbert	Fulbright Fellowship	Department of State.
Leiner, Alan L.	Award	Washington Academy of Sciences.
Loftus, J. J.	Richard L. Templin Award	American Society for Testing Materials.
Marton, L.	Elected President	Washington Philosophicial Society.
McCrackin, Frank L.	Certificate	D. C. Council of Engineering and Architectural Societies.
McNesby, James R.	Rockefeller Public Service Award	Administered by Princeton Univ. as a national trust.
McPherson, A. T.	Elected President	Washington Academy of Sciences
Reinhart, Frank W.	Honorary Doctor of Science Degree	Juniata College.
Robertson, A. F.	Richard L. Templin Award	American Society for Testing Materials.
Ruffa, Richard A.	Fellowship at Catholic University	Knights of Columbus.
Scribner, Bourdon F.	Award of Merit	American Society for Testing Materials.
Seliger, Howard H.	Rockefeller Public Service Award	Administered by Princeton Univ. as a national trust.
Youden, W. J.	Honorary Election to Life Membership	International Statistical Institute.

DEPARTMENT OF COMMERCE AWARDS

Barrow, Louis E.	Meritorious Service Award	Photometry and Colorimetry.
Bliss, Lloyd C.	Meritorious Service Award	Concreting Materials.
Brown, Frank P.	Meritorious Service Award	Instrumentation.
Bunting, Elmer N.	Meritorious Service Award	Phase Equilibrium Studies.
Crossette, Marie H.	Meritorious Service Award	Organic and Fibrous Materials.
Fuller, Everett G.	Meritorious Service Award	Elastic Scattering of High-energy X-rays by Nuclei.
Fullmer, Irvin H.	Meritorious Service Award	Standardization of Screw Threads.
Hague, John L.	Meritorious Service Award	Complex Metal Alloys.
Hayward, Evans	Meritorious Service Award	Elastic Scattering of High-energy X-rays by Nuclei.
Loebenstein, W. V.	Meritorious Service Award	Adsorption and Catalysis.
Lowell, Percival D.	Meritorious Service Award	Electronic Instrumentation.
Maryott, Arthur A.	Meritorious Service Award	Dielectric Properties of Compressed Gases at Microwave Frequencies.
Mauer, Floyd A.	Meritorious Service Award	Crystal Chemistry.
Seliger, Howard H.	Meritorious Service Award	Liquid Scintillation Counting of Beta-emitting Radioactive Nuclides.
Sweeney, William T.	Meritorious Service Award	Dental Materials.
Trees, Richard E.	Meritorious Service Award	Quantum Theory of Complex Atomic Spectra.
Wood, Lawrence A.	Meritorious Service Award	Rubber.
Wyman, LeRoy L.	Meritorious Service Award	Alloy Theory.
Bean, Howard S.	Exceptional Service Award	Metering of Fluids.
Brode, Wallace R.	Exceptional Service Award	Chemical Spectroscopy.
Mann, Wilfrid B.	Exceptional Service Award	Radionuclide Standards.

5.5. Publications

Publications in the Bureau's Series

Journal of Research. Complete scientific reports of the Bureau's research and development, both experimental and theoretical, in physics, chemistry, engineering, and mathematics, and the results of test and instrumentation activities in these fields are printed in the *Journal.* The subject matter of the reports embraces the fields of electricity and electronics, optics and metrology, heat, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building technology, applied mathematics, data processing systems, basic instrumentation, weights and measures, cryogenic engineering and radio propagation. (Annual subscription: domestic, $5.00; $1.75 additional for foreign mailing.)

Volume 59, July–December 1957

2768. Thermal length changes of some refractory castables. S. J. Schneider and L. E. Mong.
2769. Precise intercomparison of acids by differential potentiometric titration with hydrogen electrodes. Roger G. Bates and Edward Wichers.
2770. Mixed-path ground-wave propagation: 2. Larger distances. James R. Wait and James Householder.
2771. A spectroscopic study of oils used in oil-extended rubber. Frederic J. Linnig and James E. Stewart.
2772. Infrared spectra of sugar acetates in solution. Horace S. Isbell, Francis A. Smith, E. Carroll Creitz, Harriet L. Frush, Joseph D. Moyer, and James E. Stewart.
2773. A problem in self-heating of a spherical body. S. M. Genensky.
2774. Properties of arsenic sulfide glass. Francis W. Glaze, Douglas H. Blackburn, Jerome S. Osmalov, Donald Hubbard, and Mason H. Black.
2775. Thermal conductivity of beryllium oxide from 40° to 750° C. David A. Ditmars and Defoe C. Ginnings.
2776. A self-balancing direct-current bridge for accurate bolometric power measurements. Glenn F. Engen.
2777. Some observations on hydrated monocalcium aluminate and monostrontium aluminate. Elmer T. Carlson.
2778. Turbidity and viscosity measurements on some cationic detergents in water and in sodium chloride solutions. Lawrence M. Kushner, Willard D. Hubbard, and Rebecca A. Parker.
2779. Relative stress-optical coefficients of some National Bureau of Standards optical glasses. Roy M. Waxler and Albert Napolitano.
2780. Physicochemical studies of the destructive alkali-aggregate reaction in concrete. Robert G. Pike and Donald Hubbard.
2781. Insulated loop antenna immersed in a conducting medium. James R. Wait.
2782. Noncrystal ionic model for silica glass. Leroy W. Tilton.
2783. A computation of cyclic cubic units. Harvey Cohn and Saul Gorn.
2784. Estimation of the frequencies of thin elastic plates with free edges. Tosio Kato, Hiroshi Fujita, Yoshimoto Nakata, and Morris Newman.
2785. A thermochemical study of the reaction of calcium hydroxide, silica gel, and water. Edwin S. Newman.
2786. On some expansions for Bessel integral functions. F. Oberhettinger.
2787. Table of the first moment of ranked extremes. Julius Lieblein and Herbert E. Salzer.
2788. An approximate expression for gamma-ray degradation spectra. U. Fano and Ann T. Nelms.
2789. Some infrared bands of deuterium sulfide. Harry C. Allen, Jr., Earle K. Plyler, and L. R. Blaine.
2790. Some effects of low temperatures and notch depth on the mechanical behavior of an annealed commercially pure titanium. Glenn W. Geil and Nesbit L. Carwile.
2791. Determination and use of the sag point as a reference point in the heating of glasses. Sam Spinner, Given W. Cleek, and Edgar H. Hamilton.
2792. Formulas for inverse osculatory interpolation in the complex plane. Herbert E. Salzer.
2793. An X-ray study of textural stresses in two-phase alloys. C. J. Newton and H. C. Vacher.
2794. Dissociation of 4-chloro-4′-aminodiphenylsulfone. Elizabeth E. Sager and Fleur C. Byers.
2795. Speed of sound in water by a direct method. Martin Greenspan and Carroll E. Tschiegg.
2796. Pattern of a flush-mounted microwave antenna. James R. Wait.

2797. Standards for *p*H measurements from 60° to 95° C. Vincent E. Bower and Roger G. Bates.
2798. A numerical study of Dedekind's cubic class number formula. Harvey Cohn.
2799. Impact properties of slack-quenched alloy steels. Melvin R. Meyerson and Samuel J. Rosenberg.
2800. Synthesis of C^{14}-labeled L-sorbose and L-ascorbic acid. H. L. Frush and H. S. Isbell.
2801. A determination of the gamma-ray emission of radium. Frank H. Attix and Victor H. Ritz.
2802. Radiation from slots on dielectric-clad and corrugated cylinders. James R. Wait and Alyce M. Conda.
2803. Infrared emission spectrum of methane at 3.3 microns. Earle K. Plyler and Lamdin R. Blaine.
2804. Term analysis of the first spectrum of rhenium (Re I). P. F. A. Klinkenberg, W. F. Meggers, R. Velasco, and M. A. Catalán.
2805. An apparatus for measurement of thermal conductivity of solids at low temperatures. Robert L. Powell, William M. Rogers, and Don O. Coffin.
2806. Some factors affecting the surface area of hydrated portland cement as determined by water-vapor and nitrogen adsorption. L. A. Tomes, C. M. Hunt, and R. L. Blaine.
2807. Excitation of surface waves on conducting, stratified, dielectric-clad, and corrugated surfaces. James R. Wait.
2808. Cunife wire magnets of small size. Irvin L. Cooter and Robert E. Mundy.
2809. Interpretation of mass spectra of condensates from urban atmospheres. E. R. Weaver, E. E. Hughes, Shirley M. Gunther, Schuford Schuhmann, Nancy T. Redfearn, and Ralph Gorden, Jr.
2810. Infrared emission spectrum of silicon carbide heating elements. James E. Stewart and Joseph C. Richmond.
2811. Increased chemical reactivity of the surface compared with that in the bulk volume of Britton-Robinson universal buffers. Robert G. Pike and Donald Hubbard.
2812. Photometric determination of tungsten in steel and titanium alloys with dithiol. Lawrence A. Machlan and John L. Hague.
2813. On the most general form of the compatibility equations and the conditions of integrability of strain rate and strain. Edmund H. Brown.
2814. An apparatus for measuring the piezoresistivity of semiconductors. R. F. Potter and W. J. McKean.

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2815. The condition of certain matrices, III. John Todd.
2816. Infrared study of some structural changes in natural rubber during vulcanization. Frederic J. Linnig and James E. Stewart.
2817. Crystal structure of barium hydrogen orthophosphate. Gordon Burley.
2818. A study of sampling of flame gases. C. Halpern and F. W. Ruegg.
2819. Pyrolysis of polyamides. Sidney Straus and Leo A. Wall.
2820. Some thermodynamic properties of the systems polybutadiene-benzene and polyisobutene-benzene. R. S. Jessup.
2821. Infrared measurements with a small grating from 100 to 300 microns. Earle K. Plyler and L. R. Blaine.
2822. A low-frequency annular-slot antenna. James R. Wait.
2823. Relation between the absorption spectra and the chemical constitution of dyes: XXIX. Interaction of direct azo dyes in aqueous solution. May N. Inscoe, John H. Gould, Mary E. Corning, and Wallace R. Brode.
2824. Energy spectra of cascade electrons and photons. Charles A. Olson and Lewis V. Spencer.
2825. Observer differences in color-mixture functions studied by means of a pair of metameric grays. Kenneth L. Kelly.
2826. Precise evaluation of surface area with indirectly calculated dead space. William V. Loebenstein.
2827. Sample calculations of gamma-ray penetration into shelters: Contributions of sky shine and roof contamination. Martin J. Berger and James C. Lamkin.
2828. Heat content of sodium borohydride and of potassium borohydride from 0° C to 400° C. Thomas B. Douglas and Ann W. Harman.
2829. Infrared spectra of crystalline polyphenyls. James E. Stewart and Max Hellmann.
2830. On the application of steam-driven water jets for propulsion purposes. J. M. Burgers and A. Ghaffari.
2831. Mass spectra and relative sensitivities of some polyphenyls. Paul Bradt and Fred L. Mohler.

2832. Infrared spectra of thermally degraded poly(vinyl chloride). Robert R. Stromberg, Sidney Straus, and Bernard G. Achhammer.
2833. Current and potential relations for the cathodic protection of steel in salt water. W. J. Schwerdtfeger.
2834. Joule-Thomson process in the liquefaction of helium. Edmund H. Brown and John W. Dean.
2835. Changes in the properties of an asphalt during the blowing operation. L. R. Kleinschmidt and H. R. Snoke.
2836. Creep of annealed nickel, copper, and two nickel-copper alloys. William D. Jenkins and Carl R. Johnson.
2837. Stress-strain relation of pure-gum rubber vulcanizates in compression and tension. Lawrence A. Wood.
2838. Tables for diagonalizing second-order matrices. R. E. Trees and C. DeW. Coleman.
2839. Effects of capillary shape on flow characteristics and degradation of polymer solutions. Hobart S. White and Harriet V. Belcher.
2840. Ortho-para catalysis in liquid-hydrogen production. D. H. Weitzel, W. V. Loebenstein, J. W. Draper, and O. E. Park.
2841. Degradation of cellulose in a vacuum with ultraviolet light. Joseph H. Flynn, William K. Wilson, and William L. Morrow.
2842. Cavity ionization as a function of wall material. Frank H. Attix, LeRoy DeLaVergne, and Victor H. Ritz.
2843. Fragmentation of waterdrops in the zone behind an air shock. Olive G. Engel.
2844. Transient radio-frequency ground waves over the surface of a finitely conducting plane earth. J. R. Johler.
2845. Measurement of current with a Pellat-type electrodynamometer. R. L. Driscoll.
2846. Measurement of current with the National Bureau of Standards current balance. R. L. Driscoll and R. D. Cutkosky.
2847. Radial distribution of the center of gravity of random points on a unit circle. F. Scheid.
2848. An adiabatic calorimeter for the range 30° to 500° C. E. D. West and D. C. Ginnings.
2849. An evaluation of the luminous-transmittance requirements for railroad-signal glassware in terms of standard source A of the International Commission on Illumination. Francis C. Breckenridge.
2850. Random notes on matrices. K. Goldberg.
2851. Range finders using projected images. Robert E. Stephens.
2852. Effect of rib flexibility on the vibration modes of a delta-wing aircraft. Wilhelmina D. Kroll.
2853. Thermal degradation of cellulosic materials. S. L. Madorsky, V. E. Hart, and S. Straus.
2854. Role of vitrons in alkali silicate binary glasses. Leroy W. Tilton.
2855. Elastic problem for a ring of uniform force in an infinite body. William H. Pell.
2856. Description and analysis of the second spectrum of molybdenum, Mo II. C. C. Kiess.
2857. Forces on cylinders and plates in an oscillating fluid. Garbis H. Keulegan and Lloyd H. Carpenter.
2858. Reaction of portland cement with carbon dioxide. Charles M. Hunt, Vernon Dantzler, Lewis A. Tomes, and Raymond L. Blaine.
2859. Average energy of sulfur-35 beta decay. Howard H. Seliger, Wilfrid B. Mann, and Lucy M. Cavallo.
2860. Effect of structure on the thermal decomposition of polymers. Leo A. Wall and Roland E. Florin.
2861. Comparison of theoretical and empirical relations between the shear modulus and torsional resonance frequencies for bars of rectangular cross section. Sam Spinner and Rudolph C. Valore, Jr.
2862. Specific volume and degree of crystallinity of semicrystalline poly(chlorotrifluorethylene), and estimated specific volumes of the pure amorphous and crystalline phases. John D. Hoffman and James J. Weeks.
2863. Heat and ultraviolet aging of poly(vinyl chloride). Charles F. Bersch, Mary R. Harvey, and Bernard G. Achhammer.
2864. Determination of water vapor from the change in electrical resistance of a hygroscopic film. Elmer R. Weaver, Ernest E. Hughes, and Albert W. Diniak.
2865. Improved bridge method for the measurement of core losses in ferromagnetic materials at high flux densities. William P. Harris and Irvin L. Cooter.
2866. Stress-strain relationships in yarns subjected to rapid impact loading: 5. Wave propagation in long textile yarns impacted transversely. Jack C. Smith, Frank L. McCrackin, and Herbert F. Schiefer.

2867. Measurement of flame speeds by a nozzle burner method. Carl Halpern.
2868. Growth of preferentially oriented aluminum single crystals. Theodore H. Orem.
2869. Marginal performance of corrected ophthalmic lenses. Francis E. Washer and Walter R. Darling.
2870. Enthalpy and heat capacity from 0° to 900° C of three nickel-chromium-iron alloys of different carbon contents. Thomas B. Douglas and Ann W. Harman.
2871. Relative strengths of forty aromatic carboxylic acids in benzene at 25° C. Marion Maclean Davis and Hannah B. Hetzer.
2872. Shape of the liquidus surface as a criterion of stable glass formation. Edgar H. Hamilton and Given W. Cleek.
2873. Twinned epitaxy of copper on copper. Theodore H. Orem.
2874. Dielectric constant of deuterium oxide. Cyrus G. Malmberg.
2875. Additional abscissas and weights for Gaussian quadratures of high order: values for n-64, 80, and 96. Philip Davis and Philip Rabinowitz.
2876. Mass spectra of aromatic hydrocarbons filtered from smoky air. Fred L. Mohler, Paul Bradt, and Vernon H. Dibeler.

Technical News Bulletin. This monthly publication summarizes the current research development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and a bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; 75 cents additional for foreign mailing.)

Basic Radio Propagation Predictions. This is a monthly publication for those concerned with radio communication in determining the best sky-wave frequencies over any path at any time of day for average conditions for the month of prediction, which are made three months in advance. Charts of extraordinary-wave critical frequency for the $F2$ layer and of maximum usable frequency for a transmission distance of 4,000 km, of highest frequency of sporadic E in excess of 15 Mc are included. In addition, there are various maps, charts, diagrams, and nomograms needed to make practical application of the world-contour charts, together with examples of their use. (Annual subscription: domestic, $1.00; 50 cents additional for foreign mailing.)

Circulars. Circulars are compilations of information on various subjects related to the Bureau's scientific, technical, and engineering activities. They include not only the results of Bureau studies, but give data of general interest from other sources.

460. Supplement. Supplementary list of publications of the National Bureau of Standards, July 1, 1947, to June 30, 1957.
467. Volume III. Atomic energy levels. Charlotte E. Moore.
539. Volume 7. Standard X-ray diffraction powder patterns. Howard E. Swanson, Nancy T. Gilfrich, and Marlene I. Cook.
562. Supplement 1. Bibliography of research on deuterium and tritium compounds, 1953 and 1954. Virginia R. Johnson, Lawrence M. Brown, and Abraham S. Friedman.
584. Simulator for use in development of jet engine controls. Emile S. Sherrard.
585. The measurement of thickness. George Keinath.
586. Electric hygrometers. Arnold Wexler.
587. Electroforming of waveguide components for the millimeter-wavelength range. Albert A. Feldmann.
588. Determination and correlation of flow capacities of pneumatic components. D. H. Tsai and M. M. Slawsky.
590. Methods of testing thermocouples and thermocouple materials. Wm. F. Roeser and S. T. Lonberger.
591. Section 1. System design of digital computers at the National Bureau of Standards: methods for high-speed addition and multiplication.
1. A logic for high-speed addition, by A. Weinberger and J. L. Smith.
2. Shortcut multiplication for binary digital computers, by J. L. Smith and A. Weinberger.
592. Nickel and its alloys. J. G. Thompson.
593. The federal basis for weights and measures. Ralph W. Smith.
594. Preparation, maintenance, and application of standards of radioactivity. W. B. Mann and H. H. Seliger.

Miscellaneous Publications. As the name implies, this series includes material, which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series.

221. Hydraulic research in the United States, 1957. Helen K. Middleton.
222. Report of the 42d National Conference on Weights and Measures, 1957.
223. Annual report, 1957, National Bureau of Standards.

Handbooks. These are recommended codes of engineering and industrial practice, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.

28. (1957)—Part I. Screw-thread standards for federal services 1957.
63. Protection against neutron radiation up to 30 million electron volts.
64. Design of free-air ionization chambers.
65. Safe handling of bodies containing radioactive isotopes.
66. Safe design and use of industrial beta-ray sources.

Applied Mathematics Series. Mathematical tables, manuals, and studies.

49. Further contributions to the solution of simultaneous linear equations and the determination of eigenvalues.
51. Tables of the exponential integral for complex arguments.
52. Integrals of airy functions.
53. Table of natural logarithms for arguments between five and ten to sixteen decimal places.

Building Materials and Structures Reports. This series reports the results of work at the National Bureau of Standards in the field of building research. The objective is to provide the government, the interested professions, and the building industry with technical data useful in the preparation of building codes, standards, and engineering design criteria. The subjects of primary interest are the properties of building materials, structures, equipment, and facilities.

151. Thermal resistance of airspaces and fibrous insulations bounded by reflective surfaces. H. E. Robinson, L. A. Cosgrove, and F. J. Powell.

Publications in Outside Journals*

Alexander, S. N., Survey of computer development and applications, Proc. Conference on Science and Tech. for the Deans of Engineering, Purdue Univ. (Sept. 1957).

Allen, H. C., Jr., and Plyler, E. K., The structure of ethylene from infrared spectra, J. Am. Chem. Soc. **80**, 2673 (1958).

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Ambler, E., and Hudson, R. P., Absolute temperature below 1° K: chromic methylammonium alum as a thermometric substance, J. Chem. Phys. **27**, 378 (1957).

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*For completeness, a few references to publications issued previous to July 1957 are included.

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Bean, B. R., and Cahoon, B. A., The use of surface weather observation to predict the total atmospheric bending of radio rays at small elevation angles, IRE Proc. **45**, 1545–1546 (Nov. 1957).
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Patents

(The following U. S. Patents have been granted to NBS inventors; assigned to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

Ainsworth, Ernest F., No. 2,827,623, March 18, 1958. Magnetic tape inscriber-outscriber (Commerce).

Breckenridge, Robert G., and Oshinsky, William, No. 2,793,275, May 21, 1957. Photoconductive cell (Army).

Forman, Ralph, and Breckenridge, Robert G., No. 2,828,396, March 25, 1958. Magnetoresistive device (Commerce).

Gilford, Saul R., No. 2,827,040, March 18, 1958. Automatic sphygmomanometer (Commerce).

Gilliland, Theodore R., No. 2,824,218, February 18, 1958. Automatic radio control for clocks (Commerce).

Greenspan, Martin, and Tscheigg, Carroll E., No. 2,796,522, June 18, 1957. Crystal-controlled relaxation oscillator (Commerce).

Haworth, Leland J., No. 2,804,613, August 27, 1957. Ship centered P. P. I. (Navy).

Hermach, Francis L., No. 2,805,394, September 3, 1957. Alternating current voltammeters (Commerce).

Hudson, Donald C. (Col., U. S. Army) and Kumpula, John W., No. 2,798,958, July 9, 1957. Apparatus for producing radiographs within a subject (Army).

Isbell, Horace S., No. 2,791,492, May 7, 1957. Apparatus for introducing alkali metal into closed systems (Commerce).

Isbell, Horace S., and Schaffer, Robert, No. 2,796,416, June 18, 1957. Process of preparing maltobionolactone (Commerce).

Joseph, Horace M., Selgin, Paul J., Soler, Anton, and Stansbury, Carroll, No. 2,827,167, March 18, 1958. Currency counters (Commerce).

Kaufman, Joseph, and Skenes, Clarence P., No. 2,809,004, October 8, 1957. Holders for electronic components (Army).

Kuder, Milton L., Palasky, Ervin C., Gilford, Saul R., and Greenough, Maurice L., No. 2,826,079, March 11, 1958. Automatic coin weighing machine (Commerce).

Levedahl, William J., No. 2,821,856, February 4, 1958. Rapid gas sampling valve (Commerce).

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Rabinow, Jacob, No. 2,795,705, June 11, 1957. Optical coincidence devices (Commerce).

Reaves, John H., No. 2,804,606, August 27, 1957. Pulse height analyzer system (Commerce).

Reggia, Frank, No. 2,798,207, July 2, 1957. Magnetic microwave attenuators (Commerce).

Rotkin, Israel, No. 2,806,155, September 10, 1957. Piezoelectric crystal traveling-wave transducer (Commerce).

Seal, Robert K–F., No. 2,787,735, April 2, 1957. Support and housing for electronic circuits (Navy).

Seal, Robert K–F., No. 2,820,900, January 21, 1958. Magnetron overload protection circuit (Navy).

Sorrels, John R., No. 2,817,073, December 17, 1957. Multichannel tape system of storage (Commerce).

Sorrels, John R., No. 2,819,940, January 14, 1958. Drive controls for magnetic recorder-reproducer (Commerce).

Thompson, Moody C., Jr., No. 2,817,759, December 24, 1957. Crystal stabilized pulse-pair generator (Commerce).

Walsh, David A., Projector, Theodore H., and Mullis, William F., No. 2,805,357, September 3, 1957. Obturator probe for control of carbon arc lights (Navy).

White, John E., No. 2,793,314, May 21, 1957. Long-life gas filled tubes (Commerce).

White, Hobart S., No. 2,824,060, February 18, 1958. Bearing compositions containing polytetrafluoroethylene and polytrifluorochloroethylene (Navy).

Willis, Edward A., Jr., No. 2,805,898, September 10, 1957. Fluid current conveyer for fragile articles (Navy).

Yates, Wilfred A., and Davidson, Martin, No. 2,796,756, June 25, 1957. Vibration calibrator (Navy).

(The following U. S. Patents have been granted to NBS inventors; licensed to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

Kovasznay, Leslie S. G., No. 2,817,787, December 24, 1957. Cathode ray sweeps (Commerce).

U. S. GOVERNMENT PRINTING OFFICE: 1959

Errata to Accompany Miscellaneous Publication M226

RESEARCH HIGHLIGHTS OF THE NATIONAL BUREAU OF STANDARDS

ANNUAL REPORT 1958

Page	Line	Now reads	Should read
iii	15	Meterology	Metrology
34	11 from bottom	existing pair, production	existing pair production
78	15	on p. 155	on p. 15
98	4 from bottom	120,000-lb	102,000-lb
100	Title of table 1	(delete)	Table 1. Summary of calibration services
102	Title of table 2	(delete)	Table 2. Summary of testing services
102	next to last col. 8th figure	40,001	40,011
121	2d name	Austin	Astin

January 30, 1959

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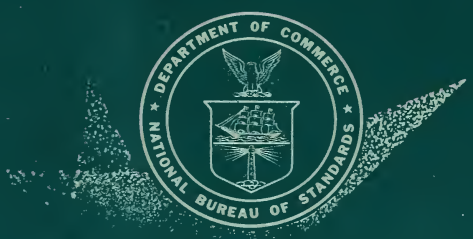

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