Biennial Report 1953 and 1954

National Bureau of Standards

U. S. Department of Commerce

UNITED STATES DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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

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Preface

Because the customary annual report of the National Bureau of Standards was not issued for fiscal year 1953, this report covers the 2-year period from July 1, 1952, to June 30, 1954. At the scheduled time for the preparation and release of the 1953 report the Bureau was undergoing a comprehensive survey by an Ad Hoc Committee appointed by the Secretary of Commerce to "evaluate the present functions and operation of the NBS in relation to present national needs." A number of important changes affecting the over-all Bureau program were made as a result of this survey. It was considered more appropriate to delay the report for a year in order to include the complete recommendations of the Ad Hoc Committee rather than to report on them partially.

The present report consists of five sections: (1) A general review or summary, (2) a résumé of the Bureau's research and development achievements, (3) a review of the testing and calibration program, (4) a discussion of the Bureau's various cooperative activities, and (5) appendix material consisting primarily of statistical and organizational material.

During the early part of fiscal year 1954, important weapons programs which the Bureau had been conducting for the Department of Defense were transferred to that agency. This transfer involved major organizational units comprising about 40 percent of the Bureau's staff. The present report includes no review of these transferred weapons programs.

A. V. Astin, *Director.*

Contents

1. General Review

During the fiscal years 1953 and 1954 the National Bureau of Standards continued to serve the Federal Government as a scientific laboratory and to provide basic standards for science and industry in accordance with the legislative authority under which the Bureau was established in 1901. The fields represented by these activities included physics, mathematics, chemistry, and various branches of engineering. Some work was also done of interest to the medical, biological, and dental sciences—for example, radiation studies, electronic instrumentation for the operating room, and properties of dental amalgams.

Within the physical sciences, the Bureau was engaged in fundamental and applied research, development, calibration and testing, and a variety of scientific services. Much of the research program is concerned with the custody, maintenance, and development of the national standards of physical measurement—a primary and unique function of the Bureau. This function requires the development of new and improved standards to meet the demands of science and industry, and the development of associated methods of measurement and instrumentation. It also involves the rendering of calibration services to science, industry, and commerce. In addition the Bureau determines fundamental physical constants and the basic properties of materials, develops improved methods for testing materials and equipment, and cooperates with other governmental agencies and private organizations in the establishment of standard practices such as codes and specifications. The Bureau serves the Government in several specific ways: by rendering advisory services on technical problems, by testing materials and supplies, and by invention and development of devices to meet the special needs of the Government.

In fulfilling these responsibilities, the Bureau has had to contend with ever-growing demands for its results and services. These demands arise principally in two ways: First, as science and technology progress, the needs for greater precision increase. Second, as new fields of science and technology develop—for example, the

exploitation of high-radio frequencies and the industrial application of atomic and nuclear physics—new standards must be developed, new methods and instruments of measurement devised, and appropriate calibration services must be made available.

1.1. Technical Activities

Fundamental Standards. Progress was made in several areas concerned with the development, establishment, and improvement of fundamental standards. Thus the range of the piston gage used as a primary standard of pressure was extended from 50,000 to 200,000 pounds per square inch to meet the requirements of modern ordnance and the chemical industry. Two new pieces of equipment which improve the precision and decrease the time required for the calibration of standard temperature measuring instruments were placed in operation. The first of these, an aluminum sulfur boiler, permits the realization of the sulfur melting point with the highest precision and stability ever attained. The second, a device for comparing thermocouples and resistance thermometers with standard instruments, has reduced the calibration time per thermocouple from 3 hours to 20 minutes. Improved equipment was assembled for the convenient and accurate measurement of standard electrical resistors of extremely high (multimegohm) values required by recent developments in atomic physics. A standard method was established for calibration of very small, intense beta-ray sources used in the treatment of eye diseases. Instrumentation was developed and placed in operation for measuring more rapidly the rates of standard alternating-current watthour meters.

To meet more exacting industrial needs, the Bureau undertook a major revision of the microwave frequency standard originally prepared in 1945. The new standard has fixed-frequency outputs corresponding to those frequencies most needed in calibration work, and the standard provides signals of higher power over a broader region of the microwave spectrum. An accurate secondary standard of complex permeability, the radio-frequency permeameter, was developed by the Bureau, made available for commercial manufacture, and adopted by a large segment of industry. An extension of this instrument, capable of measuring the temperature coefficient of the best commercially available ferrites and

nearly all other high-frequency magnetic materials, was also placed in operation. Another contribution to the field of radio standards was the development of a noise standard for measurement of noise power at microwave frequencies. The new standard will be used to calibrate secondary noise standards.

Instrumentation and Measurement. During the 2 years advances were made in the field of instrumentation and methods of measurement. A type of spectrometer employing a crystal scintillation detector was devised to measure the energy of X-rays in the range between 0.5 and 50 million volts. The characteristics of the spectrometer provide a detection efficiency that is 100,000 times better than previously available and thus opens the door to important new high-energy X-ray investigations as well as greatly expediting current studies.

A highly sensitive micromanometer was designed to measure differential pressures as low as 0.03 micron of mercury with resolutions of the order of 0.001 micron of mercury. The instrument can detect pressure differentials 100 to 1,000 times smaller than previous systems. Besides measuring static differential pressures, the micromanometer can measure pressures that are varying at rates up to 20 cycles per second. The instrument can also be modified to measure absolute pressures.

Work in aerological instrumentation resulted in the development of an improved humidity measuring element having high sensitivity and extremely rapid response. These characteristics promise increased accuracy of measurement, particularly under conditions encountered in radiosonde and aircraft use.

Properties of Matter. Studies of the properties of matter and materials were conducted in many fields. In low-temperature physics alinement of radioactive nuclei was achieved in the course of an investigation of the nuclear resonance of radioactive materials at temperatures near absolute zero. This result promises to provide a new tool in nuclear physics for studying the processes of nuclear disintegration. Another project in low-temperature physics, a study of the paramagnetic properties of matter at extremely low temperatures, was concerned with chromic methylamine alum as a temperature standard at temperatures in the vicinity of absolute zero.

Sugars labeled in specific positions with radioactive carbon 14 have long been sought by research workers in biology, medicine, and chemistry. In biology, for example, such sugars can be used in the study of complicated life chemistry. The Bureau's first results were obtained in 1952 with the development of 12 such radioactive sugars. In the last 2 years methods were completed for synthesis of 20 additional "tracer" sugars and related compounds. The number of compounds for which methods have been developed is now over 40, and quantities of these substances sufficient for extensive research in normal and pathological animal and plant metabolism have been issued to 75 laboratories.

The present shortage of materials suitable for crystal rectifiers and transistors led the Bureau to explore a new group of semiconducting materials. Germanium, commonly used in the past for the production of rectifiers and transistors, has serious limitations at elevated temperatures. Bureau scientists found that a series of compounds formed between the metal antimony and the metals indium, gallium, or aluminum may solve this problem. It has been demonstrated that these compounds are all semiconductors with properties similar to those of silicon and germanium. Gallium antimony is particularly promising, for it appears that rectifiers can be made from it which will operate at much higher temperatures than those made with germanium, and it has the advantage of a much lower melting point than silicon.

To meet the increasing need for high-temperature protection of alloys in nuclear reactors, the Bureau developed a ceramic coating material that has an extremely low thermal neutron absorption coefficient. Tests indicate that the coating satisfactorily withstands temperatures in excess of 1,000° C and in some cases reduces oxidation of the metal by 50 to 75 percent.

The process for impregnation of leather with natural rubber, originally developed by the Bureau in 1949, was modified to permit the use of polyisobutylene as an impregnant. Soles impregnated with this polymeric material have the same greatly improved abrasion and water resistance as those containing rubber. The treatment reduces water absorption by about half and increases wear by about 80 percent. In addition, polyisobutylene has a distinct advantage over rubber as an impregnant in that it eliminates the milling operation previously required. It also results

in large savings of time, labor, and materials in the tannery.

Special Development Programs. Two industrially significant developmental programs conducted for other Government agencies were concerned with electronic computers and a system for the automatic, mechanized production of electronic equipment. The computer program, which has been supported largely by the Department of Defense, has included research, development, application, and training with high-speed, automatically sequenced machines. The Bureau has also been instrumental in the establishment of commercial sources of supply for such machines and has conducted research in numerical analysis which over the past few years has contributed to the application of machine techniques to problems in many fields of science and engineering.

During 1953 and 1954 the two NBS computers, SEAC and SWAC, were in continuous operation on mathematical, statistical, and physical problems. A third high-speed digital computer—DYSEAC—was completed and delivered to the Signal Corps for a special application. DYSEAC was designed to serve as the nucleus of a complex data processing network. The flexibility with which this machine controls and responds to a variety of external devices—which may include one or more full-scale computers of similar design—should enable scientists to explore diverse new areas of interest. Examples include the automatization of industrial and commercial operations, such as the "automatic factory" and the "automatic office," or any fields where rapid information-processing and real-time control systems are necessary. DYSEAC is a portable machine, installed in a trailer van to facilitate its movement to the site of an experiment.

Developments in improved memory systems also pointed the way to future advances in the capacity and flexibility of electronic data processing systems. The Diode-Capacitor Memory, an information storage device utilizing diodes and capacitors as its basic storage units, has advantages of simplicity and extremely high speed. The Bureau also developed an experimental high-speed memory of the Williams (cathode-ray-tube) type as well as improved matrix memories. The scope and complexity of the problems which SWAC can solve were greatly extended through the installation of a magnetic drum auxiliary memory for use in conjunction with the computer's high-speed memory.

In recent years the construction of many large-scale electronic computers has brought about an increasing need for equipment to bridge the gap between the machines and their sources of information. NBS developed an instrument for the Bureau of the Census that provides rapid, automatic processing of information into a form suitable for direct input to large-scale computers. Named FOSDIC (Film Optical Sensing Device for Input to Computers), the machine reads marks on microfilmed copies of documents that have been marked with an ordinary pencil or pen, and then processes the information into electrical pulses which are recorded on magnetic tape for direct input to an electronic computer such as the Census Univac. This machine is expected to reduce considerably the massive amount of paperwork entailed in summarizing Census information on the entire population. FOSDIC may also be applied to the processing of other types of information that must be handled in large quantities.

Considerable industrial interest was shown in a new approach to the design and production of electronic systems, which was sponsored at NBS by the Navy Bureau of Aeronautics as an industrial preparedness measure in production research. The project has two significant aspects: First, a modular design system, and, second, a mechanized production system. The design system depends upon the use of stacked ceramic wafers. Some 4 to 6 of these small wafers, each about the size of a postage stamp, each bearing printed or applied resistors, conductors, capacitors, and other parts, make up a module. A module corresponds to a stage of an electronic device, consisting of the circuitry associated with a tube. A set of modules forms the completed electronic device.

The modular design system has a number of potential advantages. Perhaps the most striking is its suitability for automatic production, which was in large measure the objective of the project. The uniformity and simplicity of the parts used in the design system permit mechanized production. This system of production has culminated in the design and construction of a pilot plant. Here, starting with noncritical raw materials, wafers, capacitor bodies, and adhesive tape resistors are made. These parts are then fed into a series of machines which apply conducting inks, perform tinning and soldering, apply resistors, form completed capacitors, and assemble completed "wafer circuits" into modules. Automatic

inspection ensures reliability of the finished product. Several industrial contractors assisted in the design and construction of the machines and in engineering applications of the system to Naval electronic equipment. The Navy is currently supervising operation of the pilot line in the mechanized production of experimental lots for fleet use.

Additional examples of typical projects are given in Section 2, Research and Development, beginning on page 14.

1.2. Calibration, Cooperative, and Other Services

The calibration and testing services of the Bureau, stemming from its development, custody, and maintenance of the national standards of measurement, involved the performance of approximately 400,000 calibrations and tests during the 2 years. In addition, about 48,000 standard samples of certified chemicals, metals, and alloys were issued.

The calibration services, rendered to both Government and the public, involve thousands of instruments and devices sent to the Bureau by industry, private and university laboratories, and the Government. Some of these are standard laboratory devices; others are master instruments used by industry to calibrate such production tools as shop gage blocks. Typical activities in this area included the following calibrations and tests: 600 photographic lenses, 251 base-line invar tapes and wires, 447 steel tapes, 2,908 haemacytometer chambers, 23,593 cover glasses, 66,589 clinical thermometers, and 2,766 radioactive preparations.

Testing at the Bureau is concerned primarily with materials—usually raw materials like cement—purchased by the Government. For example, 26,000,000 barrels of cement were sample-tested during the year. The 52,000 tests involved were carried out at four field stations located near the sources of supply of cement and at the Bureau's Washington laboratories. Closely related to this work is the program of the Cement Reference Laboratory, which is concerned with appropriate equipment standards and test methods used in the testing of cement. This laboratory is located at the Bureau and is jointly supported by the Government and the American Society for Testing Materials. Another example of testing for the Government was the life-testing of 14,000 lamps, a sample from over 14,000,000. Some 5,000 samples of such materials as paints and

varnishes, soaps and detergents, metals and alloys, carbon paper and typewriter ribbons, and reagent chemicals were analyzed or tested, largely for compliance with purchase specifications. Other examples of calibration and testing may be found in Section 3, page 95.

Standard samples are materials that are certified for chemical composition or for some physical or chemical property, such as heat of combustion, melting point, or index of refraction. Primary chemical standards and metals with certified melting points make possible uniform measurements of heat and temperature in the same way that standard weights provide uniformity of measure in buying and selling. Standard pigments define the colors of paints. A large variety of hydrocarbons, supplied as single substances of high purity, calibrate the instruments that control the composition of motor gasolines, aviation fuels, and synthetic rubber. The list of standard samples issued by NBS now includes more than 500 materials.

The various advisory and cooperative activities of the Bureau (Section 4, page 109) are also of considerable technical value. Services of this kind are rendered on a variety of topics and problems to State and local governments as well as to the agencies of the Federal Government. For example, the Bureau cooperates closely with State and municipal governments in the field of weights and measures. Here the Bureau has fundamental responsibility for the standards of weights and measures while State and municipal governments possess regulatory authority concerned with the maintenance of uniform procedures. The Bureau contributes to these local bodies the means and methods whereby measurements in commerce may be made in a uniform manner, consistent with the national standards.

Continuous and more extensive work is undertaken through various scientific and technical committees. The Bureau is represented on numerous committees, panels, and commissions of other Government agencies. These include the Interdepartmental Committee on Scientific Research and Development, the Federal Fire Council, the Interdepartmental Radio Advisory Committee, the National Advisory Committee for Aeronautics, the Interdepartmental Screw Thread Committee, the Building Research Advisory Board, and a number of similar groups, including advisory

committees to the Department of Defense. Bureau personnel represent the Department of Commerce on the Physical, Chemical, and Engineering Divisions of the National Research Council.

By actively participating in the activities and projects of professional societies and standardizing bodies, the Bureau plays an active role in the development of test methods and criteria, in the application of scientific discoveries, and in fundamental research programs of a national nature. In this way the Bureau assists in developing and improving engineering standards, purchase specifications, and building and safety codes. NBS staff members participated in over 100 national groups such as the Acoustical Society of America, American Society for Testing Materials, American Standards Association, American Institute of Electrical Engineers, American Society of Heating and Ventilating Engineers, American Society of Mechanical Engineers, Institute of Radio Engineers, Instrument Society of America, American Petroleum Institute, American Chemical Society, and National Association of Corrosion Engineers.

The National Bureau of Standards is also active in many international groups (Section 4, page 109). These societies deal largely with the establishment and maintenance of international scientific standards and the establishment of values for scientific constants. Another phase of international cooperation involves a program whereby scientists or diplomatic representatives from other countries are accepted at NBS as guest workers or visitors. Both aspects, which are important to the United States in terms of commerce and trade as well as the international policies of the Government, are coordinated on the diplomatic level by the State Department. The Bureau also renders services to foreign countries in the form of calibrations, tests, and exchange of standards and publications.

During the past 2 years over 2,000 scientists and technicians, including many special groups, visited the Bureau from abroad. They ranged from directors of research establishments similar to the National Bureau of Standards to post-graduate students. Thirty guest workers from other countries spent from one to 12 months at the Bureau observing or receiving training in their fields of special interest. Countries represented included Turkey, Brazil, Belgium, Austria, Egypt, South Africa, Java, Philippines, Columbia, India, Germany, Norway, England, Spain, and Switzer-

land. Some of the guest workers directly represented their governments while others represented private industry or institutions of learning.

1.3. Administrative Activities

The program of the Bureau during the reporting period may be classified into two major budgetary divisions: First, the basic program concerned with fundamental standards, measurement, and properties of matter, which was supported by direct appropriations from the Congress. Second, various projects undertaken for other Government agencies, which transferred the necessary supporting funds to the Bureau.

During 1953 the total funds obligated for both areas of activity, including construction and facilities, were $48,242,038. Of this total, about 17 percent, or $8,157,759 came from direct Congressional appropriation for the basic program while the remaining 83 percent ($40,084,279) represented programs conducted for other Government agencies. The bulk of the transferred funds (all but $1,240,700) were provided by the Department of Defense and the Atomic Energy Commission.

In 1954 the total obligations for operations dropped to $25,152,900, of which only 70 percent was supported by funds transferred to the Bureau by other agencies. A total of $6,490,718 came from direct appropriation for the basic program. This marked shift in the total program level and in the relative proportion of transferred funds was largely the result of the transfer of the Bureau's weaponry development projects, involving obligations of over $20,000,000 a year, to the Department of Defense. (Appendix, page 124.)

Prior to 1954, the Bureau's contributions to defense activities in emergency periods had brought about the assignment of a high proportion of its total effort to applied research and development in ordnance and guided missiles. To evaluate this and other aspects of the Bureau's program in relation to national needs, the Secretary of Commerce in April 1953 appointed an Ad Hoc Evaluation Committee under the chairmanship of Dr. Mervin J. Kelly, President of Bell Telephone Laboratories. The members of the Committee (Appendix, page 125) were nominated by nine leading scientific and engineering societies. After making a comprehensive review, the Ad Hoc Committee reported in October 1953 that the

Bureau's statutory functions were well conceived and its operations generally sound. At the same time the Committee made a number of significant recommendations (Appendix, page 125) which have been or are being put into effect. These recommendations were directed mainly toward improved balance in the general program.

The first recommendation to be implemented was the transfer of the Bureau's weaponry development work to the Department of Defense. Four major divisions, including about 40 percent of the Bureau's personnel, were involved. This transfer resulted in the creation by the Army Ordnance Corps of the Diamond Ordnance Fuze Laboratories, which continue to operate adjacent to the Bureau in Washington, and also the creation of a new U. S. Naval Ordnance Laboratory by absorption of former NBS guided missile activities at Corona, California. Another transfer took place at the end of fiscal year 1954, when the Institute for Numerical Analysis, until then a section of the NBS Division of Applied Mathematics, became a part of the University of California at Los Angeles. This latter activity had been supported by the Office of Naval Research and by the U. S. Air Force.

The Ad Hoc Committee recommended more adequate appropriations for the basic program as the most important step toward improving program balance at the Bureau. Appropriations for basic programs had been declining gradually for several years and were 25 percent less for 1954 than for 1953. The Committee recommended that the Bureau's staff be built back within 2 years to its 1950 level, and this was reflected in the budget presented to the Congress in 1954. However, only 12.5 percent of the increase requested by the administration was appropriated for 1955.

Establishment of a number of technical area advisory committees (Appendix, page 127) was another recommendation of the Ad Hoc Committee. Ten such committees have now been formed. Eight scientific and engineering societies represented on the Ad Hoc Committee have nominated advisory groups. Included are recognized authorities in physics, chemistry, mathematics, metallurgy, and electrical, radio, civil, and mechanical engineering. In addition, the American Ceramic Society and the National Conference on Weights and Measures have designated groups at the Bureau's request to advise in their areas of special interest. Nominations have also been invited from the American Society for

Testing Materials and the American Standards Association. These special advisory committees, supplementing the Bureau's statutory Visiting Committee (Appendix, page 125), should prove a valuable source of consultation and stimulation and should strengthen NBS ties with the nation's scientific and technological effort.

During this period, the Secretary of Commerce also requested the National Academy of Sciences to appoint a committee to review the Bureau's work on battery additives, a topic that had assumed a controversial status. Under the chairmanship of Dr. Zay Jeffries, Vice President (retired), General Electric Company, this committee thoroughly evaluated the tests made by the Bureau over a long period and concluded that the quality of the work had been excellent and that the Bureau was correct in its findings.

A third survey, of a somewhat different type, is being conducted by Social Research, Inc., under contract with the Bureau. The purpose is to supply executives and supervisors at the Bureau with specific information about working relationships and internal communication needs and to point the way toward strengthening the Bureau's environment for creative research.

Three new research facilities were completed during the 1953–54 period. One, a specially designed radioactivity (gamma-ray) laboratory, places the Bureau in a stronger position to meet increasing scientific and technical demands growing out of advances in the uses of atomic energy. Another was a major addition to the Bureau's Betatron Laboratory which permits greater safety and efficiency in the operation of the betatron and synchrotron. The third was a radio research laboratory in Boulder, Colorado. By the end of 1954, after several years of planning and preparation, the NBS Central Radio Propagation Laboratory was moved to the Boulder site to provide a more favorable environment for its work. The NBS Boulder Laboratories also include the NBS–AEC Cryogenic Engineering Laboratory, which has been engaged primarily in low-temperature work for the Atomic Energy Commission since its establishment in 1951.

At the end of the reporting period total employment at the Bureau was about 2,800. Of this number, about 80 percent were members of the various technical divisions, including the small number of administrative, secretarial, and clerical personnel in-

volved in divisional operations. The remaining 20 percent was made up of the central administrative, plant, shops, and various service personnel. Most of the staff was stationed at the Bureau's laboratories in Washington, D. C. However, about 400 were located at the NBS Boulder Laboratories, and a much smaller number were distributed among 20 field stations in this country and abroad.

1.4. Publications

In general, the output of the Bureau's technical program is embodied in its reports and publications. Even when the work is developmental in nature—for example, the development of a specific device—a report will represent the culmination of the activity, and it is this report which will often prove of most value to science and industry. The reports and publications of the Bureau are therefore suggestive of the scope of its activities. During the 2 years these totaled over 2,600 exclusive of calibration and test reports and of general administrative documents. Some 2,000 classified and unclassified reports were issued to other Government agencies, particularly the Department of Defense, while over 600 papers and documents were published formally. Of the formal publications, some 550 consisted of scientific and technical papers, 174 of which were published in the *Journal of Research of the National Bureau of Standards* (a monthly periodical) and the remainder in the journals of various professional, engineering, and trade organizations. In addition, approximately 200 summary reports were published in the Bureau's monthly *Technical News Bulletin.* The third monthly periodical of the Bureau, *Basic Radio Propagation Predictions*, presented each month, for a 1-month period 3 months in advance, radio-propagation data needed in determining the best frequencies to use in long-range radio communications.

Seventy papers were published in the Bureau's nonperiodical series of publications: 20 in the Applied Mathematics Series, 5 in the Handbook series, 30 in the Circular series, 8 in the Building Materials and Structures Report series, and 7 in the Miscellaneous Publication series.

A list of publications issued during the two fiscal years is given in the Appendix, Section 5, (page 132).

2. Research and Development Program

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

2.1. Electricity

The work in electricity is devoted primarily to the establishment, maintenance, extension, and dissemination of the units of measurement for electrical and magnetic quantities. The object is to provide electrical standards which are as far as possible constant with time, uniform throughout the nation, and consistent with the more fundamental mechanical units. The electrical work includes dissemination of standards for resistance, inductance, capacitance, voltage, current, power, energy, magnetizing force, and magnetic induction.

Dielectric Properties at High Temperatures. Some modern plastic materials can be operated satisfactorily as electrical insulators at much higher temperatures than were previously possible. To secure accurate quantitative data on the dielectric constant and dielectric loss at higher temperatures, the Bureau developed new techniques and constructed special apparatus which will operate up to 500° C.

Measurement of Multimegohm Resistors. Recent developments in atomic physics often require measurements of very small electric currents which result from radiation-produced ionization. For such measurements standard resistors of very high values (often millions of millions of ohms) are required. Improved equipment has been assembled for the convenient and accurate measurement of such resistors; and studies of their change with voltage, humidity, and time have begun.

Pin Insulators. A pin-type porcelain insulator intended for use on an electric transmission line is so designed that, when excessive voltage is applied, spark-over should occur through the air around it without damage to the porcelain. The Rural Electrification Administration has found that certain types of insulators are

punctured and shattered when lightning strikes the line near them. Lightning insulator research has been conducted under REA sponsorship in the NBS High Voltage Laboratory. Studies at various rates of voltage application show that some insulators, which would flash-over at slower rates of application, puncture when the rate is as high as 10 million volts per microsecond. As a result, specifications and laboratory test methods are being designed to discriminate between insulator designs that are and those that are not subject to this kind of failure. Similar tests were applied to lightning arrestors. Test conditions and procedures were devised to determine which types of arrestors would fail when exposed to sudden applications of high voltage.

Thermal Transfer Instruments. Earlier NBS studies of error sources in thermal converters in precise measurements of audio-frequency electric currents have led to prototype development of two new measuring devices using such converters. These are: (a) A convenient "volt-ampere converter," which can be used with a d-c potentiometer, measuring to an accuracy of ± 0.05 percent up to 20,000 cps; and (b) a portable thermocouple volt-ammeter incorporating a self checking circuit accurate to 0.5 percent up to 50,000 cps. The former device is now in commercial production by an instrument company.

Kilowatthour Standard. Equipment was completed for quicker testing of standard watthour meters. A picked meter of high quality was fitted with a mirror and surrounded by a phosphorescent scale to record accurately angular position of its rotor as a signal light flashed. The meter is calibrated by applying a known electrical power to its circuits and flashing the light at the beginning and end of a measured time interval. The standard meter is then connected to measure the same energy as the meter under test, and the light is flashed at the beginning and end of a preset integral number of revolutions of the tested meter. Two additional standard meters, kept at constant temperature, serve as references to check on any possible drift in calibration of the working standard. Calibration against the more basic direct current standards is made about once a year. Use of the new equipment will decrease the previous test time and still retain most of the precision of the primary d-c method.

2.2. Optics and Metrology

A large part of the Bureau's work in optics and metrology was concerned with measurement, instrumentation, and standardization problems in photometry, colorimetry, optical instruments, photographic technology, and those phases of metrology which are most dependent upon optical methods. Calibration of line and end standards, interferometric measurements of length, and determination of the coefficient of linear expansion were included in these activities. In addition, specific development programs were carried out for other Government agencies. Typical fields of activity included lighting of naval aircraft and of landing fields; measurement of atmospheric transmittance and its application to airplane landings; ships' navigation lights; measurement of the index of refraction of optical glasses and crystals through the ultraviolet, visible, and infrared spectral range; application of new high-speed electronic computing machines to optical design; objective methods for quantitatively measuring and evaluating the performance of photographic lenses and other optical systems; study of spectacle lens performance; development of improved methods of testing photographic emulsions; intercomparison between the International Prototype Meter and the secondary standards of the Bureau; and interferometric methods of calibrating gages.

Relative Luminous Efficiency of Spectral Regions. World trade in lighting devices requires that the relative luminous efficiency of the various parts of the spectrum be accurately known and agreed upon so that lighting devices may be competitively evaluated on a reliable and uniform basis. The standard luminous-efficiency function, recommended in 1924 by the International Commission on Illumination (CIE), has served this purpose well. These standard data have also been incorporated into a standard method recommended by the CIE for specifying the colors of objects and light sources. However, among the many satisfactory applications of this method are a few cases of commercial importance (titanium pigments, fluorescent lamps, white ceramics, plastics and enamels) yielding poor correlation with direct visual comparisons. The poor correlation is traceable to errors in the standard luminous-efficiency function for the extreme short-wave (violet and blue) portion of the visible spectrum. The Bureau

has completed a redetermination of the relative luminous-efficiency function for this portion of the spectrum. It is expected that the results of the redetermination will be used by the CIE to revise the standard luminous-efficiency function by amounts unimportant in photometry but sufficient to correct the poor correlation in the colorimetry of fluorescent lamps and white materials.

Searchlight Reflectors. A method for determining the focal point and evaluating the quality of searchlight reflectors was developed for the Navy. The technique is rapid, convenient, and easily applied in confined space; it does not require precision equipment nor highly trained personnel. A very small light source is placed at or near the focal point of the parabolic reflector, and a specially designed opaque mask is interposed in the collimated beam. When the light source is at the focal point, the shadow of the mask falls exactly on a traced outline of the mask on a screen. In addition, the appearance of the light pattern on the screen indicates quickly and sensitively any imperfections in the reflector and any inaccuracy in its figure.

Lighted Suit for Carrier Landing Officer. Landing aircraft on a carrier at night requires the closest possible coordination between the landing signal officer on the deck and the pilot of the aircraft, who must see and interpret quickly the signals of the landing signal officer. To provide high visibility and to insure ease and speed of identification, a lighted suit and signal paddles were developed for the Navy Bureau of Aeronautics. Each complete equipment has 210 miniature lighting fixtures mounted on flexible strips attached to the suit and paddles. Signals made with this equipment are highly conspicuous and give the pilot the same "feel" that he obtains from signals during daytime landings.

Color Measurement of Signal Smokes. Pyrotechnic smokes of various colors for ground-to-air signaling are used in the establishment of a line in advance of infantry to prevent inadvertent attacks by air forces on their own ground positions. To be easily visible the signal smokes must be distinctly different in color from the terrain forming the background, and vivid colors must be used lest the signal smokes be confused with the uncolored smokes of ordinary battle operations. The Army Chemical Corps carries on continuous research to improve the formulations of these signal smokes and has sought the aid of NBS. The Bureau is engaged in develop-

ing methods of measuring the colors of smokes, not only to give members of the Chemical Corps a sure way of knowing when their research efforts are proceeding toward the development of more vivid colors but also for color checking delivered pyrotechnics. For laboratory evaluation of smoke color, the Bureau designed and built a photoelectric colorimeter and an associated smoke chamber. In cooperation with General Aniline & Film Corporation, the Bureau also developed color standards systematically color-spaced for field evaluation of smoke colors by visual comparison. Through use of fluorescent dyes, the color range was extended beyond that covered by previous surface-color systems.

Calibration of Pyrheliometers. A method of calibrating pyrheliometers by use of the Bureau's 15-foot light integrating sphere was devised for the Weather Bureau. Pyrheliometers measure the intensity of solar radiation. In the past pyrheliometer calibrations had to be made outdoors on clear days. This dependence on the weather often resulted in lengthy delays and low accuracy. The new method gives results accurate to about 0.5 percent instead of the 5 percent obtainable by the old method.

Reflectance Standards. The demand for "nonselective" (white, gray, black) reflectance standards necessitated procurement and calibration of new sets. Eleven hundred 4¼-inch square porcelain enameled iron plaques were obtained, enough to make 100 sets containing 11 standards each. These new plaques could have been calibrated by comparison with the NBS master reflectance standards. It was decided, however, to make a fundamental calibration of a set of the new plaques and to recalibrate the old master set to determine whether the old set had changed. Results obtained on the master set indicate no material changes although the newly determined values are higher in general by a few tenths of a percent than the values adopted in 1945.

Electronic Computer Used in Optical Design and Analysis. Nine lenses submitted by the Department of Defense were analyzed by electronic computing machines. For each lens 16 graphs were prepared to show the chromatic aberration and other deviations from perfect imagery at four different field angles. To present aberration effects more clearly, "spot diagrams" corresponding to each field angle have been prepared for some of the lenses. For each spot diagram 30 rays are traced, permitting the derivation of

a polynomial by which the intersections of from 800 to 1,500 rays with the image plane are determined. Ray intersections are plotted and their distribution and departures from a point image permit an estimate of energy distribution. All computations, including point plotting, are made by automatic machines. Without the use of electronic computing machinery, such diagrams could not be produced in a reasonable time.

By use of electronic computing techniques, a lens of 40-inch focal length covering a small field with nearly perfect imagery was designed and a prototype constructed. Three triplets of the Cooke type were also designed in this way.

Quality of Optical Imagery. A current study deals with objective methods of evaluating the image formed by an optical system and development of the instrumentation required to perform this evaluation. A number of methods have been proposed, involving such test objects as sine wave and square wave periodic patterns, knife edges, and variable slits. All these methods are being investigated, not only for the information that may be obtained from each, but also for the correlations existing among them. One instrument developed for this work at NBS is the photoelectric image scanner. It converts the spatial brightness variations in the image being examined into a graphic trace on an oscilloscope screen. This device has shown considerable usefulness for measuring the transmission of optical systems and also for measuring shutter speeds.

An exhaustive theoretical study of the problems associated with image evaluation has been completed. This study dealt with an analysis of the point image, extension of point-image relations to fine-line images, and relations between fine-line and knife-edge images. The superior reliability of long-line patterns as compared to short-line patterns for use in resolving power test charts was established.

Refractometry of Optical Glass. A coordinated study was made of the physical properties of five selected optical glasses produced and annealed in the Bureau's experimental glass plant. This study yields comparative data on refractive indices, spectral transmissive properties, densities, and thermal expansivities of each of the materials investigated. The resulting charts and tables are expected to be of considerable utility in optical glass technology and research because they provide so great a variety of data on

each specific glass. Ordinarily these properties are not all measured on the same glass. Because of recent interest in image forming systems utilizing infrared radiations, the measurements of index of refraction and transmittance were extended considerably beyond the spectral range for which optical glass is generally cataloged.

Photographic Sensitometry. A system of photographic sensitometry known as Bargamma, designed at the Bureau specifically for the sensitometry and grading of photographic papers, was adopted as American Standard PH2.2–1953. Most manufacturers of photographic papers are using this system for product control, and it is expected that the grading of papers by contrast, scale, maximum density, and other properties will soon become standard practice with all American manufacturers.

Along with the Bargamma system of sensitometry, a proposed general specification was developed which defines the various photographic and physical characteristics of photographic papers. Promulgation of this specification is expected within the coming year.

Chemical Analysis of Photographic Solutions. Several procedures were devised for analyzing chemicals in photographic developing and fixing baths. A new procedure was worked out for estimating the carbonate content of developing solutions by precipitating the carbonate as barium carbonate and titrating with standard acid. Previously the carbonate had generally been determined by measuring the volume of carbon dioxide evolved when the carbonate is acidified. However, the older method is more difficult for the average analyst and requires special apparatus not readily available.

Intercomparison of Secondary Length Standards. The Bureau periodically standardizes its secondary length standards by comparison with the National Prototype Meter, upon which all length measurement in this country is based. The intercomparison of the total lengths of the NBS meter bars had been completed during fiscal year 1952. All but three of these bars have the 1-meter interval subdivided to millimeters. A calibration of the subintervals of the subdivided bars was begun in fiscal year 1953 and completed in fiscal year 1954.

The probable error of the calibrations varied from ± 0.02 to ± 0.04 micron. It was found that individual measurements varied

in some cases by as much as 0.15 micron from those previously determined. These differences do not necessarily represent actual changes; in most cases they are probably due to better equipment and operating conditions.

Low-Expanding Cobalt-Iron-Chromium Alloys. An investigation of cobalt-iron-chromium alloys was completed. Within a limited range of composition, some of these alloys have very low coefficients of linear thermal expansion at atmospheric temperatures. However, at low temperatures they expand on cooling because of martensitic transformation. If these alloys are then heated after complete or incomplete transformation, the coefficients of expansion are greater than before the transformation.

Measurement of End Gages. An NBS-Meggers mercury 198 lamp was placed in operation as a standard light source in the interferometric measurement of gage blocks longer than 1 inch. The sharpness of the interference bands, as compared with those from sources formerly utilized, permitted a 50-percent reduction of observational errors in visual estimation of band fractions. However, as the range of wavelengths of mercury is more limited than that of other sources previously used, the band fractions must be read very accurately in order to determine the order of interference with certainty.

In the past, slight variations and uncertainties in determining temperatures have been a source of observational error in absolute measurement of the lengths of 2-, 3-, 4-inch, and longer master gage blocks. Several improvements were made in the equipment to reduce these errors. Another source of uncertainty within a range of about one-millionth of an inch is due to variations in light-wave phase shift upon reflection from different gaging surfaces. Improved techniques were developed for more accurate measurement of this shift.

2.3. Heat and Power

To provide a fundamental basis for precise measurements of heat and power, the Bureau maintains temperature scales covering most of the range from the lowest obtainable temperature to the highest temperature of incandescent bodies and flames. The Bureau is also responsible for determining and maintaining standards of viscosity, heat capacity, and heat of combustion; it main-

tains the primary standards for determination of the octane number of automotive and aviation fuels. Research is conducted to increase the accuracy of these standards and to develop improved measuring instruments and apparatus.

From the standards of temperature, the work broadens to include the determination of quantities of heat by calorimetry at temperatures extending over a large part of the scale. Concurrent theoretical programs relate thermal properties to molecular structure and permit the calculation and compilation of tables of thermal properties over an even wider temperature range. Particular emphasis is placed on investigations of electrical, magnetic, and thermal properties of matter at extremely low temperatures. In cooperation with the research programs of medical agencies, the Bureau applies thermodynamic techniques to the measurement of biologically important materials. Rheological studies, dealing with the flow characteristics of lubricants and of rubber solutions, are also conducted. From these fields of activity, the work in heat and power extends to research on the mechanism of combustion in engines, bearing and lubrication studies, applied thermodynamic investigations of such heat engines as compressors and internal combustion engines, high pressure pneumatics, and cryogenic (low-temperature) engineering.

Temperature Standards. Two new pieces of equipment that improve the precision and decrease the time required for calibrating standard temperature-measuring instruments were placed in operation. The first of these, an aluminum sulfur boiler having wells for 10 thermometers, replaced the earlier type accommodating only 1 thermometer. In addition to a saving in time previously required for individual thermometers to come to equilibrium, this design also permits attainment of the sulfur melting point (444.6° C.) with the highest precision and stability ever achieved. The reliability and stability of the temperature obtained with this boiler led to the discovery of a previously unknown temperature drift that must be taken into consideration in the precise calibration of resistance thermometers. The temperature of the liquid sulfur and its vapor falls slowly for over a day after the boiling pressure is reached but then remains constant for periods up to 10 days, the longest time of continuous observation. The equilibrium temperature after the first day is taken to define the fixed point.

The second instrument is a comparator for use with standard platinum versus platinum-rhodium thermocouples and resistance thermometers. This device consists of copper blocks in a nickel-chromium shell with holes extending into the uniform temperature region for insertion of resistance thermometers and thermocouples. Calibration time per thermocouple has been reduced from 3 hours to 20 minutes with the new comparator.

High-Temperature Research. As part of an investigation of radiation from systems at high temperatures, emission and absorption in flames were studied over a very wide range of conditions. Flames of hydrocarbons and oxygen from 0.002 to 1.0 atmosphere pressure were investigated to determine the value of OH, CH, and C_2 spectra as temperature indicators. Several types of atomic flame apparatus were constructed and used in studies of the mechanism of hydrocarbon combustion. Intensity distributions in the ultraviolet and visible bands of OH, CH, and C_2 were measured for flames of acetylene with OH and of acetylene with atomic oxygen. At the same time samples of the combustion products were taken for mass spectrometric analysis in an effort to correlate composition with radiation data.

High Polymers. Studies of rheological and thermodynamic properties of elastomeric polymers have been undertaken to improve existing knowledge and control of their behavior in processing operations, and to increase knowledge of their molecular and technological properties so that new polymers with specified properties can be developed on a controlled rather than on a trial and error basis.

Thermodynamic data on polymer solutions are meager, discordant, and in disagreement with theoretical predictions. To obtain a better understanding of polymer solutions, measurements of heat of solution, density, and vapor pressure were begun on several polymer-solvent systems. The densities of polystyrene in benzene, toluene, ethylbenzene, and 2-butanene were measured, and the vapor pressure and heat of solution of polybutadiene in benzene are being measured.

Properties of Fluorine and Deuterium Compounds. Fluorine compounds are utilized in refrigeration, polymer, metallurgical, and other industries. Members of this large class, ranging from high stability to extreme reactivity, are being investigated as materials

that may help satisfy the increasing severe requirements of military development programs. In such investigations complete sets of thermodynamic data are usually needed to evaluate or predict performance for all substances involved in the process. A research program aimed at the eventual fulfillment of such needs was initiated several years ago. This research, carried out largely with funds transferred from the Defense Department and from the National Advisory Committee for Aeronautics, has included measurements of specific heats of gases, liquids, and solids at temperatures within the range of 12° to 1,200° Kelvin. Various related properties—such as vapor pressure, heat of vaporization, melting point, heat of fusion, and entropy—also were determined experimentally. A new apparatus has been developed for determining heat of fluorination and another for density and compressibility of corrosive gases. The heat of formation of carbon tetrafluoride—important in the thermodynamics of fluorocarbons and in the interpretation of other properties of these materials—was recently determined.

The molecular and spectroscopic properties of key fluorine compounds are also being intensively analyzed and interpreted. Theoretical studies of the results obtained from infrared, Raman, and microwave spectra, and from electron and X-ray diffraction experiments, provide the basis for calculating the thermodynamic properties of a large number of related gases from 50° to 5,000° Kelvin—far beyond the range in which accurate measurements are feasible. Thermal functions of about 30 fluorine compounds have been calculated to date, and calorimetric measurements on 8 compounds have been completed.

High-speed computing techniques have been developed and applied to problems in thermodynamics and molecular structure. These advances have now made it possible to make calculations with a speed, accuracy, and economy heretofore unobtainable. For example, tables of thermodynamic functions that formerly required several weeks to complete can now be obtained in a matter of minutes.

With the aid of these high-speed techniques, it has been possible to correlate the behavior of compounds of hydrogen and its isotopes (deuterium and tritium) and to obtain an insight into the fundamental nature of isotope effects in general. Similarly, some of the

forces which act within and between molecules can now be determined with far greater reliability.

Isotopic Determination of Water Content. An optical spectroscopic method which uses heavy water to determine the total water content of biological tissues and other materials was reported in 1952. Since that time, study of operating characteristics has increased the precision and speed of measurement. Applications of the technique have been investigated, and the procedure is being extended to isotopes of carbon and nitrogen. The method is based on a spectroscopic measurement of the ratio of ordinary to heavy water in a solution containing the sample. With a sample of about 1 ml, a precision of between 0.1 and 2.0 percent is obtained in an hour or less. A determination can be made on a sample of less than 0.1 ml, in less than 10 minutes to a precision of a few percent. Reproducibility is good over a period of several months.

In cooperation with Walter Reed Army Medical Center, the technique was applied to research on body-water variation in hemorrhagic fever. Field teams in Korea collected 73 blood samples which were then frozen and shipped to NBS for analysis of water content. In this way body-water variations were studied to determine whether the treatment being used was causing excessive dehydration of the patients.

Low-Temperature Physics. At present, temperatures below approximately 1° Kelvin are measured only by magnetic techniques. Investigation of the paramagnetic properties of matter at extremely low temperatures has centered on the study of chromic methylamine alum as a possible temperature standard. This paramagnetic salt has been employed both for cooling by adiabatic demagnetization to about one-hundredth of a degree above absolute zero, and for measuring these temperatures in terms of magnetic susceptibility. The salt has proved particularly useful for such temperature determinations because it follows the theoretical predictions exceptionally well. Correlation with theory holds quite accurately down to temperatures of 0.08° Kelvin, making this alum an effective "thermometer." The magnetic properties of the substance are reproducible down to the lowest temperature attained—about 0.01° K. Development of equipment for measuring true thermodynamic temperatures in this range below 0.08° K is under way. The vapor pressure of liquid helium, a secondary temperature

standard, has been measured in the range from 1.3 to 4.9° K, using chromic methylamine alum as a thermometer. Errors are known to exist in the presently accepted helium temperature scale and these measurements, coupled with the results of other workers, should make a revision possible.

Experimental and theoretical investigations were conducted on the thermodynamic properties of superconductors—metals which lose all electrical resistance at temperatures near absolute zero. A contribution to theory was made in the development of a generalized treatment of the so-called "two-fluid model" of a superconductor. The possibility of the transition temperature being modified by application of torsional strain was also investigated, and an upper limit for the magnitude of such an effect was obtained. Extremely fine metal filaments are under development for a study of size effects. This study should aid in the development of the electronic, as opposed to phenomenological, theory.

A continuing program dealt with second sound, a unique wave-like form of heat transfer occurring only in liquid helium II. Measurement of second sound velocity in helium II was extended down to the region of one-hundredth of a degree above absolute zero. The dependence of this velocity on temperature has been of critical significance to an understanding of the nature of helium II, the only known "quantum liquid." Besides providing thermodynamic data relating to the behavior of liquid helium II, the study revealed various unexpected tendencies in velocity of propagation at the lowest temperatures which suggest the need for further refinement of the theory.

A program was initiated for investigating nuclear resonance of radioactive materials at temperatures near absolute zero. In the course of this work, alinement of radioactive nuclei was achieved in a low-temperature investigation of gamma-ray emission from cerium-141 nuclei in a cerium salt cooled to 0.003° K. At such low temperature the effects of thermal agitation become so small that nuclear alinement can take place. This result promises to provide a new tool in nuclear physics for studying the processes of nuclear disintegration. For example, the magnetic moment of the nucleus can be determined as well as the changes in angular momenta accompanying the emission. Thus, a common meeting ground

has been found for nuclear physics and low-temperature physics, normally regarded as widely separate fields.

Cryogenic Engineering. Low-temperature liquified gases—oxygen, hydrogen, and nitrogen—are finding increased application in industry and national defense, making necessary larger, more convenient, and less hazardous equipment for producing and handling them. As a result, many new and highly complex engineering problems have arisen in the low-temperature field, where much remains to be learned about the mechanical and thermal behavior of engineering materials and the nature of low-temperature processes. With the cooperation of the Atomic Energy Commission, NBS has carried on a program of research and development in cryogenic (low-temperature) engineering since 1951.

In 1953, applying results of pioneer research at the Los Alamos Scientific Laboratory, the Bureau succeeded in producing high-concentration (97-percent) liquid para-hydrogen in large quantities. Normal hydrogen consists of 25-percent para-hydrogen and 75-percent ortho-hydrogen. At low temperatures the ortho-hydrogen spontaneously changes slowly to para-hydrogen, with the liberation of heat. Consequently, liquid para-hydrogen has much better storing properties than liquid normal hydrogen. This development is expected to have two important consequences: (1) It will make it practical to store liquid hydrogen for long periods with small loss, and (2) it will make it possible to reduce the size of future liquid hydrogen plants because liquid para-hydrogen can now be accumulated slowly and stored efficiently with greatly reduced loss. Unrefrigerated liquid hydrogen containers will henceforth be satisfactory for many applications, with a resultant saving of perhaps half the cost of present equipment as well as large reductions in weight and number of operating personnel.

Recently a 400-liter, all aluminum Dewar was designed and fabricated. Besides its light weight, the Dewar has a low rate of loss: 0.75 percent of liquid para-hydrogen per day. The inner liquid hydrogen container is surrounded, in its insulating vacuum space, by a liquid nitrogen shield. The low loss rate is due in part to another NBS development, a low-thermal-conductance multisurface mechanical support. Now that the feasibility of vacuum-tight aluminum construction has been demonstrated, larger containers,

up to 2,000 liter capacity, are being designed. These are expecte to have an even lower loss rate.

To provide engineering data for the design of cryogenic equipment, apparatus was designed and constructed for measuring mechanical and thermal properties from 20° to 300° K and for investigating emissivities of metal surfaces to determine their thermal radiation transfers across insulating vacuum spaces. Emissivities of 60 different metal surfaces have been measured.

Combustion in Engines. As compression ratios of modern gasoline engines are continually raised, knock and preignition become more troublesome. The rapidly expanding use of Diesel engines has also emphasized problems of cold starting and engine roughness and smoking under heavy-load operation. All these difficulties are associated with the combustion phenomenon known as *autoignition*, which occurs when a fuel-air mixture is heated by compression until it ignites spontaneously without spark. Fuel injected into the hot air in a Diesel cylinder ignites by this process, while knock in a gasoline engine is caused by explosive autoignition of the last, unburned portion of the fuel-air mixture to be traversed by the normal flame from the spark plug.

Seeking information that will lead to more efficient utilization of fuels, the Bureau is conducting an intensive investigation of autoignition. The apparatus includes a specially built single-cylinder engine of variable compression ratio in which a wide range of operating conditions may be simulated. The engine has been modified to permit compression-ignition of a single homogeneous premixed charge of fuel and air in the absence of burned residual gases, cylinder hot spots, and lubricating oil. Pressure, rate of change of pressure, and light emission are oscillographically recorded as functions of crank angle or time. In order to follow the reaction by mass spectrometric analysis of the mixture, a mechanical device was developed to take samples of the rapidly changing gas in the combustion chamber during extremely short intervals—0.2 millisecond or less.

The rapid sampling valve has been useful in tracing the reactions that take place in the combustion of hexane. The hexane is degraded by thermal decomposition and oxidized into nearly all predictable fragments, including olefins, aldehydes, and acetylene. In order to obtain more useful analyses, current emphasis is being

placed on simpler hydrocarbon fuels, such as propane and isobutane. The products found clearly indicate that two types of reactions take place. In one the fuel is thermally decomposed and dehydrogenated; in the other it is oxidized to oxygen-containing compounds.

There is considerable evidence, both from the NBS studies and from those in other laboratories, that acetylene may be the essential intermediate in carbon formation in burning mixtures. Additional experiments are being carried out to verify this premise by burning fuels having isotopic carbon in selected places in the molecule. Carbon is readily formed in knocking combustion, even with lean mixtures, and this may indicate that formation of carbon from the acetylene present is a faster reaction than the direct oxidation of acetylene under these conditions.

Heat Engines. The octane number of gasoline is determined in a standard laboratory engine under prescribed operating conditions. One operating variable which is not directly controlled in the current standard test methods is the altitude or ambient pressure at the point of test. To improve the uniformity of test methods and reproducibility in octane rating, two sets of experiments were conducted in the Bureau's altitude chamber in cooperation with the American Society for Testing Materials. In the first series of experiments, an evaluation was made of several types of auxiliary equipment designed to pressurize the air-induction system to one atmosphere, regardless of the ambient pressure. The equipment operated satisfactorily, and reproducible ratings were obtained at all altitudes. The second series investigated the possibility of compensating for changes in altitude by adjusting the compression ratio and inlet air temperature, thereby eliminating additional equipment. These adjustments were made in accordance with theoretical calculations to give a constant charge density and temperature at the instant of ignition. This approach was found to be inapplicable because of the effects of secondary variables. However, it did serve as a basis for empirical development of the desired conditions. The empirical results appear quite satisfactory in the great majority of cases. These conditions are being standardized and studied for reproducibility.

Pneumatic Tires. The Synthetic Rubber Division of the Reconstruction Finance Corporation has been engaged in an extensive program to develop large-size, heavy-duty pneumatic tires from

synthetic rubber for trucks and buses. In connection with this program, the Bureau is conducting power-loss and contained-air temperature-rise investigations on experimental tires using different materials, compositions, and designs. Equipment specially developed for this purpose include dynamometers for power measurements and a thermocouple-slipring arrangement for measuring the contained-air temperature. Investigations to date show that relations between power loss and contained-air temperature rise are essentially linear. The results further indicate that with tires of the same design, changing from natural rubber to a synthetic rubber increases the power loss up to 50 percent or more, depending upon the type and proportion of the synthetic rubber. The power loss is also greatly affected by tire design, to such an extent that natural rubber tires of some designs gave almost as much power loss as synthetic rubber tires of other designs.

Oil-Free Bearings. It is essential that aircraft clocks and similar instruments operate satisfactorily over a temperature range from −55° to 70° C. At subzero temperatures congealing of watch and clock oils prevents satisfactory performance. A current project, sponsored by the Navy Bureau of Aeronautics, is concerned with investigation of materials for use as oil-free bearings to replace jewels, which require lubrication. Materials investigated include plastics, plastics with fillers, impregnated metals, and impregnated carbon. Wear tests, conducted with both rotating and oscillating shafts, have indicated good wear resistance with several materials. The investigation is being continued in an attempt to find materials having good wear resistance in combination with low coefficients of friction that are not adversely affected by the wide range in temperature nor by operation for long periods.

2.4. Atomic and Radiation Physics

Basic atomic and nuclear research is important to other research laboratories, medical institutions, industry, the military services, and other Government agencies. The Bureau's program in atomic and radiation physics is concerned primarily with studies of (1) particles such as atoms, nuclei, neutrons, and electrons; (2) properties of radiations, particularly gamma and X-rays and ultraviolet, visible, and infrared light; and (3) the interactions between such

radiations and particles. Emphasis is placed on the fundamental research and development necessary to meet the increasing demand for new standards, more accurate values of atomic and nuclear constants, reliable data on the properties of high-energy radiations, new and improved methods of measurement, and the calibration of radiation sources and radiation detection instruments.

In addition to Bureau-sponsored programs, investigations were carried out for the Atomic Energy Commission, the Department of Defense, and other Government laboratories. Typical programs included the studies of radiation protection, the development of radiation detectors, research on semiconductors and solid state electronics, and development of new techniques in electron physics and mass spectrometry.

Hyperfine Structure of Technetium. When suitably excited and examined with high resolving power, many spectral lines exhibit more than one component. In general, these hyperfine components are ascribed either to different isotopes of a given chemical element or to a hyperfine splitting of atomic energy levels because of interactions between valence electrons and atomic nuclei. Increased knowledge of such hyperfine structures will permit quantitative evaluation of certain properties of atomic nuclei, which are prerequisite to an eventual understanding of the structures and forces in these nuclei. As an important step toward this goal the Bureau has completed investigation of the hyperfine structure in the first spectrum of technetium, an element sought for 80 years and only recently separated from uranium fission products. A two-milligram sample of $_{43}Tc^{99}$ was excited to emit light in a liquid-nitrogen-cooled hollow cathode, and spectrograms were made with an interferometer and quartz-prism spectrograph. Several dozen technetium lines were resolved into 4 to 10 components each, permitting calculation of hyperfine interval factors and nuclear moments. The mechanical moment or spin of the technetium nucleus was found to be about 9/2 units, the magnetic dipole moment was calculated to be about $+5.5$ nuclear magnetrons, and a small electric quadrupole moment indicated that charge distribution in the technetium nucleus is nearly spherically symmetrical.

Electron Scattering. Considerable progress has been made in instrumentation for medium-energy electron scattering studies. This program, sponsored by the Office of Naval Research, is directed

toward a better understanding of the processes by which electrons lose energy upon impact with atoms. The instrumentation for these studies consists of two main assemblies. The first of these is a high-resolution "electron spectrograph," which is capable of detecting a loss of less than 5 volts out of an initial electron energy of 50,000 volts. To complement this instrument, which is limited to only slightly deflected electrons, and to permit studies of collisions resulting in greater electron deflection, the Bureau also constructed another apparatus. This instrument is arranged for automatic data recording, and gives, in less than one-half hour, energy loss and intensity as a function of angle of deflection at ⅛° intervals over a range of more than 100°. Data on copper, aluminum, beryllium, and gold have been obtained. The small-angle measurements have been equally successful, data having been obtained for 25 metals and insulators. The small-angle studies have provided much new knowledge about the mechanism of electron energy losses.

Calibration of Beta-Ray Opthalmic Applicators. Beta-ray therapy is used in the treatment of certain diseases of the eye, and intense beta-ray sources of small size are being produced commercially for this purpose. The active material normally consists of radioactive strontium-90 or of radium D+E. The Bureau developed a standard method for calibrating these beta-ray sources that expresses the dosage delivered to the patient in terms most useful to the physician. Extrapolation ionization-chamber techniques determine the dose rate at different depths in tissue-equivalent material along the axis normal to the plane face of the applicator. Autoradiographic techniques have also been perfected to study radiation distribution at various depths in tissue-equivalent material.

Formamide Counting. In order to determine the activities of radioactive nuclides for medical and research purposes the investigator generally uses a known aliquot of a solution of a salt of the nuclide in question. From this a solid source is prepared either by precipitation or by evaporation, and beta-ray strength is determined by normal counting methods. It would be advantageous to be able to assay beta-emitters also in the solution form. In the case of soft beta-emitters, the attenuation in the normally used membrane cover makes this method impractical; without this

cover the vapors from the water solution interfere with the operation of the counter.

To obviate this difficulty, especially in counting soft beta radiation from radioactive carbon-14, the Bureau carried out experiments with the organic solvent, formamide, which has an extremely low vapor pressure. It was found that a specially constructed 2π beta counter containing a small dish of formamide behaved in a perfectly normal fashion. Moreover, small amounts of aqueous solutions of radioactive nuclides could be dissolved in the formamide without changing the counting characteristics of the 2π beta counter. Formamide counting, developed for radioactive carbon-14, has been satisfactorily extended to the secondary standardization of radioactive phosphorus-32, cobalt-60, iodine-131, strontium-90 and yttrium-90, and thallium-204. This method could also prove very convenient for calibration in research and hospital radiological laboratories.

Spectral-Line Intensities for 70 Elements. In principle any chemical element can be uniquely identified by its spectral line wavelengths, and the composition of any mixture of chemical elements can be determined accurately by comparing its spectral-line intensities with those of standard samples. The wavelengths of atomic radiations of all chemical elements are accurately known, but their relative intensities have never been presented on a uniform physical scale for the entire useful range of wavelengths. To supply such information the Bureau has measured the relative intensities of all spectral radiations of 70 chemical elements detectable when each element was diluted one-thousand-fold in copper, excited in a direct-current arc, and its spectrum recorded photographically from the ultraviolet (2000 A) to the infrared (9000 A). The spectral-line intensities of the diluted elements were estimated by comparison with accurately measured relative intensities of copper lines and then converted to true relative intensities on the same scale for all 70 elements. Wavelengths and intensities of about 30,000 spectral-lines of these 70 elements, together with the atomic levels that account for the radiations, are being compiled for publication.

Intermetallic Semiconductors. An important development in electronics achieved during the last 2 years at NBS was an independent discovery of a new group of semiconducting materials that may alleviate the present shortage of crystal rectifiers and

transistors. Past experience has shown that, although germanium can be used successfully for rectifiers and transistors, the units do not function well at high temperatures. This limitation, which prevents the use of some devices and severely restricts others, is fundamental to the electronic nature of germanium and cannot be removed. A possible solution is the use of silicon as a germanium replacement. Unfortunately, because of its high melting point and reactive nature, it is extremely difficult to grow the required single crystals of silicon of sufficient purity for use in practical units. A series of intermetallic compounds formed between the metals antimony or arsenic and the metals indium, gallium, or aluminum may solve this problem. It has been found that these compounds are all semiconductors with properties comparable to those of silicon or germanium. In particular, the compound gallium antimonide can be used to make rectifiers that will operate at temperatures much higher than are possible with germanium. This compound has a much lower melting point than silicon, making it much easier to fabricate. The development of transistors made of this material is under way.

In addition, recent observations of photoconductive effects in these intermetallic compounds suggests that they may be useful as photocells, particularly in the infrared region. This possibility is now being explored.

Synchrotron Operation. Successful operation of the NBS synchrotron at 180 million electron volts (Mev) has been attained during the past 2 years. The X-radiation output of this synchrotron has been maintained reliably at an intensity higher than that of any other similar accelerator operating in this energy range. Although it has been desirable to reserve approximately half of the operating time for a study and improvement of operating characteristics, a considerable amount of radiation research has already been done. Some of the research problems utilizing the synchrotron during the past year were (1) attenuation measurements of high-energy X-radiation in concrete, (2) side scattering of photons in hydrocarbons and its effect on ionization dose measurements, (3) tests for a pattern amplifier to permit visual radiography, and (4) nuclear absorption of photons.

Elastic Nuclear Scattering. A high-energy spectrometer recently developed at the Bureau makes possible the study of X-radiation

photon interaction with the nucleus. For example, the probability of a photon of a given energy being absorbed and reemitted by the nucleus at energies of the order of 15 Mev is now being examined.

The first experimental observation of the "resonance" character of the excitation function for elastic nuclear scattering of high-energy photons (5 to 30 Mev) was made with the Bureau's 50-Mev betatron. This work was supported by the Air Force. The "resonance" character of the nuclear absorption of high-energy photons has been known experimentally for a number of years. Although very general dispersion theory indicated that a similar "resonance" should be observed in the elastic scattering cross section, this fact has never before been verified experimentally. The analysis of these scattering results is leading to valuable information about the energy-level structure of nuclei studied at excitation energies of 5 to 30 Mev.

X-ray Spectrometers. The Bureau has developed a scintillation crystal detector to measure individual X-ray photon energies in the range from 0.5 to 50 Mev. The detector is especially suited to research with betatrons and synchrotrons. In this spectrometer a single X-ray photon is totally absorbed in a large bath of scintillator, producing a light flash of magnitude proportional to the X-ray energy. This spectrometer provides a detection efficiency 100,000 times better than that previously available from spectrometers with comparable energy resolution. In consequence, many high-energy X-ray experiments are now possible and their interpretations will be facilitated.

Accurate analysis of X-rays having energies between 0.2 and 12 Mev is made possible by another new spectrometer. Called the NBS magnetic Compton spectrometer, it operates in an energy range that bridges the gap between other types of X-ray spectrometers. Data obtained with the spectrometer are used in studying X-ray absorption properties of various materials. It is expected that the spectrometer will also provide information leading to a better understanding of the nature of X-ray production.

High-Sensitivity Fluoroscopic Unit for High-Energy X-Rays. The betatron laboratory has developed a sensitive fluoroscopic instrument that can be used industrially with high-energy X-rays for rapid inspection of fixed slabs of material. The fluoroscope displays continuously a replica of the X-ray image on a TV kine-

scope. When 180-Mev X-radiations from the synchrotron are used, the instrument is sufficiently sensitive in its present state to reproduce scenes through as much as 6 feet of concrete or 12 feet of water. The high sensitivity of this instrument makes it capable of responding to a single X-ray burst from the synchrotron. This means that it can be used either as an X-ray stroboscope, to stop cyclic action occurring inside the object being viewed, or as a single shot X-ray camera, with an effective shutter speed equal to the time length of an X-ray burst. With a burst time of the order of a microsecond, the camera is extremely fast, and can be used to investigate very rapid transient phenomena.

Data Transmitting System. At the request of the Atomic Energy Commission, a system was developed by the Bureau for monitoring and transmitting radiation intensity and other data to a central control station. Evaluation tests were conducted by the AEC with NBS assistance at atomic-bomb tests in Nevada. These tests were highly satisfactory, and the AEC is proceeding with plans for wide application of the system.

The data can be transmitted over considerable distances because the system utilizes an FM radio link operating in the VHF band. Because propagation is "line of sight" at these frequencies, the system utilizes repeater stations. The operator at the control station has complete control over the data stations, is able to interrogate them and have any station he chooses transmit at any desired time. The operator can also select from several transmission programs. Except for the control station, the entire system is battery operated and is designed to operate unattended for long periods of time.

X-Ray Protection. Radiation tests have been completed with the Bureau's 50-million-volt betatron on X-radiation attenuation in concrete. Increasing applications of high-energy radiations to such work as cancer therapy and inspection of thick metal castings have made these data valuable to hospitals and industries. For economy of construction in X-ray installation it is important to know as exactly as possible what barrier thicknesses will provide adequate protection to personnel.

The Bureau is concerned with determining radiation attenuations in barriers designed to stop X- and gamma radiations of various energies. In determining barrier thicknesses required to

stop obliquely incident radiations, the usual assumption has been that adequate protection can be calculated from attenuation curves known for normal incidence, the significant factor being the length of beam path irrespective of the angle of incidence. Experiments were carried out to determine the validity of this assumption. The results showed that for large angles of incidence it was in error by as much as a factor of 10. The Bureau now has available experimental data on oblique radiation attenuation and hence is in a better position to assist those who plan X-ray installations. Detailed procedures for designing X-radiation barriers are presented in NBS Handbook 50, *X-Ray Protection Design.*

2.5. Chemistry

A wide range of fundamental and applied research is carried on in physical, analytical, organic, and inorganic chemistry. Special laboratories are devoted to organic protective coatings, detergents and adsorbents, carbohydrates, metals and alloys, pure substances, electrodeposited coatings, gases, acid-base indicators and pH standards, and hydrocarbons. Highly varied techniques are used in the analytical work of the several groups; many types of physicochemical measurements are made: an entire section, by way of illustration, is occupied with emission spectroscopy as an analytical tool. Most of the Bureau's Standard Samples, critical in industrial quality control and in research throughout the Nation, originate in this division.

Colloidal Dispersions. Fundamental studies have been made of certain properties of nonpolymeric colloid solutions. Detergents, typical of that class of material known as association colloids, have been the subject of viscometric and light-scattering measurements, by which the size and shape of the colloidal detergent particles have been determined. The importance of the electric charge carried by the colloidal aggregates in determining the properties of their solutions has been reaffirmed, and the effect of adding small ionizing salts has also been investigated. Extension of this work by means of electrophoretic and diffusion experiments will lead to results of fundamental significance in fields as diverse as detergency, corrosion, and physiological processes.

Basic Calcium Phosphates. The basic calcium phosphates are important in agriculture, in clarifying sugar liquors, in water puri-

fication, and in studying tooth and bone structure. They are a group of basic compounds of rather widely varying ratios of calcium to phosphate. Because physical properties of calcium phosphates depend not only on chemical composition, but to a greater extent upon method of preparation, fundamental studies have been made of their chemical and physical properties as related to method of preparation. Practical applications of these materials depend largely on their adsorptive properties; control of crystal size and surface area (that is, available surface per unit weight of substance) is therefore of importance. Basic phosphates having 7-fold variations in surface area and comparable variations in other properties can now be prepared at will.

Thermochemical Measurements. One of the fundamental branches of chemistry is the study of the forces or binding energies with which atoms are held together in molecules. Thermochemical measurements of heats of formation are essential to the evaluation of total binding energies in molecules. In general, quite detailed information on binding energies can be obtained from studying differences in heats of formation of those molecules having certain aspects or groups in common, such as isomers and homologous series of organic compounds. Thermochemical data are also essential to the engineer calculating heat balances in chemical plants and are required for determining reaction equilibrium constants that are necessary to chemical process development.

Thermochemical studies at NBS have determined heats of formation of *o*-, *m*-, and *p*-tert-butyltoluene, yielding information on steric effects in hydrocarbon molecules. Measurements of heats of formation of all pentenes and pentadienes and a few hexenes have given information on effects of alkyl substituents on double bond energetics, which are valuable in synthetic rubber development. Measurements have also been made on the boron hydrides and other boron compounds. These measurements will aid in understanding these relatively new compounds in which the usual laws of chemical binding do not apply.

Research in Analytical Chemistry. During the past decade many metals have been employed for the first time in production of alloys that are strong and durable under conditions such as the high temperatures developed in jet engines. Control of composition necessary for the production of such alloys has created many

new problems for the analyst, because the metals are among the less common elements that have received relatively little study and in addition are much alike in their chemical properties as to make analytical separations difficult. A technique of separation based on ion exchange—the differential retention of metal ions on the surfaces of certain resins—has aided in the solution of these problems. This technique, which has proved successful elsewhere for difficult separations, has been successfully applied in NBS laboratories to the quantitative separation of cobalt, nickel, iron, and manganese as they occur in cobalt-base jet-engine alloys. Ion exchange has also successfully separated niobium, tantalum, titanium, tungsten, and molybdenum as they occur in stainless steels. For the latter elements, photometric methods have been developed to give quantitative determinations after ion-exchange separation.

Spectrographic methods of analysis were developed for the following applications: (1) Determination of impurities in nickel used in cathodes of electron tubes, (2) analysis of complex dental alloys for major and minor constituents, (3) determination of impurities in highly purified titanium tetrachloride, (4) determination of trace elements in portland cement, (5) a rapid method for determining beryllium in dust, and (6) flame photometric determination of alkalies in refractory materials. These methods offer advantages of speed or sensitivity over classical methods.

Phenomena of Crystallization. One of the most widely used methods of purifying substances is to recrystallize them repeatedly, either from solution or from their own liquid state. In this process there are two important limitations to the degree of purification that can be accomplished in a single step, the extent to which the less pure liquid can be separated mechanically from the more pure solid, and the extent to which impurities accompany the major constituent during crystal formation.

A distinct advance has been made in providing optimum conditions for mechanical separation of solid and liquid upon crystallization from the molten state. The substance is placed in an evacuated glass vessel and lowered by a special device through a bath consisting of two immiscible liquids, the upper one kept above the freezing point of the substance and the lower one kept below it. At the boundary between liquids there is a sharp difference of temperature. As the substance passes through this boundary it

tends to form large single crystals having minimum surface in contact with the liquid. When solidification is nearly complete, the remaining liquid is allowed to flow into a side arm of the vessel and is there sealed off without opening the system. The entire operation is repeated several times and eventually there is obtained a single crystal of extremely high purity that is optically homogeneous and without inclusions.

pH Standards. In many manufacturing and research operations measurement and regulation of acidity, or pH, is essential for controlling process steps. NBS maintains and issues standards for the precise calibration of instruments used in measuring and controlling pH. The temperature range over which these standards are certified, previously 0° to 60° C, has been extended to 95° C, to bring the upper limit nearer to the boiling point of water. To fix the extended pH values it was necessary to determine the standard electrode potentials of the silver–silver-chloride electrode at the higher temperatures. These potentials are expected to serve also as standard reference potentials for measuring the electromotive force of cells.

Precise Intercomparisons of Acidic Substances. One of the Standard Samples issued by the Bureau, potassium hydrogen phthalate, is probably the most widely used standard of its type to establish the accuracy of the innumerable assays of acids and alkalies that are made by the chemical industry. Although the acid strength of the standard itself has been well enough known for all ordinary purposes, it has never been fixed with the accuracy that is desirable for a primary standard. In the past its acid value has been fixed by a chain of three comparisons, with the resulting possibility of an accumulation of small errors. A refined technique has been employed with satisfactory results. The procedure involves potentiometric titration in a cell provided with a differential hydrogen-electrode system for determining the equivalence point. The strength of the potassium hydrogen phthalate has been compared, through the medium of a selected basic substance common to both reactions, with benzoic acid whose purity was determined by independent means. The precision thus attained has decreased by a factor of ten the uncertainty which has existed in the knowledge of the acid value of the standard.

Titanium Compounds. In recent years the Navy has sponsored a broad program of basic research on the extractive metallurgy of titanium, a metal of rapidly growing industrial and technological importance. The preparation of a series of titanium compounds of high and thoroughly established purity was assigned to NBS. Extraordinary purity has been achieved in the preparation of the first of this series, titanium chloride, and the new methods used for the purification have already attracted the interest of industrial producers of titanium and its compounds. Work is in progress on four other compounds for which the highly purified tetrachloride provides the starting point.

Electrodeposition from Nonaqueous Media. The art of electroplating has widespread and important uses but its application has been limited by the relatively small number of metals that can be electrodeposited from water solutions. Many other elements have physical and chemical properties that would make them extremely useful as coatings plated on other metals or in other electrodeposited forms. Among them are beryllium, aluminum, titanium, zirconium, niobium, tantalum, molybdenum, and tungsten, but their chemical nature is such that they cannot be plated from aqueous solutions.

Many new types of compounds have been studied in efforts to deposit these metals from nonaqueous solvents, or from fused salts. Although most of them have proven unsatisfactory, the Bureau has made some advances in processes for aluminum and molybdenum plating.

Ways have been found to correct the earlier faults of the aluminum-plating bath in which ether is the solvent. Addition agents that promote the brightness of the deposits have been found, and adherence of the deposited aluminum to the basis metal has been improved. Means have also been found to plate alloys of aluminum with zirconium, and of beryllium with boron. Successful plating of beryllium alone has not yet been accomplished. Satisfactory deposits of molybdenum in the form of the granular metal have been obtained from fused-salt baths under conditions which may have significance for the recovery of the metal from its ores. There has also been preliminary success in depositing the metal as a surface layer on other metals.

Labeled Sugars. Preparation of sugars and related compounds labeled with radioactive carbon-14 (C^{14}) in specific positions in the molecule has continued, and methods have now been developed for preparing more than 40 compounds. The project, sponsored by the Atomic Energy Commission, first brought results in 1952 when 12 labeled sugars were announced. Because nongovernment laboratories have begun regular production of only two of these substances (it is hoped that others will follow), it has been necessary for the Bureau to maintain a supply of 30 others as well as to continue work on additional compounds. Quantities sufficient for extensive research in normal and pathological animal and plant metabolism have been issued to 75 laboratories, among them several actively engaged in cancer studies.

Gas Analysis Procedures of Extreme Sensitivity. The method for determining the purity of hydrogen by thermal-conductivity measurements has been refined to yield a procedure at least 10 times more sensitive than any previously known. The method will detect as little as 1 part of any other gaseous substance in 10 million parts of hydrogen, with an apparatus designed to give direct instrumental readings from any one of more than 50 sampling points.

A prototype field instrument for determining water in gases at pressures as high as 6,000 pounds per square inch and with a frost point as low as −65° F has been completed for the Air Force. The instrument, with a unique combination of accuracy, range, sensitivity, portability, and speed, is capable of determining the water at high pressure in gas that after expansion will have a frost point as low as −100° F. Mounted on wheels, it can be trundled to any part of an airfield and a determination can be made at subzero temperatures in a minute or two with an extremely small sample.

2.6. Mechanics

Basic research in mechanics is concerned with the determination of mechanical properties of materials in the gaseous, liquid, and solid state; the propagation of waves through solids, liquids, and gases; fluid flow (such as that occurring on the surface of an airplane wing or during the break of a dam); and the response of mechanical bodies (such as metallic structures) to applied forces. Applied research in mechanics seeks to improve calibration pro-

cedures for mechanical standards (laboratory weights, force dynamometers, vibration pickups, microphones, pressure gages) and to find solutions to problems in the evaluation and development of such devices as aircraft oxygen apparatus for high-altitude flight or after-burners for jet engines.

Throughout this program increasing use is being made of electrical and electronic methods. For example, precise calibrations of vibration pickups, vibration generators, and microphones at high frequencies are being made more and more by electrical measurements alone, utilizing the reciprocity principle; the NBS electronic computer, SEAC, is being employed to save computation time in studies of vibrating structures; and precise determinations of humidity are being made by a microwave refraction technique.

Speed of Sound in the Sea. A velocimeter that automatically measures and records the speed of sound at ocean depths as great as 3,000 feet was developed for the Navy. The device is being used by the Chesapeake Bay Institute, and improved models are under development. These instruments promise to be useful for research into the physics of sound in the ocean as well as in studies of signal propagation under water.

Free Molecule Propagation of Sound. A new type of sound propagation was discovered as a byproduct of the Bureau's investigation into the propagation of sound in rarefied gases. This type of propagation occurs if the sound path is much shorter than the mean free path of the gas molecules so that intermolecular encounters are not significant. The simple theory for the velocity and attenuation of free-molecule sound was confirmed in its main features by experiments with the ultrasonic gas interferometer. It may be possible to apply the results of this work to the study of gas-molecular reflection and accommodation coefficients and to other problems in gas dynamics.

Artificial Mastoid. An artificial mastoid is needed to represent an "average human head" in tests of hearing aids of the bone conduction type. A mechanical driver was designed and built to measure the mechanical impedance of the head at audiofrequencies. Results of preliminary measurements with this device indicated that the head may be represented by a simple mechanical system consisting of a very stiff spring with a small amount of damping. From the data obtained so far, it appears that a simple

artificial mastoid can be constructed that will make it possible for the Bureau to supply calibrations of bone conductors for audiometric purposes.

Properties of Electroacoustic Transducers. A method was devised for monitoring and controlling the motion of a sound source. This method makes it possible to stabilize the behavior of a sound source under varying conditions of load. In addition, it was found that the method could be applied to measurements of sound pressure using carrier-modulated microphone amplifiers with precision equivalent to that previously available only with microphones operated through direct audiofrequency amplifiers. This makes it possible to make acoustic measurements of high accuracy while taking advantage of the favorable signal-to-noise ratios which can be achieved when radiofrequencies are used to detect the sound impinging on the microphone.

Architectural Acoustics. An improved method was developed for measuring and recording continuously the sound transmission loss of a partition wall at various frequencies. Continuous recording at low frequencies has proved particularly useful in reducing errors arising from sound wave interferences in reverberant measuring rooms. The presence of the interference patterns of "random" sound wave fields was predicted theoretically and confirmed experimentally.

Noise Reduction in Jet Engines. Jet engine noise presents a hazard to hearing and is sometimes severe enough to cause damage in aircraft structures. Apparatus was built for measuring the noise attenuation provided by cylindrical space absorbers designed to reduce the noise of jet engines being tested. To determine the mechanism of noise generation, preliminary measurements were made of the total sound energy produced by model jets.

Calibration of Vibration Pickups at Audiofrequencies. By means of a modified pistonphone, a technique was developed for obtaining the response of a capacitance-type vibration pickup probe. The reciprocity calibration of a condenser microphone was used as a reference. The instrument consists of a barium titanate driver coupled to a circular piston, which generates a sound pressure in a small vibration-isolated enclosure. Measurement of the sound pressure with the condenser microphone permits computation of the motion of the piston and calibration of the capacitance probe.

A probe calibration accuracy of 5 percent is achieved for the frequency range from 100 to 10,000 cps. Vibration amplitudes as small as 10^{-9} cm have been measured with comparable accuracy.

Calibration of Microphones. Microphones having absolute calibrations are used to measure sound pressures to an accuracy of about 1 percent. Such calibrations have hitherto been made over the frequency range from 50 cps to 10,000 cps. By means of specially designed small enclosures, calibrations can now be made up to 20,000 cps. At the other end of the frequency range, accurate calibrations have been extended down to a frequency of 1 cps. This has been achieved with the aid of a mathematical investigation into the cooling effects of the walls of the microphone-calibration enclosures at very low frequencies.

Measurement of High Pressures. Modern chemical industry and modern ordnance both require an extension of the range of the piston gage to serve as a pressure standard from 50,000 to 200,000 pounds per square inch. Under the sponsorship of Watertown Arsenal, two of the difficulties preventing this extension were overcome. First, the dimensional change from internal pressure on the cylinder of the piston gage was compensated by balancing with a controlled external pressure. Secondly, a special insulator solved the problem of leakage through pressure-indicator lead holes. The insulator consists of a small sapphire bushing that has been subjected to pressures up to 180,000 pounds per square inch without failure. Installation of new piston gages is being completed to give primary standards for measuring pressures up to 200,000 pounds per square inch.

Aerological and Flight Test Instruments. Work in aerological instrumentation resulted in the development of an improved humidity measuring element having high sensitivity and extremely rapid response; these characteristics promise improved accuracy of measurement, particularly under conditions encountered in radiosonde and aircraft use. Improved flight test instruments developed for special purposes include a helicopter airspeed gage and a compact high-speed photo-panel unit for recording temperatures at 96 locations on an aircraft every 6 seconds. Research in the application of thin evaporated films resulted in the development of electrical resistors having improved characteristics.

Turbulent Flow. Chaotic motions, known as turbulence, play a key role in nearly all technological applications of fluid flow. When water flows through a pipe, for example, only under exceptional circumstances does it move in an orderly fashion. In general, it becomes jumbled and confused, partially blocking its own progress through the pipe. Similar phenomena occur in the flow of air along the surface of an airplane and in the flow about a body moving through a fluid. Here the forces experienced by the body are strongly influenced by turbulence. The Bureau recently concluded a 2-year investigation of the mechanics of turbulent motions which was sponsored by the National Advisory Committee for Aeronautics. Studies were conducted with air flowing along a flat wall in one case and with air flowing in a pipe in another case. Hot-wire anomometers were used in various ways to derive such information as the following: where and in what quantities turbulent motions were produced; where and at what rate turbulent motions were dissipated by viscosity.

Hot-Wire Anomometer Development. Under the sponsorship of the National Advisory Committee for Aeronautics, the factors governing the cooling of fine heated wires were investigated in the transonic and supersonic speed ranges. The purpose was to find those characteristics of the hot wire that can be exploited to produce a tool for research at high speeds. By covering a wide range of speeds, air densities, and wire temperatures with wires of different sizes set at various orientations to the stream, new possibilities were uncovered. Wires as small as 0.00005 inch in diameter were used. With such fine wires, rapidly fluctuating quantities can be measured. The investigation has made it possible to measure fluctuations in velocity, density, and temperature at speeds up to twice the speed of sound. Such measurements aid in evaluating data obtained in supersonic wind tunnels.

Positive Waves. Positive waves are flood waves caused by the sudden break of a dam. The nature of the wave depends not only on the height of water behind the dam but also on the roughness of the valley or channel into which the water is discharged. This important type of transient flow was studied theoretically and in the laboratory. High-speed photography and other techniques were used to observe a flood wave discharging into a channel after the sudden raising of a vertical gate simulating the dam.

The waves were discharged into channels of three degrees of hydraulic roughness. The results indicate that there is a short time interval just after the opening of the gate during which the resulting flow is primarily determined by viscosity effects rather than by turbulent resistance. The initial flow shows good agreement with the results of a theoretical analysis.

High-Temperature Strength of Aircraft Structures. The development of jet- and rocket-powered aircraft and the subsequent penetration of the sonic barrier have resulted in a steady increase in structural temperatures resulting from skin friction. The problem of building structures capable of withstanding these temperatures is becoming a major obstacle to the attainment of higher speeds. Many materials and components in aircraft construction undergo severe weakening at temperatures produced by aerodynamic heating. One weakening effect is *creep*—i. e., continuing deformation with time under constant loading—while losses in material strength and stiffness constitute another.

To increase available information on creep of aircraft structures, the National Advisory Committee for Aeronautics, sponsored studies of riveted aluminum alloy joints at 300°, 400°, and 500° F and of spotwelded joints of stainless steel at 800° F. The results show that the creep of the riveted joints is considerably greater than the creep of unriveted sheet, although not so large that the creep of the sheet could be considered negligible compared to that of the joints. Limited data indicate that the creep rupture strength of a riveted joint may be approximated by assuming that the creep rupture efficiency of a joint at any temperature is equal to the room-temperature efficiency. The creep of the spotwelded joints in stainless steel was found to be negligible after 200 hours at 800° F at loads up to 97 percent of their ultimate strength.

Solution of Structural Problems with SEAC. In the design of machines and structures, an important factor in the choice of methods of analysis is the time available. Limited time results in the use of estimates and approximate formulas where more accurate though cumbersome formulas are available, and in the study of only a few design variables where a more thorough search might yield a more efficient design. Any means of reducing analysis time, particularly if it does not result in an increase in cost, is therefore of prime importance in determining what design

methods will be used. The advent of high-speed digital computing machines showed promise of such a large reduction in analysis time that their application to the difficult and tedious problems of static and dynamic analysis of aircraft structures has been pursued vigorously.

One of the first applications was the computation of the influence coefficients, or deflections per unit increase in load, for tapered cantilever beams. A basic code was devised for SEAC (National Bureau of Standards Eastern Automatic Computer), making it possible to compute influence coefficients for beams having up to 23 stations at which the deflections must be known. In an example for a beam having nine stations, the computing time was 3 minutes as compared with 2 days when done by hand on a conventional computing machine.

An additional application has been the analysis of delta wings for high speed aircraft. Wings of this type, when formed of a thin metal skin reinforced by spanwise beams and chordwise ribs in a conventional manner, form highly redundant structures. Structural analysis of such wings is thus extremely complex. General codes to be used in SEAC for carrying out such analyses have been devised and found to give satisfactory results.

In the dynamic analysis of large aircraft structures subject to vibration and shock, it is frequently necessary to analyze a many-degree-of-freedom system because of the high flexibility of the lightweight structure and the presence of heavy engine weights, as well as the fuselage weight, in addition to the distributed structural weight. The development of a general code for computing the vibration modes and natural frequencies of such structures with up to 63° of freedom has been completed. For shock loads, a step-by-step method of dynamic analysis has been coded for several specific problems.

Failures in Welded Ships. NBS research efforts undertaken at the request of the Ship Structure Committee have provided additional evidence on the major causes of structural failures in welded merchant ships—in particular, the critical role of certain properties of steel which, in the past, have not been recognized in specification requirements. The Bureau has received and examined samples from nearly 100 ships in which fractures have occurred, and studies of 126 plates selected from 65 of these ships have been completed.

When sufficient and suitable material was available, the laboratory investigation included examination of the fracture and of welds, microscopic examination, chemical analyses of the plates, Charpy V-notched bar tests over a range of temperatures, and tension tests.

Photoelectric Interference Fringe Counter. The interferometer makes use of the sharpness in the interference fringes between wave trains of monochromatic light for precise measurement of distances. Because of its precision, interferometry has become a favorite procedure in the calibration of strain gages. However, the operator may suffer considerable fatigue and eye strain in counting several thousand fringes. Fatigue may even cause him to lose count of the number of fringes and may limit him to a slow counting rate with frequent rest periods.

To overcome these disadvantages, a simple, low-cost counting device was developed. This device is attached to the eyepiece tube of the viewing system and, by means of a photo-multiplier tube, amplifier, and digital counter, enables the operator to count large numbers of fringes at a rapid rate without loss of accuracy. It is believed that this device will be of considerable utility in other laboratories because of the ease with which calibrations of improved accuracy may be carried out.

Stress-Strain Curve in Shear. The stress-strain curve in shear is of direct interest to structural designers for estimating the shear load carried by sheet beyond the plastic range. It is of indirect interest to those studying the plastic behavior of materials under combined stress.

Several procedures have been suggested for determining the stress-strain curve in shear of thin isotropic sheet material. Two of the most promising among these were the twisted-square-plate method and the annulus method. The theory for these methods was developed and then tried out in the laboratory on aluminum alloy sheet. The results agreed closely with those obtained from tensile and compressive tests on the assumption of certain formulas derived in the theory of elasticity and of plasticity.

Gas-Turbine Combustion. A fuel injection system embodying simultaneous control of the rates of admission of liquid fuel and air to the primary combustion zone was developed and evaluated. Considerable progress has been made in the development of a similar unit which vaporizes the fuel before mixing it with the

primary air. With this device, conditions favorable to high combustion efficiency and short flames are realized in the primary combustion zone over a wide range of operating conditions. Comparisons of the field of mixing of primary flame gas with secondary air have revealed that the large differences in temperature and density are important in promoting mixing. Relatively minor vibrations of the flame have also been found to be effective in accelerating the mixing process.

Fuel Metering Accessories for Aircraft. Studies of the effects of fuel density and viscosity on the performance of metering devices have led to the adoption by the military services of high-purity normal heptane as a standard test fluid for aircraft carburetors. A continuously indicating meter for kinematic viscosity, devised in the course of these studies, is now being produced commercially. A hydraulically-driven test bench for turbojet fuel-control units has been developed for evaluating these units under conditions simulating rapid engine acceleration. This bench now serves for the testing of master fuel-control units, which are then circulated among Navy overhaul stations and used in correlating the results obtained with other test benches.

2.7. Organic and Fibrous Materials

The Bureau conducts both fundamental and applied research in the field of natural and synthetic polymeric substances such as rubber, textiles, paper, leather, plastics, and related materials. These polymeric materials are unique in that they are basically composed of long, chainlike molecules in which as many as several million smaller molecules may be joined together by a process known as polymerization. Many important properties of polymeric substances are related to such characteristics of the large molecules, as size, shape, distribution, flexibility, and interaction with other molecules. Studies of the fundamental mechanisms involved in the formation of large molecules are important in advancing the understanding of this valuable group of industrially important materials.

Basic research activities of the past 2 years included studies of phase transitions and crystallization phenomena in polymers, nature of polymerization and degradation mechanisms involved in the formation and deterioration of polymeric materials, the rela-

tion between structure and stability of polymeric materials, and the propagation of stresses in fibers. Contributions were also made in the development of methods for the characterization of macromolecules.

Representative projects in applied research were concerned with the preparation of new types of paper from inorganic fibrous materials, development of a hot-dip plastic packing material, dimensional changes in dental amalgams, high-speed dental cutting instruments, dental therapeutic agents, treatment of heat-resistant plastic glazing materials to decrease crazing and increase impact strength, surface deterioration of plastic trays, creep of transparent plastics used in windows of aircraft, development of simulated performance tests for meteorological balloons, and abrasion of aircraft coatings.

Synthetic Rubber. As part of a continuing program for improving the tests used in controlling the quality and uniformity of synthetic rubber, studies were made of the Mooney viscometer. This instrument, which measures the viscosity or plasticity of the rubber, is used to control rubber polymerization. Variations in viscosity seriously affect the processing of rubber during manufacture. The NBS investigation included the influence of variations in rotors, dies, and rate of shear on the Mooney viscometer. As a result, rotors and dies of improved design have been constructed and are under test in a number of synthetic rubber plants.

Rubber is subjected to dynamic stresses in its most important uses, and its dynamic properties are more significant than the static properties normally used in testing. In order to avoid complexities associated with vulcanization and aging, polyisobutylene, a nonvulcanizable elastomer, was selected as a prototype for intensive study of dynamic properties. Data were accumulated to represent the dynamic response of a polyisobutylene polymer over the complete range of frequencies.

Dynamic Properties of Fibrous Materials. Textiles, plastics, and other organic materials are subjected to very high-speed impact or shock loading in such uses as safey belts and appliances. Important criteria of suitability for these uses include the magnitude and propagation of the stresses and strains developed in the material, the energy absorbed and recoverable, and energy to rupture. Equipment was constructed for evaluating these characteristics of

textile fibers, yarns, and cords at rates of deformation of the order of 1,000 to 100,000 percent per second. A procedure was developed for obtaining load-deformation curves for periods of the order of a millisecond.

Degradation of Record Papers. The degradation of record papers due to light, heat, or adverse storage conditions has long been an important problem to librarians and archivists. When papers undergo this deterioration, the aldehyde content of the cellulose in the papers usually changes. Some means of measuring the aldehyde content is therefore important in order to study and evaluate such degradation. A reaction that can serve as a basis for such a method is that of chlorous acid with the aldehyde. Studies of the stoichiometry and kinetics of the reaction of chlorous acid with glucose and similar sugars have been completed. Glucose served as the model in these experiments because it contains an aldehyde group and because it is the principal building unit of the natural high polymer, cellulose. Both iodometric and photometric procedures for determining chlorous acid were included.

Papers Made From Inorganic Fibers. A broad program of research on the manufacture of papers from inorganic fibers has been conducted under the sponsorship of the Naval Research Laboratory. Major attention has been centered on glass fibers. Although paper made entirely of glass fibers was originally developed by NBS for military uses, the all-glass paper is now used in respirators for mine workers and as a laboratory filter paper. Experimental papers have also been made from fibers of nearly pure silica produced in the laboratory, from a commercially obtainable alumina-silica compound, and from asbestos. In recent studies of glass-fiber paper, the effects of certain mechanical treatments in the paper mill and of the acidity of the fiber suspension in the beater were investigated. As a result, the tensile strength of the paper was increased from about 40 to nearly 400 pounds per square inch. By proper choice of fibers and control of the settings of the papermaking machine, glass papers were made in thicknesses ranging from 2 to more than 50 mils.

Impregnated Leather. The process for impregnation of leather with natural rubber, originally developed by the Bureau in 1949, was extended to permit the use of polyisobutylene as an impregnant. Soles impregnated with this polymer have the same greatly im-

proved abrasion and water resistance as those containing rubber However, polyisobutylene has a distinct advantage over rubber as an impregnant in that it eliminates the milling operation required to reduce the molecular size of natural rubber sufficiently to allow deep penetration. It also results in large savings of time, labor, and materials in the tannery.

Research in materials and techniques for leather impregnation is continuing at NBS. The Bureau is also carrying on pilot-plant studies of butyl-impregnation processes under the sponsorship of the Department of the Navy. Recent developments include a versatile economical latex-pigment finish with an embossed grain, and a method for blending hard resins, such as modified rosins, with polyisobutylene or butyl rubber to produce leather with almost any desired stiffness.

Sonic Studies on Leather. In recent years the use of sonic techniques for the nondestructive study of polymers has become widespread. Measurement of the velocity and attenuation of a sound wave as it travels through a given material reveals a number of important physical properties—e. g., elasticity and internal friction—which are characteristic of the material.

During the past 2 years, sound propagation studies have been applied to the development of equipment and methods for the nondestructive evaluation of leathers for use in military footwear. Transmitted sound waves presumably travel along the fibers of the leather, undergoing apparent velocity changes dependent on fiber orientation. The occurrence of stain, shrinkage, or aging tends to modify the fibrous structure, and hence the transmission of sound. Under the proper conditions nondestructive velocity tests show good correlation with destructive tensile strength or breaking elongation tests. The effects of accelerated aging, tannage, grease, and moisture can also be effectively demonstrated. Sonic studies with leather may thus be expected to contribute substantially to a better understanding of the mechanical and thermodynamic behavior of collagen and other long-chain molecules.

High-Pressure Studies. An investigation of the effect of high pressure on polymers at different temperatures was undertaken in order to obtain fundamental information on pressure-volume-temperature relations. During the last year this work was

sponsored by the Office of Naval Research. The compressibilities of a large number of synthetic and natural polymers were found to be intermediate between those of true liquids and true solids. This result indicates that the polymers have an intermediate type of molecular structure.

Pressure-volume-temperature measurements on a series of natural rubber-sulfur compounds showed no observable effect of pressure on the glass transition temperature and no isothermal glass transition pressure. Similar data on most members of the homologous polyfluoroethylene series resulted in a complex phase diagram for Teflon which was studied to temperatures of 80° C. No other member of the series showed any transition in the range studied. Calculated thermodynamic quantities revealed differences in intermolecular forces with varying degrees of fluorine substitution.

The work on polymers was accompanied by compression studies of glasses and cements. Data were obtained on a series of two-component glasses—alkali silicates and borates—of various compositions. The compressibility of dry hydrated cement was found comparable to that of silicate rocks. With added moisture the compressibility increases, and above some minimum moisture content an isothermal transition analogous to a phase transition is observed. Additional studies were made of aging and composition of the cement.

Compression studies of several pure materials prepared in both glassy and crystalline modifications indicated that compressibility of the glassy form is the greater. A single exception was found in arsenious oxide, in which both modifications exhibit the same compressibility.

Blood Plasma Expanders. In cooperation with the Office of the Surgeon General of the Department of the Army and the National Research Council, the Bureau continued to study the molecular properties of polymers for use as blood plasma volume expanders. Since the primary function of these materials is to provide adequate colloidal osmotic pressure in the blood vessels, their interaction with normal blood constituents and their diffusion through tissue membranes are of great clinical significance.

Both the equilibrium ultracentrifuge and osmotic pressure methods were used to investigate the interaction of the polymers

with human serum albumin. The effective osmotic pressure was greater than that calculated from the single components, indicating a definite interaction, possibly due to a mutual repulsion of the solutes. A technique using carbon-14 labeled materials was successfully developed and used to study the sorption of blood volume expanders by natural blood components.

Degradation of Polymers. One of the primary considerations in the industrial utilization of polymeric materials is their resistance to various environmental factors such as sunlight, temperature, mechanical forces, oxygen, and attack by chemicals. The stability of polymers depends both upon the molecular structure, which determines the mechanisms and kinetics of breakdown, and upon various traces of additional chemical compounds. Knowledge of the mechanisms of degradation should make it possible to devise means of lengthening the service life of these materials and should also aid in the development of new polymers with improved properties.

During 1953, the Bureau perfected methods for investigating the nature of degradation processes in polymers. These methods are based on the isotope effects in deuterated materials. Investigations also revealed that traces of residual catalytic substances materially lower the thermal stability of some types of polymers. Evidence was obtained that deterioration resulting from exposure to heat and ultraviolet radiant energy can be attributed in many cases to the presence of traces of oxygen combined in oxygenated structures in the polymer molecules.

New Polymer Structures. Military and industrial developments of recent years, particularly in the fields of jet propulsion and atomic power, have brought about increased demands for new materials capable of withstanding very high temperatures. A comprehensive investigation has been undertaken with the ultimate aim of developing new monomers and polymers of greater thermal stability. This work is a part of a broad research program which seeks to obtain basic data for understanding the relationship between the structure of polymers and their stability.

In the course of the investigation, a number of new fluorinated organic and semiorganic compounds not hitherto reported in the literature have been successfully synthesized. A new polymer, a fully fluorinated polyphenyl, has been prepared from

one of these materials and appears to be very stable to thermal degradation.

Aircraft Plastics. The causes of many of the failures of transparent plastic windows on aircraft are unknown. To aid in the solution of this problem, NBS conducted an investigation for the Navy Bureau of Aeronautics of the effect of differential temperature conditions on the creep of the plastic materials. To simulate flight conditions, the temperature of one face was kept higher than that of the other while the materials were subjected to a tensile stress; the extension in length was then measured. The resulting data explain why some of the service failures occur. For example, when one face of a laminated plastic window is at a relatively high temperature, the major part of the load is carried by the face at the lower temperature. Thus, failure occurs at an apparently low stress, calculated on the basis of the total thickness of the laminate. Although the thermoset materials creep less than the thermoplastic materials, they fracture in a short time under relatively low stresses.

Plastic Packaging Materials. Hot-dip plastic packaging materials for metal parts are difficult to strip from the coated parts at low temperatures. This is a serious hindrance to repairs on military equipment in the field. The packaging materials also deteriorate rapidly during the hot-dipping operation, which causes a serious loss in their protective properties. Recently the Bureau developed several improved hot-dip strippable plastic packaging materials for the Department of the Navy. These improved materials can be stripped at −65° F and applied by hot dipping at less than 300° F. They have good resistance to high-temperature degradation and protect the coated metal parts from corrosion.

Aircraft Coatings. Abrasion resistance is one of the most important of the properties which determine the service performance of protective coatings for military aircraft. However, thoroughly reliable measurement of this property in the laboratory has not been possible with existing methods, either because of poor reproducibility or failure to correlate with actual service.

Under the sponsorship of the Navy Bureau of Aeronautics, a laboratory test method was developed for measuring the abrasion resistance of organic coatings on metals. The method is expected to be of considerable value in the selection of coating materials

capable of withstanding the rigors of service on modern military aircraft. It utilizes a jet of fine abrasive particles under closely controlled conditions of pressure, distance, and angle to abrade through the coating. The abrasive jet method is rapid, possesses good reproducibility, and makes it possible to differentiate significantly between materials that are difficult to distinguish by qualitative methods.

Dimensional Changes in Dental Amalgam. Although silver-alloy amalgams have been widely used in dental restorations for over a hundred years, the metallurgical processes involved in the hardening of these materials have never been completely understood. This is particularly true of the reactions responsible for the dimensional changes which occur during and immediately following solidification. Recently a new approach to the problem was made at the Bureau. Through use of X-ray diffraction techniques at low temperatures, the dimensional changes were correlated with the presence of uncombined mercury in the alloy after its initial hardening.

From these data, it appears that the initial shrinkage observed during the hardening of amalgam results from the reaction of mercury with the alloy to form compounds having a smaller volume than that of the original alloy and mercury together. The subsequent expansion is caused by diffusion of uncombined mercury throughout the material, and the final shrinkage then results from combination of this mercury with existing phases or with residual alloy. On the basis of this explanation, a reduction in the size of the alloy particles or a heat treatment which would make the particles more reactive would tend to cause a reduced expansion or even a net shrinkage of the amalgam.

Hydraulic Turbine Dental Handpiece. At present the maximum speed of conventional dental cutting instruments is about 6,500 rpm. Because of the small size of dental burs, this rate of rotation gives too low a linear speed for efficient cutting of tooth structures. For example, a recent NBS study shows that a steel bur can remove the same amount of material in 4 seconds at 12,000 rpm as it can in approximately 30 seconds at 2,000 rpm. However, in spite of the disadvantages of using low rotational speeds, dentists have hesitated to use higher speeds with the conventional gear-type handpiece because of the excessive vibration and heat developed

and the potential hazard to the patient caused by the high inertia of the revolving instrument.

To make high-speed operation safe and convenient, a hydraulic-turbine dental handpiece which attains a speed of 61,000 rpm was developed. At this speed, very low cutting pressure is required and dental enamel can be cut rapidly with a minimum of vibration and heating. By positioning the turbine in the head of the handpiece and connecting it directly to the cutting tool, the mechanical difficulties involved in the use of high rotational speeds with the conventional belt-and-gear propelled cutting tools have been eliminated. Besides making possible more efficient cutting of tooth structures and reducing the time spent by the patient in the dental chair, the hydraulic-turbine handpiece also promises to be of considerable utility in other fields where small amounts of hard materials must be removed by grinding, as in tool and die making.

High-Speed Motion Picture Study of Dental Burs. Significant information on the cutting action of rotating dental instruments was provided by a photographic technique developed at the Bureau. In this technique, a high-speed motion picture camera is used in combination with an optical magnification system to make a greatly enlarged, slow-motion record of the action of each blade of a dental bur throughout the cutting cycle. It was thus possible to obtain dynamic observations of clogging, intermittent cutting, eccentric rotation, and other hitherto unsuspected details of the passage of the bur blades through the tooth structure. Used in combination with conventional test procedures, the photographic method should prove of considerable value for experimental study of new types of dental burs since it will permit rapid evaluation of new disigns prior to extended laboratory and clinical investigations.

Zinc Oxide-Eugenol Materials. A mixture of zinc oxide and eugenol is used as the essential ingredient in a wide variety of dental products, such as impression pastes and temporary filling materials, where compatibility with the oral tissues is necessary. However, the reaction responsible for the setting or hardening of the zinc oxide-eugenol mixture has not been understood, and the hardening characteristics of the materials have been inconsistent in dental practice, particularly where climatic conditions vary widely. An investigation of these materials demonstrated that particle size, degree of hydration, relative humidity, and tempera-

ture greatly affect setting time. X-ray diffraction patterns of the mixture showed the formation of a hitherto unreported crystalline compound. Chemical analysis indicated that this compound has the formula $(C_{10}H_{11}O_2)_2Zn$.

2.8. Metallurgy

The work in physical metallurgy is concerned with the melting, working, and heat treatment of metals and alloys; determination of their structure and properties; and studies of the effects of various factors on structure and behavior under normal and abnormal conditions of service. In general, this program is directed toward a better understanding of the properties and behavior of metals in order that new or improved metals and alloys may be developed for better performance in established uses and to meet the requirements of new applications. Recent investigations have dealt with the purification of iron and chromium, the structure and fracture of metals, and metallic corrosion.

Pure Metals. The direct and accurate determination of the properties of pure iron serves as a basis for understanding the behavior of steel, which is essentially iron modified by the presence of carbon, alloying elements, and impurities. The purest iron previously available was prepared at the Bureau about 1935 and contained 200 parts per million total of impurities. However, recent increased knowledge of the effect of extremely small concentrations of certain constituents indicates the desirability of further reduction in impurity content. Iron that contains only 30 parts of impurities per million parts of iron has now been prepared, and attempts to convert it into useful form for determination of its properties are in progress.

Chromium metal is strong, hard, and resistant to corrosion and to high temperatures, but its possible applications are restricted by its brittleness. There is reason to believe that this brittleness is affected by the very small amounts of oxygen, nitrogen, and hydrogen that may be present. Processes have been devised to reduce materially the content of gaseous elements in high-purity chromium, and the effect of this superpurification on the properties of the metal is being investigated.

Structure of Metals. Accurate knowledge of the intimate structure of metals and alloys—and of the changes in structure that

result from fabrication operations, heat treatment, and applied stress—is essential to a better understanding of the utilization of known metals and of the possible applications of new metals.

Constitution diagrams were completed for four binary systems: uranium-beryllium, uranium-titanium, uranium-silver, and uranium-gold. In comparing the new uranium-silver and uranium-gold diagrams with the existing uranium-copper diagram, it was found that the Hume-Rothery and Pauling generalizations do not explain satisfactorily the differences evident in the diagrams of these three Group 1B metals, but that inclusion of ionization potential considerations improves the explanation of the relations of these three elements to uranium. Results of X-ray diffraction and microscopic examination of iridium-osmium alloys increased the limited amount of information available on these binary alloys. The Bureau established possibilities and some limitations in the use of polarized light to identify structural features of tin, aluminum, and monel, particularly to demonstrate the crystalline orientation of individual grains of metal. In a study of the possible use of metals or alloys to replace quartz or mercury for ultrasonic delay lines in thermionic equipment, certain isoelastic alloys showed promise because of the small attenuation and distortion of the sound pulses and because of their thermal stability over the desired range of temperature.

When steel is hardened by quenching from elevated temperatures, the solution of carbon in gamma iron (austenite) may decompose to form various combinations of iron carbide and alpha iron, depending upon the carbon content of the steel and upon the conditions of the heat treatment. The structural arrangement of iron carbide and alpha iron that is called martensite is the hardest of these combinations; consequently, the hardness of the quenched steel is proportional to the amount of martensite it contains. In a study of the effect of various factors on the transformation of austenite to martensite in steels containing 0.50 percent carbon, it was shown that the temperature at which the transformation begins is affected by the grain size at the beginning of the quench but that variations in austenitizing temperatures (except for their effect on grain size) and in the rate of quenching from these temperatures are without appreciable effects.

Fracture of Metals. The demands of present-day engineering design require increasingly detailed understanding of the service metals may be expected to render and the mechanism by which they fail. Many metals fail by creep under loads appreciably less than the normal tensile strength at corresponding temperatures. However, a recent study showed that high-purity nickel can be strengthened by strain-aging so that it has an appreciable creep life under stresses in excess of the short-time tensile strength at this temperature. The mechanism of fatigue failures in helical springs made from steel spring wire was studied; the relation was shown between the bending fatigue properties of the wire and the strength of springs wound from the wire. In other studies of the susceptibility of metals to fatigue, it was shown that the fatigue notch sensitivity of certain high-strength aluminum alloys is affected by structural constituents.

Lowering the temperature increases the tensile strength of many metals and alloys without appreciably affecting their ductility. On the other hand, some metals, including many structural steels, show an abrupt loss of ductility at low temperatures. This abrupt transition has been the cause of many structural failures such as those that have occurred in welded ships during and subsequent to World War II. Properties of the ship plates that had fractured in service were extensively studied. The information thus obtained is of value in the development of better specifications for ship steel.

The deformation of steel, as a result of applied stress, produces progressive work-hardening which reduces ductility. It has been assumed that the development of deformation twins in the microstructure is an indication of the development of a brittle structure; but recent work has shown that the deformation twins formed in ingot iron, either by impact or tension at low temperatures, are formed before the iron loses its ductility. In another investigation it was shown that commercially pure titanium retains its ductility down to $-196°$ C unless stress-raising notches are present in the surface. The decrease in ductility was greater for shallow notches than for deep ones.

Corrosion. NBS research on the corrosion of metals in different environments is primarily concerned with the mechanism of corrosion. However, these studies are accompanied by others with more direct practical applications.

During the past 2 years, studies of the corrosion of sheet metal for aircraft were continued in both marine and inland atmospheres. Investigations of the corrosion of metals in service underground were brought to a close after continuous operation since 1922. All specimens have been removed from the test sites and have been evaluated in the laboratory.

A number of monocrystalline specimens were prepared to determine the reactions of corrosive media with exposed areas representing different crystallographic planes of the metal. Results to date, with monocrystalline aluminum, show that attack by acids is greatest on the octahedral (111) planes and least on the cubic (100) planes. Alkaline solutions were found to have the reverse effect: the attack is greatest on the cubic planes and least on the octahedral planes. Further work is in progress to correlate and explain these directional effects.

Other investigations dealt with intergranular cracking of alpha brass and low-carbon steel under the combined action of applied stress and a corrosive environment. It was demonstrated that the cracks occur in those grain boundaries that have high interfacial energies because of the crystalline orientation and contact angle of adjacent grains.

A reinvestigation of the Preece test, for the evaluation of galvanized coatings, was made for the American Society for Testing Materials. The results confirm earlier NBS conclusions that the Preece test cannot be relied upon to indicate the thickness of galvanized coatings because of the different rates of solution of zinc and the zinc-iron alloys that are present in varying proportions in different commercial galvanized coatings. A procedure for electrolytic stripping of the galvanized coatings was shown to yield more information than is obtained from conventional stripping procedures.

2.9. Mineral Products

Technological advances in many industrial fields, as well as the needs of various branches of the defense agencies have created a demand for materials useful at temperatures above the service range of unprotected metals. Ceramic materials—inorganic, nonmetallic mineral products—are finding many new applications to meet these demands. Determination of their physical and chem-

ical properties, and the basic mechanisms of their behavior in service, are of vital importance to their more efficient utilization.

During 1953 and 1954 the high-temperature reactions of refractory systems important in the development of atomic energy were investigated. Two studies of ceramics for nuclear power reactors were initiated, and special ceramic coatings which permit the use of high-temperature alloys in nuclear reactors were developed. The viscosities, densities, surface tensions, and electrical conductivities of simple glass systems were studied to increase the knowledge of glass constitution.

A fundamental study of the mechanism of ceramic coating adherence to metals has led to a consistent theory of the role of adherence-promoting oxides in the ceramic-metal bond. Low-temperature adsorption techniques were used to determine the nature of cement-hydration products. A combination of X-ray and thermal analysis has given information on the mechanism and reaction products of thermal decomposition of some bivalent carbonates.

Ceramic Single Crystals. Under the sponsorship of the Wright Air Development Center, an investigation was undertaken of the plastic deformation of ceramicoxide single crystals in order to relate their mechanical and optical properties to comparable polycrystalline oxide bodies. The work so far has been confined to single crystals of sapphire, rutile, and periclase. It has been demonstrated that single crystals of these three oxides begin to deform at about one-half of the respective melting point temperatures on the absolute scale. The slip planes for sapphire, rutile, and periclase have been determined. Data on the shear stresses required at various temperatures to cause these deformations, and information regarding the effects of deformation and "annealing" in sapphire on electrical conductivity have been obtained. This knowledge of single-crystal behavior will form the basis for further study of polycrystalline ceramics at elevated temperatures.

Improvement of Ceramic Dielectrics. Ceramics first came into prominence for use as dielectrics because of the unusually high capacitance of barium titanate. This material has a capacitance at room temperature of 1,200 to 1,500 (compared to mica with a specific capacitance of about 6), thus making miniaturization of capacitors of practical interest. However, the electrical loss of

barium titanate is quite high, and its change in capacitance with temperature is very large; thus, the characteristics of an electronic circuit using barium titanate will vary widely with temperature. During a course of investigation for the Signal Corps, the Navy Bureau of Ships, and the Office of Ordnance Research to improve the characteristics of this material, more than a hundred ceramic compositions have been developed for electronic equipment. In some Signal Corps apparatus, constancy of performance over a wide temperature range is of primary importance. $BaO \cdot 5TiO_2$ is a composition typical of several developed for such use; its capacitance is 37, its quality factor is 2,300, and its capacitance change is zero over a range from $-40°$ to $+200°$ C.

Lead-Titanate Lead-Zirconate Dielectric Ceramics. Piezoelectric ceramics serve as the active component in many devices such as phono-pick-ups, microphones, underwater sound devices, and vibration detectors. Until recently, barium titanate has been used for these purposes, but its application to high-temperature devices has been seriously limited due to its narrow operating temperature range—from 0° to 100° C. Following a study of a new ceramic compound—a lead-titanate lead-zirconate solid solution—the Bureau developed a particular compositional range which has a uniform response approximately equal to that of barium titanate but over a much wider temperature range—from $-50°$ to $+200°$ C. Potential applications for the new material include military equipment and ultrasonic generators which operate at high frequencies.

Constitution of Glass. Basic information resulting from a continuing study of the physical, chemical, and mechanical properties of simple glasses has been useful in a number of projects where glasses are being developed to meet military specifications requiring materials with unusual or closely specified properties.

A special glass system (Na_2O-TiO_2-SiO_2) was studied to determine the limits of glass formation and the optical properties. While the range of compositions that will yield color-free glasses is quite limited, glasses which are useful for optical work have been found and others may evolve when current studies are completed.

Investigations have been made on some selected properties of alkaline earth borates. The properties measured included surface tension, electrical resistivity, and density of the molten glass.

Homogeneous glasses are not formed at low concentrations of alkaline earth materials but the melt consists of two immiscible liquids. The extent of the two-liquid region is inversely related to the size of the alkaline earth ions; that is, the two-liquid region is larger in the glasses containing the small calcium ion than in those containing the larger barium ion. It was found that at low concentrations of the alkaline earth the volume of the glass was less than the volume the boric acid alone would occupy. This contraction of volume is greater in the case of the small calcium ion with higher electrical field strength than for the large barium ion. Additions of selected oxides will reduce the two-liquid region.

Projects are in progress directed toward the development of silicate glasses with special properties, such as good transmittance in the near infrared, high softening temperatures, high refractive index, good chemical stability, and flame working characteristics. In another study, it was found that the modulus of rupture for arsenic sulfide glasses could be increased from 2,100 to 6,500 pounds per square inch by quenching the material in oil.

Cermets. Materials that will withstand high temperatures are essential to the improved design of jet aircraft power units. The combination of suitable metal and ceramic components provides a high-temperature-resistant material possessing properties of both metals and ceramics. These comparatively new materials, designated "cermets," are generally quite brittle because of the ceramic phase. Cermet brittleness makes tensile strength measurements difficult. To evaluate various designs and grips used in the tensile testing of cermets, plastic models of several cermet specimens commonly in use were photoelastically investigated. As a result, three cermet specimen designs were chosen for studies. Indications are that cermet tensile strengths may range up to 30 percent greater than previously accepted values.

Hard Coating for Metal. A new coating technique was developed by which a hard, erosion-resistant cermet layer can be applied to a metal or alloy, by using standard ceramic coating procedures. The coating—a chromium boride-nickel combination—consists of a mixture of cermet powder, ceramic frit, clay, and water. The mixture is ball-milled, applied to the base, and fired at about 2,000° F. During the firing the ceramic phase in the coating serves as a flux to permit welding of the cermet particles without

the necessity of a highly purified oxygen-free atmosphere. Depending on the firing temperature, the ceramic material either sweats out to the surface or remains as occlusions in the cermet network. Coating thicknesses can be varied from 0.001 to 0.030 in. are reasonably ductile, and provide protection against oxidation in low-strategic alloys and molybdenum during extended periods at temperatures up to 1,800° F. The coating also provides a hard facing for the metal or alloy surface.

Ceramic-to-Metal Bonding. Investigations recently completed have yielded additional information on the ceramic-to-metal bond mechanism. This work, sponsored by the NACA, has shown the importance of roughness or anchor points at the surface of the metal in controlling the adhesiveness of the coating. It was found that the nickel-dip process roughens the steel surface of the basis metal during the subsequent firing of the coating. Using radioactive nickel as a tracer, it was shown that the nickel selectively plates the steel surface during the nickel-dip process. When the specimen is at firing temperature, the coating acts as an electrolyte; the nickel-plated areas are protected cathodically while the areas of exposed steel are attacked galvanically. The result is a pitted surface which contains numerous undercuts or anchor points where the enamel can readily anchor itself.

Ceramic Coatings for Nuclear Reactors. To meet the increasing need for high-temperature protection of alloys in nuclear reactors, a ceramic coating material was developed which has an extremely low thermal neutron absorption coefficient. Most promising of the materials investigated were boron-free coatings of the frit-refractory type in which a high-barium frit is combined with ceria-chromic oxides. Tests indicate that these coatings (with neutron absorption coefficients in the range of 0.15 to 0.50 barn) satisfactorily withstand temperatures in excess of the 1,000° C found in nuclear reactors. Metallographic examinations of tested metal specimens, coated and uncoated, show that the presence of the coating in some cases reduces the amount of oxidation of the metal by 50 to 75 percent.

Durability of Concreting Materials. The durability of concrete under exposure to freezing and thawing, wetting and drying, and salt action is of major concern to the construction industry. Durability is closely related to cement pore size and distribution, and

may be studied with the aid of gas adsorption techniques. These techniques are also useful to evaluate the physical differences in cement structures which result from different chemical compositions. Nitrogen adsorption tests have indicated that the surface area of the micropores within the material may range from less than 1 square meter per gram to more than 50 square meters per gram, depending on the degree of hydration.

Similar techniques in the studies of aggregates have indicated that the internal surface as determined by nitrogen adsorpton may range from 0.02 square meter per gram for such materials as granites to more than 5 square meters per gram for unsound aggregates such as cherts. Opal, an amorphous silica which has a deleterious effect when used in concretes with cements of high alkali content, has an internal surface of from 50 to 100 square meters per gram when determined by water vapor adsorption but a negligible surface as determined by nitrogen.

A versatile freezing and thawing apparatus was constructed and placed in operation to determine the effects of the many variables upon the rate and type of disintegration produced in concrete specimens. It is now being used to compare the results being obtained by the four current ASTM types of freezing and thawing cycles as applied to various types of concrete; the apparatus can test concrete by all four methods simultaneously.

Fundamental studies have been carried out to determine the mechanism of the reaction between certain aggregates and the alkalies in cement. This reaction is known to cause deterioration and disintegration of concrete structures.

Nature and Structure of Portland Cement. A program of basic research, conducted in cooperation with the Portland Cement Association, is now concerned with systems containing soda, potash, lime, alumina, ferric oxide, and silica. The purpose is to learn the effects of every variable in composition and heat treatment as reflected in the behavior of the concrete. These studies are expected to give not only a new understanding of the behavior of cement in concrete but new principles of control in manufacture and utilization of cement.

Two useful tools have recently been developed in connection with cement research. One is a high-temperature centrifuge that separates the liquid and solid phases of a small (3 g) charge in a furnace

at temperatures up to 1,600° C. By this means the boundary curves and invariant points in a polycomponent system may be followed with a great saving in time over conventional methods. Another tool is a hot-wire apparatus used for growing single crystals under direct observation and control of the operator. Although designed for use in X-ray structure analysis, many other applications have been found, including the determination of melting points of materials and preliminary exploration of mineral systems.

Electron-microscope techniques have been employed in conjunction with electron diffraction, X-ray diffraction, and other methods to discover the nature of cement hydration compounds. These studies indicate that particles ranging from 50 to 200 angstroms in diameter may result from the hydration of calcium silicate and constitute experimental verification of theoretical deductions based on adsorption data. Similarly, spherical particles of slightly smaller diameter were observed in fully hydrated portland cement paste. Low-angle X-ray scattering data further confirm the existence of such discrete particles.

Hydrothermal Reactions. Many chemical reactions that take place slowly or not at all at ordinary temperatures progress rapidly under hydrothermal conditions—in the presence of steam under pressure at temperatures above the boiling point of water. Using this technique in a study of hydrated strontium silicates, seven compounds not hitherto described were discovered. A study of the lime-water-alumina system at room temperature has now been extended with this technique to include several isotherms up to 2,500° C. This is of considerable interest because of the increasing use of steam curing in the concrete industry. The stability ranges of calcium aluminate hexahydrate, hydrated alumina and calcium hydroxide were defined in this study. A similar study of the lime-silica-water system, at 180°, is nearing completion.

Standard X-Ray Diffraction Patterns. The work on production of accurate X-ray powder patterns of inorganic solids has been continued. This is part of the work of increasing and improving the ASTM file, which is used extensively for identification of solid phases by industrial and research groups. At present, 180 patterns of high precision have been produced. Of these, 22 are of compounds not previously represented in the file.

Thermal Expansion by X-Ray Diffraction. There is a growing need for accurate thermal-expansion data on compounds which are to be intimately mixed with other compounds and subjected to heat treatment. One example is cermets. To obtain such information by conventional means on nonisotropic bodies requires a single crystal of known orientation. To eliminate the difficulty of obtaining such a crystal, a study of thermal expansion by high-temperature X-ray diffraction has been inaugurated. Through this method, accurate thermal expansions in the various crystallographic directions can be measured accurately on a small powder sample of a compound. The changes in angles of diffraction from known crystallographic directions are determined by Geiger counter from a sample at temperatures up to 1,400° C in a helium atmosphere.

Automatic Recording Balance. In recent years there has been a great increase in the use of differential thermal analysis for the identification of mineral products and for studies of thermal changes. As a tool to augment and check the information so obtained and to make it possible to interpret better the results of such tests, a recording weight loss apparatus has been developed. With this equipment the change in weight of a sample due to hydration, oxidation, reduction, etc., can be recorded simultaneously with the differential thermal analysis curve. This equipment, based on an electronically activated balance, has been used in the study of the breakdown with heat of the bivalent carbonates, with particular attention to mixed carbonates in solid solutions. The automatic recording balance should find application in studies of the rate of drying, oxidation, decomposition, etc., in many industrial applications. Considerable interest has been shown in this development by scientific and industrial laboratories.

2.10. Building Technology

Over the past several years the Building Technology Division has conducted a critical examination of old building practices and a search for new practices based on sound engineering principles. The major aim is to increase economy of construction and maintenance. Before full advantage can be taken of the kind of engineering approach that has guided the rapid technological development of other industries, the building profession must be supplied with

adequate standards of measurement, new testing procedures, fundamental engineering data, and performance standards. No industrial organization has the facilities or incentive to obtain the needed fundamental engineering data. The building profession, therefore, depends on the National Bureau of Standards for basic research in the fields of building materials, structures, and equipment (excluding forest products which are studied by the Department of Agriculture Forest Products Laboratory).

The Bureau's fields of interest include structural engineering, building codes, safety engineering, fire protection, heating and air conditioning, as well as flooring, roofing, and wall finishing materials. Typical studies completed during 1953 and 1954, or presently under way, concern durability of masonry materials, determination of concrete impact resistance, structural and fire resistance properties of prestressed thin-shell concrete structures, fire endurance tests on building structures, effects of edge insulation upon temperature and condensation on concrete slab floors, flooring material in Army structures and asphaltic materials, floor surfaces, and bituminous roofing. The Bureau continued to render assistance to Federal, State, and municipal bodies on the development of adequate building codes and safety standards.

Resistance of Concrete to Impact. Designers concerned with safety of structures subjected to impulsive loads need information on the dynamic properties of concrete. At the request of the Navy Bureau of Yards and Docks, the Bureau conducted a study of the resistance of concretes to compressive forces applied at high loading rates ranging from 10^{-6} to about 10 inches per inch per second. The highest straining rate obtained by using a drop-hammer machine, was about 10^{6} times as great as that attained normally in "static" tests performed on conventional testing machines. The properties determined included the compressive strength and the modulus of elasticity of the concrete.

Two types of concrete were investigated: a "weak" concrete of 2,500 pounds per square inch nominal static compressive strength and a "strong" concrete of 6,500 pounds per square inch. For both types of concrete, the dynamic compressive strength was found to be higher than the static strength, and became relatively greater as the rate of loading increased. Modulus of elasticity in both types of concrete was also affected, but to a lesser extent.

Lightweight Concrete. Lower dead-weight and better heat insulation may be obtained in many types of structures by using concrete with such light-weight aggregates as expanded shale, slate, clay, and slag. The lower densities achieved with these materials are usually accompanied by some sacrifice of strength and increases of shrinkage and water absorption. Bureau studies of light-weight aggregates have shown that when the usual fine aggregate is partially or entirely replaced by small uniformly distributed spherical air cells, there is a further but tolerable decrease in strength even though other improvements are obtained.

Compressive strength of 500 to 1,000 pounds per square inch, sufficient for walls of one or two story structures, were achieved with air-entrained concretes having dry densities of 45 to 70 lbs per cubic ft, depending on the type of aggregate and the amount of entrained air. Using 20 to 30 percent of entrained air, an increase in freezing and thawing resistance resulted, as well as decreased water capillarity and absorption, and lower thermal conductivity.

Self-Ignition of Materials. A significant portion of the fires which occur in the United States each year are attributable to spontaneous ignition of certain combustible materials. During a study of the self-heating properties of such materials a special (adiabatic) furnace was devised which tends to keep the exterior of a test specimen at the same temperature as the interior and simultaneously measures and records the increase of temperature within the sample up to the ignition point. With this apparatus, exploratory tests have been performed on a number of fibrous and liquid materials, and a study is under way to determine the relationship of thermal constants to the self-ignition hazard of various materials. Recently the apparatus was used as a means to determine the cause of a fire which occurred spontaneously in a Government structure.

Thermal Insulating Value of Air Spaces. In recent years there has been an increased interest in the utilization of aluminum foil and other reflective surfaces to form thermally insulating air spaces in buildings. Extensive measurements by the Bureau on the quantitative effects of surface emissivity, orientation, thickness, and temperature conditions of such air spaces have provided useful information for Government agencies, engineers, and architects. Sponsored by the Housing and Home Finance Agency this program has provided basic data and methods of calculation by which the

insulating values of air spaces can be computed for almost all of the conditions encountered in ordinary buildings.

Hydraulics and Pneumatics of Plumbing Systems. The last of a series of laboratory investigations started in 1946 for the National Housing Agency (later succeeded by the Housing and Home Finance Agency) on optimum pipe dimensions and arrangements, capacities of plumbing drainage and venting systems was completed and the principal results were published. Significant use was made of these results by the coordinating committee for a National Plumbing Code and the New York State Building Code Commission in the development of model plumbing codes.

A preliminary investigation of the hydraulics and pneumatics of drainage and vent piping systems required in connection with food-waste disposers was conducted for the National Electrical Manufacturers Association.

Water Vapor and Heat Flow Through Insulated Panels. Moisture accumulation in the insulated walls, roofs, and floors of refrigerated structures impairs their insulating effectiveness, leads to serious difficulty in maintaining low temperatures internally, and causes rapid deterioration of the structure. To assist the Army Quartermaster Corps in the evaluation and improvement of present refrigerated structure designs, the Bureau undertook a study of moisture accumulation in panels subject to typical heat flow under severe moisture conditions. An apparatus was constructed to expose a 4- by 8-ft test panel to certain temperature-moisture conditions, and simultaneously determine the heat and moisture flow as well as moisture accumulation in the test panel. The entire apparatus can be rotated to permit tests of the panel in positions simulating its use as a wall, floor, or roof.

Edge Insulation of Concrete-Slab Floors. In recent years there has been a great increase in the number of basementless houses constructed. The floor most generally used in this type of house is the concrete slab, sometimes placed on the ground but more often on a fill of gravel or similar material. Because concrete is a good conductor of heat as compared to wood flooring, a concrete floor will be relatively cool in the region near the outside walls in cold weather, often making it uncomfortable for those who occupy that part of the room. Various methods for overcoming this difficulty have been considered by the building industry, but one which

has attained considerable usage is the insulation of the slab edges exposed to the outside temperature. A systematic study conducted by the Bureau under the sponsorship of the Housing and Home Finance Agency has shown that edge insulation does in fact reduce cooling at the exposed edges of the floor slab, and has provided quantitative data on the relative merits of different methods of edge insulation.

Ventilation Measurements. Computation of heat loss of a building usually includes an item for the heat carried out of the building because of cold air infiltration. Although these computations are only approximations, they are widely used because accurate air leakage measurements for different structures have not been available. The Bureau therefore studied a number of methods for measuring infiltration and the ventilation of attics and crawl spaces in an experimental house. Several tracer gas methods, such as helium gas with a katharometer, ethane gas with an interferometer, and methane gas with an infrared gas analyzer, were evaluated and found to be more accurate and better suited to field use than calorimetric methods or direct air-flow measurements. The heated thermocouple anemometer was found to be the best instrument for measuring the very low air velocities in ducts and rooms. Such an anemometer and a portable helium katharometer were designed and built at the Bureau, and calibration tests were made to evaluate their performance.

Asphalt Roofing. Since 1926 the Asphalt Roofing Industry Bureau has maintained a Research Associate at the Bureau to study industry-wide technical problems of asphalt roofing. Many of the current materials and techniques used in the roofing industry are direct results of these investigations. Presently under study is the mechanism of weathering and ways of modifying asphalt to increase its durability. Because of the inert nature of many asphalt constituents, new methods of analysis have been devised to follow the process of weathering. Two asphalts, differing widely in durability, were exposed outdoors as well as in an accelerated durability machine. Study of changes in composition, molecular weight, unsaturation, infrared absorption, carbon-hydrogen ratio, oxygen, sulphur, and nitrogen revealed trends and differences in the behavior of the two asphalts.

2.11. Applied Mathematics

The National Bureau of Standards mathematics laboratories were established in recognition of the need for a central, mathematical consulting and research facility equipped with high-speed automatic machinery, capable of providing analytical and computing services for the technical staff of the Bureau and for other Government agencies. In this area the Bureau engages in basic mathematical research directed principally toward better utilization of the new electronic computing machinery and progress in mathematical statistics and mathematical physics; and in addition acts as a service organization, particularly in the fields of computation engineering statistics and quality control.

Numerical Analysis. Experiments on matrix problems of various sorts were conducted on the National Bureau of Standards Western Automatic Computer, SWAC. Problems of stability and control of round-off error by special programing devices were undertaken. Some interesting inequalities were obtained between the eigenvalues of certain special matrices and those of the corresponding linear operators. Research was carried out on differential equations of a special type having to do with numerical methods and questions of stability and asymptotic series solution.

Other studies were conducted on exhaustive methods of search and methods of embedding discrete variables in continuous spaces; eigenvalue problems in classical mechanics and scattering in quantum mechanics; Monte Carlo problems; sampling problems; and problems in logic relating to design, programing, and coding automatic digital computers, and locating malfunctions in such equipment. In addition program planning studies were conducted. Special attention was given to the so-called assignment problem and to various problems in communication.

Computation. Considerable progress in the theory and applications of linear programing has been made. New methods of handling the so-called "transportation" problem, and the problem of awarding purchase contracts to bidders at minimum total cost, have been devised and tested. Answers obtained on SEAC (the National Bureau of Standards Eastern Automatic Computer) were used directly in the award of contracts to bidders for over 30 cases submitted by the New York Quartermaster Purchasing Agency.

A collection of integrals of the higher transcendental functions

was compiled. Progress was made on computations arising in studies of atomic radiation; more specifically, the calculation of conversion coefficients for the atomic K and L shells. Significant results concerned with the relation between the characteristic values of integral equations and those of corresponding algebraic systems were obtained. Theoretical and practical studies were carried out in connection with certain nonlinear differential equations; in particular, the equation of Painleve was investigated.

A problem originating in studies of the reaction of nerve fibers to electrical stimuli, carried on at the National Naval Medical Center, involved the solution of a system of four nonlinear ordinary differential equations containing a parameter that describes the input current to the nerve. The output potential generated by the nerve exhibited two distinct behavior patterns depending on the parameter. The transition value of the parameter defining the two modes of behavior were obtained to an accuracy of one-thousandth of a milliampere. This work was done on SEAC, and the results were found to check very closely with experiments involving more than a million nerve fiber reactions. The numerical results as obtained on SEAC provided information concerning the transition value which could not be determined accurately by experiments.

Statistical Engineering. Activities in statistical engineering were directed toward providing assistance to physical scientists of NBS and other Government agencies. In addition, the Bureau prepared manuals and bibliographies on selected phases of statistical methodology, and conducted basic research in mathematical statistics and the theory of probability.

The major portion of the research activity continues to be concerned with design arrangements for physical science experimentation. During this period, NBS mathematicians developed an important new class of designs involving a partial replication of a Latin square arrangement to meet the needs of experimentalists who wish to ascertain the existence of interactions without a complete repetition of the original design. Other examples include the discovery of new designs with two plots per block derivable from the incidence matrix of a balanced or partially balanced incomplete block design, and the discovery of a new class of designs involving only two replications. These designs are especially useful in

physical science experimentation where large numbers of replications are either too expensive or yield more than the necessary degree of precision.

Results relating to necessary conditions for the existence of partially balanced incomplete block designs with two associate classes were worked out. These results are useful in delimiting the area within which new arrangements can be found.

Extreme-value theory is intimately connected with the concept of safety factors. In building codes it is the maximum wind that is of concern. In tensile strength testing it is the weakest point of the cross section that often determines strength. The Bureau carried on research in methods of estimation of parameters of the extreme-value distribution and found new estimators with improved properties over those previously known, resulting in more efficient methods of analysis of extreme value data.

2.12. Electronics

In electronics the Bureau carries out a broad and diversified program including both research and development. Research is directed toward certain basic phenomena and properties of materials of potential significance to electronics. Development covers not only the field of electronic circuitry for the performance of new functions by electronics but also the broader phases of fabrication technology by which optimum designs for electronic equipment may be achieved. Emphasis has also been placed on improving operational reliability of electronic equipment by development of new components and application of new materials and assembly techniques. This work is of particular importance to the military in adapting electronic devices to climatic and operational extremes. Much of the work is sponsored by the Department of Defense as well as by other Government agencies.

During 1953 and 1954 the work in electronics consisted essentially of an expansion and intensification of the various phases of the program already under way, including new components and new techniques; the publication of detailed information on subminiaturization techniques for low-frequency receivers; a program of electronic circuit standardization; investigation of the properties and mechanisms of cathodes in electron tubes; continuation and

expansion of a tube information service; and studies of resistor wire.

A large amount of attention was directed toward application engineering and instrumentation, and to introducing new equipment. Examples of such work include an instrumentation system for improved meteorological sounds, an error voltage detector for servomechanisms, a liquid level indicator for cryogenic production facilities, a miniature electrostatic high-voltage generator for use with radioactivity detectors, a coin weighing machine useful in the manufacture of United States coins, and a physiological monitor which automatically detects changes in the condition of a patient under anesthesia throughout the course of an operation.

One NBS project which attracted considerable industrial interest has established the feasibility of mechanized production techniques for electronic equipment. Formerly code-named PROJECT TINKERTOY, this development was announced to the public in the fall of 1953.

Mechanized Production of Electronics. A totally new mechanized production system and a novel electronic design which makes this possible were developed by the Bureau under the sponsorship of the Navy Bureau of Aeronautics as an industrial preparedness measure. The objective of the program was to establish facilities or systems suitable for rapid mobilization in emergency periods. These facilities have a dual purpose, being rapidly convertible from military to civilian products (and back again) on short notice, and are expected to reduce substantially the lead time in production.

The key to automatic, mechanized production of electronic equipment is the MDE—for Modular Design of Electronics. The system establishes a series of mechanically standardized and uniform modules that have a wide range of electrical characteristics. Each module, in general, consists of some 4 to 6 thin ceramic wafers, bearing various circuits associated with an electronic stage. Combinations of modules into major subassemblies of electronic equipment is possible because there is great similarity between circuits and parts of circuits in modern electronic equipment.

The production of modules and assemblies, designed in accordance with the MDE system, is achieved mechanically. The production system, called MPE—Mechanized Production of Electronics,

utilizes noncritical raw materials. Ceramic wafers and capacitors are produced directly in quantity from the raw materials, while another part of the line produces adhesive tape resistors. These and other basic parts are fed into the production line. The appropriate circuits are printed by automatic machines. Quality control is established by automatic inspection, directed by information prepared in punched card form. Special components, not suitable for "printing" techniques, can be incorporated into the modules. Automatic physical and electronic inspection is provided for in the production line.

Industry has shown considerable interest in applying the NBS-Navy modular and mechanized production techniques to civilian products. An independent study recently completed by a private management consulting firm concluded that the development could reduce the manufacturing cost of certain electronic equipment as much as 44 percent. At present, the MDE-MPE pilot plant, operated by an industrial organization, is turning out an important item of Naval electronic equipment whose design and performance are equal to or superior to its conventional counterpart.

Circuit Standardization. The possibility of electronic circuit standardization for aeronautical equipment has been studied for the Navy Bureau of Aeronautics. A degree of standardization would not only simplify the mobilization of the electronics industry in times of national emergency and contribute to advances made in the machine production of electronic assemblies, but also would minimize variations in electronic circuit designs to reduce design costs, provide simplified, reliable circuits, reduce parts procurement and engineering maintenance costs, decrease maintenance training, and decrease stocking problems. Thus far, the Bureau has developed 22 "preferred" circuits now undergoing acceptance studies by industrial and technical groups.

Vibration Generator. Electronic equipment is being called upon increasingly for applications where it is subjected to severe shock and vibration, requiring the development of special rugged components. Because electron tubes are especially troublesome under severe vibration, an improved wide-range vibration generator was developed at NBS to study tube microphonics. The instrument produces accelerations up to 20 times that of gravity over the wide

range of 100 to 10,000 cycles per second. The tube under study is fitted into a hole in the vibrator's moving element, or armature, which is driven by an audiofrequency voltage. Although this model was built to accommodate subminiature tubes, the design can easily be modified for microphonic studies of miniature or octal tubes.

Improved Meteorological Soundings. Atmospheric temperature and humidity gradients—the rates at which air temperature and moisture change with altitude—can be measured with increased accuracy, at heights up to 20,000 feet, by means of a low-level sounding system developed for the Navy Bureau of Ships. Airborne instruments consisting of an electromechanical altimeter, a hygrometer, and a thermoelectric measuring device are carried aloft by a balloon or kite connected to a ground station by a light-weight 3-conductor electrical cable. The information provided by this "wiresonde" is useful in making measurements of the propagation of radio waves in the lower atmosphere.

Error Voltage Detector. Some of the most important and rapid technological advances of the past decade have been in the automatic control of machines and processes. Many significant applications are based on servo feedback systems. A crucial element of any servo system is the method or device used for sensing an error signal, which usually means detecting the difference between two voltages. The Bureau's detector provides an answer to the need for precise error-voltage sampling in many servo-control applications. This broad-band, low-level device utilizes crystal diodes in a bridge circuit, operates on the rf chopper principle, and shows a resolution to 1 millivolt with a bandwidth of at least 1 megacycle. The flexibility, accuracy, and reliability the detector provides should make it suitable for many applications in nucleonics and other processing plant operations where precise operating controls are needed.

Liquid Level Indicator. A low-temperature instrument that measures, indicates, records and controls the level of liquefied gases such as hydrogen or nitrogen has been developed for the liquefaction installation at the NBS–AEC Cryogenic Laboratory at Boulder, Colorado. This electronic instrument operates on the capacitance principle and makes use of the difference in dielectric constants of the liquid and vapor states. The sensing element

is a vertical cylindrical capacitor whose capacitance is a function of the height of the liquid refrigerant column. The instrument is designed to be used interchangeably with hydrogen, nitrogen, oxygen, or helium by changing the sensitivity and range controls on the associated electronic circuitry. It also incorporates a control system that maintains the liquid level at a predetermined point.

FOSDIC. An instrument that provides rapid, automatic processing of information into a form suitable for input to large-scale electronic computers has been developed for the Bureau of the Census. Named FOSDIC (Film Optical Sensing Device for Input to Computers), the machine reads marks on microfilmed copies of documents that have been marked with an ordinary pencil or pen, and then processes the information into electrical pulses which are recorded on magnetic tape for direct input to an electronic computer such as UNIVAC. FOSDIC is designed to reduce the work that is now involved in converting written records into a medium acceptable to input by data-processing machines, allows considerable freedom in design of the documents, and does not require the use of any special writing instrument. It is anticipated that ultimately the use of this machine will reduce appreciably the massive amount of paper work entailed in summarizing Census information on the entire population. Although designed for Census operations, FOSDIC may be generally applied to the processing of other types of information that must be handled in large quantities.

A High-Speed Coin-Weighing Machine. A fully automatic machine for weighing coins rapidly has been developed for the Department of the Treasury. The NBS machine will weigh and sort 18,000 coins per hour with an accuracy of ¼ of 1 percent in the weighing of 25-cent pieces and with even greater accuracy for the half- and one-dollar coins. This system has the advantages of high sensitivity, low susceptibility to seismic noise, and independence of other physical properties of the coin except diameter, which, however, is held to extremely close tolerances in manufacture. The machine is much faster than the automatically fed analytical beam balance now in use at the Mint.

The machine weighs coins by measuring the degree of unbalance imparted to a rapidly moving flywheel into which two coins, the

standard and the one to be weighed, have been placed. If the flywheel is precisely balanced initially, the difference in weight between the two coins will displace the center of gravity slightly from the geometric center of the wheel. Detection of this displacement provides the basis for measuring the weight of the coin.

Electro-Optical Image Processing System. An experimental optico-electronic system was constructed that will facilitate the study of visual perception and recognition of patterns. The system also promises to have a number of useful engineering applications. The device can clarify blurred images or produce outline pictures and line drawings from halftone photographs. Developed under the NBS basic instrumentation program, the system operates on patterns in the form of photographic transparencies placed in an optical assembly between a cathode-ray tube with a moving spot and a photomultiplier tube. The signals resulting from scanning the picture are amplified and fed back to the intensity control of the cathode-ray tube, and thus, produce a picture on its screen.

The negative feedback obtained in this way improves the tonal rendition of the picture. The same signals are also supplied to another amplifier and the resulting signal is used to control a monitor cathode-ray tube which reproduces the same picture. Altering the monitor for the image processing is accomplished by introducing modifying circuits between the phototube and the monitor. This freedom to modify the picture on the monitor is the essence of the system.

Physiological Monitor. Working under the sponsorship of the Veterans' Administration, NBS developed an electronic instrument which automatically detects changes in the physiological condition of a patient under anaesthesia throughout the course of an operation. Known as the NBS Physiological Monitor, the instrument measures changes in the patient's blood pressure, heart beat, and respiration as they occur and presents the data on a panel for interpretation by the surgeon or anaesthesiologist. A permanent record of the patient's condition during the operation is also provided by a recording device incorporated in the assembly.

Because the Physiological Monitor provides a continuous indication of the patient's physiological condition during surgery, it should help greatly in the prevention or control of emergencies confronting the surgeon at the operating table or during certain

critical postoperative periods. The instrument is also expected to aid in those phases of medical research—such as studies of the effect of drugs on blood pressure—that require a knowledge of the behavior of physiological variables over long periods.

High-Resolution Micromanometer. A highly sensitive micromanometer, designed to measure differential pressures as low as 0.03 micron of mercury with resolutions of the order of 0.001 micron of Hg, was developed by the Bureau's Office of Basic Instrumentation. The NBS micromanometer utilizes a thin diaphragm combined with a capacitance-type pickup and a resonant-bridge carrier system to detect pressure differentials 100 to 1,000 times smaller than previous systems. Although designed to measure differential pressures, the NBS micromanometer can be modified to measure absolute pressures below 1 micron in apparatus where the presence of mercury, oil, or other liquid is undesirable. This may be accomplished either by maintaining a high vacuum on one side of the diaphragm or by sealing one side at a high-vacuum level. The micromanometer should then be particularly useful for calibrating ionization gages. The characteristics of the instrument are such that it could possibly be used also as a secondary standard of low pressure in the range between 0.001 and 1 micron of Hg.

Wide-Range Barium-Titanate Accelerometer. A barium-titanate accelerometer with exceptionally wide frequency and acceleration ranges has been designed and constructed by the Office of Basic Instrumentation. Known as the NBS–33–14 Accelerometer, the device combines small size and low mass, uniformity of response, good shielding, very low cable noise, small transverse response, and other desirable characteristics. In connection with performance tests on this accelerometer, several experimental techniques have been developed or improved for obtaining accurate calibrations at high levels of acceleration.

As a result of the widespread availability of barium titanate, a great many types of piezoelectric accelerometers using crystals of this material have been built over the past few years in industrial and Government laboratories. In an effort to improve the characteristics of these devices, the Bureau is conducting a number of investigations of barium-titanate accelerometers as part of a program of basic instrumentation. Designed to meet

the exacting requirements of a specialized military application, the NBS–33–14 Accelerometer has a range of ±50,000 *g* and a natural frequency of 90,000 cycles per second.

2.13. Automatic Electronic Computers: Information Processing

During 1953 and 1954, the Bureau continued its work in research, development, applications analysis, and technical consultation on electronic digital techniques in mathematical and scientific computations, massive paperwork operations, and control systems. A new high-speed computer, the DYSEAC, designed to serve as the experimental nucleus for a complex data-processing network, was completed and delivered to its sponsor, the Department of Defense. Successful test of the DYSEAC on a radar tracking program that required interaction of the computer with special input, output, and external control equipment demonstrated the versatility of the DYSEAC system in real-time problems. Another experiment involved the interconnection of SEAC and DYSEAC so that the two machines worked cooperatively on a common task. These developments are indicative of the rapidly expanding opportunities for high-speed digital techniques in new areas such as air traffic control, information processing for large-scale paperwork operations of the Government, and automatic equipment control.

An exploratory program to determine the applicability of electronic techniques to problems of supply management was carried out with the cooperation of the Navy Bureau of Supplies and Accounts. The study involved problem definition and machine coding of a major supply replenishment procedure, the development of a new and much faster method of sorting and simultaneously merging new data with master files, and promising developments in the design and prototype construction of an automatic type-character reader.

Studies in applications of digital techniques to control systems, especially military applications, resulted in comprehensive reports on various weapons—systems planning problems and the development of special display and control equipment which has been successfully operated with the DYSEAC. This work now includes studies of the development of tactical training systems.

Developments in improved high-speed memory systems have also pointed the way for significant advances in the capacity and flexibility of electronic data-processing systems. In particular, high-speed memory development included a new experimental Williams-type unit as well as improved matrix memories. A diode-capacitor memory has been successfully tested in conjunction with SEAC.

SEAC. The experimental modification, operation, and maintenance of the SEAC continued during 1953 and 1954. The computer performed regularly scheduled productive operation on a variety of problems with an over-all operating efficiency of 80 percent. The SEAC was also used for experimental engineering evaluation of input-output, auxiliary storage and other equipment and components. Examples of such uses were the testing of the diode-capacitor memory and cavity wire drive device, and the experimental interconnection of SEAC and DYSEAC. Engineering modifications of SEAC included improvement of the Williams memory so that it is available for regular productive use, construction and testing of a new high-speed outscriber, and the trial use of a multichannel modified tape unit for productive runs.

DYSEAC. The systems design, construction, and program checking of the DYSEAC was a major project of the electronic computers laboratory during 1953 and 1954. The new computer uses dynamic circuit techniques similar to those used in SEAC, but its operating capabilities are considerably extended by special logical design features. Developments in component packaging techniques and standardization of circuitry so that only two types of etched-circuit plug-in packages are used enabled modular construction of the machine which is installed in a trailer van. An additional van provides space for supporting power supply and personnel.

The special design features enable DYSEAC to communicate in an extremely flexible manner with a wide variety of external control devices and to serve as a major element in a generalized feedback control loop. Special manual-monitor facilities, flexible program-control features, and versatile input-output selection and control provide DYSEAC with the properties of concurrent operation, self-regulation, and interruptability. The machine can therefore respond effectively to new information and control sig-

nals originated either by the human operators or by remote external devices on an unscheduled basis.

Diode-Capacitor Memory. Continued research on rapid-access memories for electronic computers has resulted in the development of an information storage device utilizing diodes and capacitors as basic storage units. This recently completed unit appears to be faster than any other system and more than matches the speed of the arithmetic unit now used in SEAC. Because of its simplicity, it should be more reliable than other memories now in use. The most difficult part of the basic problem of high-speed access was overcome by the development of a selector matrix using diodes and transformers. SEAC was used to determine the unit's reliability; on five occasions it ran continuously for 3-day periods and on another occasion for 1 week without error.

Input-Output Equipment. With the development of many large-scale electronic computers in recent years has come an increasing need for equipment to bridge the gap between the machines and their sources of information. The Bureau has therefore been actively engaged in the development of high-speed input-output equipment. External magnetic tape and wire units have been devised as aids to the computer on problems which require auxiliary memory capacity or considerable input-output operations. One such device can store 12,000 words on a 1,200-foot magnetic tape. Other developments in this field include promising work on high-density tape-recording—up to 400 or more bits per inch—as well as a new prototype tape cartridge. Initial work on new devices is exemplified by the design and construction of a novel automatic tape tester, and the completion of a model notched-disk memory for random-access data storage.

SWAC. During 1953 and 1954 SWAC, the National Bureau of Standards Western Automatic Computer, operated at 93 percent efficiency on a 80- to 120-hour a week basis, solving a wide range of problems in physics, engineering, mathematics, statistics, and meteorology. The scope and complexity of the problems which SWAC can solve were greatly extended through the installation and successful operation of a magnetic drum auxiliary memory. This new memory is a revolving metal drum that retains numbers and instructions on its surface in the form of magnetic pulses like those used in tape recording. It was used in conjunction with the

already existing cathode-ray-tube memory to enlarge the over-all memory capacity of the machine, providing a storehouse for a library of numerical methods of routines of instructions which, when obeyed by the machine, can facilitate the solution of a large class of problems. The new magnetic memory can store 4,096 "words" of 37 binary digits each, in contrast with the 256 words of the cathode-ray-tube memory. This high-capacity memory makes possible the solution of very large sets of simultaneous equations such as arise in logistics; certain types of partial differental equations which occur frequently in aeronautical research, in heat transfer problems, in electromagnetic theory, and in other fields; and combinatorial problems, applications of which have recently engaged the attention of scientists.

2.14. Radio Propagation

The Central Radio Propagation Laboratory is responsible for the collection and coordination of radio propagation data, and for the custody and development of the national primary standards for electrical quantities at radio frequencies. Research programs are undertaken in the fields of radio physics, geophysics associated with radio propagation, properties of matter at radio and microwave frequencies, precise measurement techniques for electrical quantities at radiofrequencies, and primary radiofrequency standards. The Laboratory operates eight ionospheric sounding stations, participates in the operation of seven additional stations, and assembles, analyzes, and distributes data received from approximately 75 other ionospheric stations. Advisory and consulting services are provided other agencies of the government such as the Department of Defense, Federal Communications Commission, Civil Aeronautics Administration, and State Department.

Because the ionosphere makes possible the long distance propagation of radio waves, major emphasis is placed on a study of this medium. Theoretical and experimental studies are aimed at obtaining a better understanding of the formation of the ionosphere, causes and characteristics of ionospheric disturbances, and the interaction between the ionosphere and radio waves. Radio sounding data serve as research data as well as for the regular preparation of predictions. The sounding stations themselves are important links for research in which geographic location is

important. In addition, permanent, temporary, and mobile field stations assist in special experiments.

High-frequency propagation through the troposphere is being studied because of its importance to the Defense Department, commercial airlines, and TV and FM broadcasters. Such factors as terrain, climate, and meteorology affect propagation and studies are carried out to determine this influence. Because of the close relation between propagation phenomena and some aspects of radio systems, communication reliability has been studied as a function of antenna patterns versus radiowave angle-of-arrival, various schemes of diversity reception, modulation methods, and radio noise.

Ionospheric soundings and solar data assembled from the world-wide network of ionospheric sounding stations and solar observatories make possible Bureau predictions of optimum frequencies for long-distance communication throughout the world. These predictions are published each month for a period covering 3 months in advance of the date of publication. Long-range predictions are supplemented by short term ionospheric disturbance notices communicated over the Bureau's radio stations, which also broadcast time and frequency standards.

A long-range program designed to extend the range of standard frequencies, include additional types of measurements, and increase the magnitude range of radio measurements is now under way. Atomic clocks, made possible by techniques of microwave spectroscopy, are being developed as part of this program. The NBS radio propagation program will be greatly aided by the new specially designed radio laboratory at Boulder, Colorado. This building provides integrated facilities for researches that have heretofore been widely scattered.

Ionospheric Disturbances. A better understanding of ionospheric disturbances would provide a better insight into the formation and characteristics of the ionosphere. A new technique for studying such disturbances over the North American continent has been applied using maps which are similar in appearance to meteorological pressure or temperature maps. The study showed clearly for the first time the existence of disturbance centers that move several thousand kilometers at speeds up to 300 kilometers per hour.

Data for 3 years of operation at 2.3 megacycles per second have now been gathered and analyzed, and regular diurnal variations in the direction and amplitude of these winds have been observed. Simplified automatic phase shift correlation equipment has been constructed and is in operation. This equipment operates automatically and gathers extensive data efficiently.

Arctic Radio Propagation. The Aurora, which occurs most often in a narrow circular band surrounding the magnetic North Pole, causes frequent interruption in long-distance high-frequency radio communication. A north-south chain of field strength recording stations has been operated to provide data on this region. Analysis of the results shows that the antenna pattern is of great importance in determining the effective mode of propagation. Of particular significance is the discovery that north of the maximum-auroral-frequency zone signal propagation takes place with high reliability. Signals were received over one path 98 percent of the total time of operation.

Oblique Incidence Studies. Because much higher frequencies will be reflected from the ionosphere at oblique incidence than at normal incidence, current theory relates the maximum usable frequency at oblique incidence to that at normal incidence. Characteristics of the oblique reflection are therefore customarily inferred from normal incidence measurements. However, an analysis of communication operations records has indicated that communication (and therefore reflection) seems to be taking place at frequencies several percent higher than current theory would indicate. A series of tests are being carried out not only to study this effect but to investigate ionospheric reciprocity and determine the origin of backscatter echoes. Results of measurements made over 1,150- and 2,370-kilometer paths indicate that the current theory would predict a maximum usable frequency of the order of 5 or 6 percent low. Actual radio traffic data, however, seem to indicate that for even longer paths (very low angles of incidence) the errors in the current theory should be larger than have been observed so far. Extended propagation paths will be studied to check this point.

Low-Frequency Ionospheric Measurements. A study of data obtained with the NBS low-frequency ionosphere recorder led to the discovery of a new "intermediate layer" at about 160 kilometers out of which the regular E layer forms at daybreak and into which

it recedes at sunset. Although it appears irregularly at night, the intermediate layer seems to be a nighttime equivalent of the high-frequency daytime regular *E* layer.

An ordinary wave echo from a low layer usually shields the reflections of the same polarization from higher layers, but passes the extraordinary wave echoes from above. The converse is true of an extraordinary wave low level echo. However, an anomaly has been seen—an extraordinary-wave *F*2 layer echo has at times been noted exhibiting a retardation cusp apparently due to the ordinary wave intermediate layer below. This will be studied further following the move to Colorado where canyon sites offer shielded areas for the erection of special equipment.

Radio Astronomy. The Bureau continued its study of cosmic and solar radio waves from outer space utilizing the recently developed techniques of radio astronomy. Three 25-foot parabolic reflectors for receiving solar radio noise were transferred from Washington to a field station in Colorado, where automatic controls have been installed and routine measurements undertaken at 167 and 460 Mc/s. At the new location, the mountains of the Continental Divide provide a natural knife edge horizon at sunset, and a study of the records of successive days at sunset during a period of activity on the sun provides a means of locating the active region on the sun as it sets behind the mountains. Regular summary reports of solar activity were initiated.

Work on a nonlinear theory of plasma oscillation shows that the period of a space charge wave is a function of its amplitude and phase velocity. The theory developed explains the second harmonic component in solar radio noise as well as the decrease in fundamental frequency with increase in burst intensity. Theoretical investigations of shock wave propagation in an ionized atmosphere with a superposed magnetic field show departures from Maxwellian distribution. The effect may explain the anomalous dual temperature which has been obtained experimentally for the solar chromosphere. Effects of shock waves on space charge waves suggest that the fine structure of solar radio noise may be due to space charge waves.

Theoretical Studies. Information theory concepts were applied to propagation through time-varying media with a view toward ascertaining the fundamental limitations imposed upon communica-

tions systems which utilize propagation links. The signal fading present in such systems represents a type of information degradation not considered in conventional information theory which postulates steady signals contaminated by noise.

In continuing previous work on tides in the earth's atmosphere, both thermally and gravitationally excited oscillations were considered in a rotating atmosphere composed of a perfect gas in hydrostatic equilibrium. Several current atmospheric models were tested and in all but the isothermal atmosphere the solar thermal action exceeded the gravitational by a factor of the order of one hundred. The predicted time of maximum tide was off by about 2½ hours, however, and it was suggested that eddy viscosity effects at the base of the atmosphere could account for the discrepancy. The atmospheric profile as determined by V–2 rocket measurements gave closest agreement with observation regarding magnitude of the tidal effect. The above results represent a vast departure from ideas held since 1924 that thermal and gravitational effects would be of equal importance.

Radio Warning Service. A study of vertical soundings obtained at Canadian stations has resulted in an ionospheric disturbance index for use in day-to-day forecasting. The index, based on the relative deviation from normality of $F2$ region electron densities is expressed on the quality figure scale and has been shown to be strongly correlated with nighttime North Atlantic radio propagation quality figures. This work represents progress in the difficult problem of relating ionospheric storms to radio propagation disturbance. The indices are being derived currently and used on a trial basis as a guide to forecasters.

The average magnetic activity associated with solar flares and classified according to the nature of the associated 200 megacycle radiofrequency event has been analyzed in considerable detail. The results point towards an important refinement in the methods of forecasting magnetic disturbance on the basis of combined radio and optical observation of flare-type solar activity.

Radio Noise Studies. For a number of years the radio division has studied radio noise of both terrestrial and extraterrestrial origin. Atmospheric radio noise, which determines the ultimate limit to radio reception on frequencies below about 30 megacycles, originates principally in thunderstorms throughout the world.

However, man-made radio interference causes considerable difficulty in measuring noise of natural origin and necessitates the careful selection of recording sites. A mobile recording unit has been used to investigate various recording locations in an effort to locate those with a low man-made noise level. The lowest levels observed were in the vicinity of Bill, Wyoming, which has been chosen as the site for a third recording station.

A highly specialized recording-receiver has been developed to meet the need for improved accuracy and standardization in measuring radio noise. This receiver incorporates many improvements over commercially available equipment. Some of the principal features are low noise figure, good gain and frequency stability, narrow bandwidth, wide dynamic range, provision for absolute average power measurement, and improved presentation of data. Provision is made to record data automatically on 8 frequencies from 50 kilocycles to 20 megacycles. Several receiver-recorders are being built.

Tropospheric Propagation. Research was continued on the problem of allocating radio frequency channels to very-high-frequency communication and broadcasting services. Experimental studies were continued to determine meteorology effects of the lower atmosphere on the received signal strength. A remarkable phenomenon was observed on radio circuits operating within the line of sight at frequencies of the order of 1,000 megacycles and higher. This phenomenon, known as the space-wave fadeout, is thought to be a result of ducting in the lower atmosphere which is fairly common to all geographical areas. The Bureau's study indicates that space-wave fadeouts may be of serious consequence to UHF services, particularly where low antennas are involved, as in UHF air navigation systems.

Obstacle gain measurements were made of television broadcast signals received on a 100-mile path with a 14,000-foot mountain, Pike's Peak, in the middle of the path. These measurements demonstrated both the marked decrease in transmission loss and the reduction in fading associated with optimum location of large obstacles in such propagation paths.

Cheyenne Mountain Experiments. Tropospheric propagation research facilities have been established at the NBS Cheyenne Mountain Field Station at Colorado Springs, Colorado, to deter-

mine the necessary propagation factors for the effective allocation and use of air navigation and communication facilities. The program has included the development, installation, and operation of a system for studying propagation factors at 1,000 megacycles. A moderately directive semipyramidal horn antenna radiates 1.6 megawatts of effective power at an operating frequency of 1,046 megacycles. The transmitter is now operating on a regular schedule for the systematic collection of tropospheric propagation data. This program marks a new departure in propagation research which in the past has often followed rather than preceded the use of a new portion of the frequency spectrum.

In addition to the 1,000-megacycle system, complementary 100- and 200-megacycle systems are operated side by side to determine the frequency dependence factors in this region of the spectrum. Transmission losses measured at these three frequency ranges over a variety of path lengths and antenna heights are being analyzed to determine diurnal and month-to-month variations in median signal level as well as range and rate of short term fluctuations in instantaneous signal level. The prolonged space-wave fadeouts occurring primarily in 1,000-megacycle transmissions over line-of-sight paths were analyzed to determine the mechanisms influencing the propagation of VHF and UHF radio waves both within and beyond the radio horizon and to provide basic information for use in determining service and interference ranges of various radio systems.

A large amount of data obtained from continuous recordings of commercial transmitting stations by universities, engineering consultants, and the Federal Communications Commission was received from various geographical areas of the United States. These data have been used for developing more complete and accurate physical, mathematical, and statistical methods of describing tropospheric propagation. Work has progressed on the theoretical aspects of the problem of tropospheric scattering. A new method of numerical integration has been developed which handles more adequately the complicated integral involved in tropospheric scattering. Propagation charts, technical reports and memoranda, and special methods of analysis were prepared on the problem of predicting transmission loss versus distance and antenna height for any time of day or season. A new approach to the problem of prediction was made by the development of the concept of "angular

distance." This parameter has been found particularly helpful in accounting for gross effects of terrain irregularities.

Modulation Studies. Because of the premium placed upon space in the radiofrequency spectrum and the necessity for more reliable communications, a study of various types of modulation efficiency and methods of communicating over radio paths was undertaken. The effect of transmitter keying wave shape on interference produced was investigated and a relatively simple filter designed that can be used in the keying circuit of linear transmitters to provide a very marked reduction in adjacent channel interference. The frequency spectrum of a frequency-shift keying transmitter has been analyzed to determine the effect of audio low-pass filtering of the keying wave applied to the reactance tube. The mathematical analyses, confirmed by experimental measurements, have indicated that a considerable reduction in side band energy can be obtained.

Standards for Characteristics of Materials. An accurate secondary standard of complex permeability, the radiofrequency permeameter, was developed, privately manufactured, and adopted by a sizeable segment of industry. An extension of this instrument capable of measuring the temperature coefficient of the best commercially available ferrites and nearly all other high-frequency magnetic materials was also placed into operation. The frequency range covered by these instruments (100 kilocycles to 40 megacycles) was extended by the design, construction, and evaluation of a re-entrant cavity system capable of performing complex permeability measurements in the region of 55 to 200 megacycles.

A standard solid-dielectric specimen holder was modified to allow dielectric measurements to 100 megacycles and to 100° Centigrade under controlled temperature and humidity conditions. A new resonant-cavity-type specimen holder was designed and is nearly completed. It will extend the frequency range to 1,000 megacycles and the temperature range from −40° to +500° Centigrade.

Primary Microwave Frequency Standard. A major revision of the microwave frequency standard was undertaken to incorporate the most modern features and to simplify its operation. The new standard has fixed-frequency outputs corresponding to those frequencies for which there is greatest demand for calibration service. The signals are of higher power and extend higher in the frequency range. The power available at the 10 and 50 megacycle

outputs of the frequency multiplier chain is 5 watts; at the 250 and 3,000 megacycle outputs, 1 watt; and at 9,000 megacycles, 20 milliwatts. A new technique of mixing at the end of the multiplier chain rather than internally resulted in the elimination of spurious and poor-quality signals within specific frequency regions. In addition, this mixing technique simplifies the generation of equally-spaced standard signals used in calibrating adjustable frequency meters. It is now possible to set up the standard with combinations of outputs along the multiplier chain such that a single direct-reading control selects each successive desired standard frequency over the range of the common type of meter. This feature is in operation over the frequency range of 550 to 40,000 megacycles.

Microwave Noise Standards: An apparatus for measuring noise power at microwave frequencies was developed for calibrating secondary noise standards. Noise sources such as fluorescent tubes or noise klystrons, when calibrated as secondary standards permit an easy determination of the noise factor of microwave networks. Equivalent noise temperatures of typical secondary sources may be calibrated with an absolute accuracy of approximately 0.1 decibels, the temperature being known to within 2 deg Kelvin. The noise-measuring apparatus consists of a standard noise source together with a noise comparator which balances the noise powers of the unknown and standard sources.

Atomic Time and Frequency Standards. The program for atomic frequency and time standards has been carried to the point where the relative merits of the gas absorption and atomic beam techniques can be assayed, and decisions made on the next phase of the program. Progress on the atomic beam technique was such that it is definitely the most accurate now available, with further improvements in accuracy still possible. It appears possible to make beam equipments simple enough to compete in running time with gas cell clocks.

Work on a cesium atomic beam method was begun shortly after the initial work on the ammonia clock. With this equipment a spectrum line having the sharpest resonance ever obtained has been excited. This sharpness of resonance, or "*Q*", is commonly of the order of a few hundred for radio circuits. For a good quartz crystal resonator it may be from a hundred thousand to a few

million. For the cesium beam, a Q value of 30 million has been obtained.

Absolute measurements of the cesium resonance frequency against WWV and Naval Observatory time have been completed, and have resulted in tentative values of an independent primary standard of frequency. These tentative values are now being cross-checked to ensure that they provide a firm absolute value.

3. Calibration, Testing, and Standard Samples

The reduction in the appropriation to the Bureau for Research and Testing for Fiscal Year 1954 and the studies by the Ad Hoc Committee of the Secretary of Commerce that were concluded early in that fiscal year initiated a general reexamination of the Bureau's services to the Government and the public in the testing area. Testing, as understood when reference is made to research and testing, includes the following three types of activities: (1) The comparison and calibration of instruments and other standards of measurement; (2) quality control and qualification, acceptance, regulatory, and referee testing; and (3) preparation and distribution of standard samples.

3.1. Ad Hoc Committee Recommendations

The findings of the Secretary's Ad Hoc Committee regarding the testing area may be summarized by the following excerpts from its report:

"This area might be considered as one of the important end products in the Bureau's basic programs. It is made up of so large a number of specific items that they have not received individual examination by the Committee. The Committee is concerned that a larger amount of repetitive testing is now done by the Bureau than is necessary with the present state of development of technology in industry . . .

"The Committee recommends that the repetitive test operations of the Bureau be critically examined by the Bureau and the proposed advisory committees . . .

"The personnel and facilities of the test program area of the Bureau should be primarily employed in the development of specifications and testing and quality control procedures. The Bureau should exert a leadership for the maintenance of high quality in the products of Government purchase with the minimum of participation in repetitive tests.

"Increased funds for maintenance of present standard samples supply and for the development of new standard samples are urgently needed."

In keeping with these recommendations, the Bureau instituted a policy of restricting the calibration services, insofar as possible, to the calibration of basic standards. As in previous years, tests of products were made only at the request of other Government agencies except when the Bureau possessed facilities not available elsewhere or in the rare instances when referee tests were required. The standard sample program was maintained to the fullest extent permitted by available funds.

3.2. Conferences With Government and Industry Users of Bureau Services

In August 1953, the policy of emphasizing calibration of basic standards was announced at two major conferences. One conference was with representatives of Government agencies; the other was with scientific apparatus manufacturers and dealers and representatives of industries that make extensive use of the Bureau's calibration services and standard samples. At these conferences basic standards were defined as including (1) standards used to calibrate other standards or working instruments; (2) standards required by law or regulation to be certified by the National Bureau of Standards; and (3) standards for measurements requiring such high precision that direct comparison with the standards of the Bureau is essential.

In the conference with other Government agencies it was agreed that the Bureau would continue to provide the minimum essential calibration service from its directly appropriated funds. Specifically, the Bureau would calibrate without charge one instrument of each kind and type required by any given laboratory in the course of a year, and would repeat the calibration as necessary. If, as a matter of economy or convenience, the agency wished to have replicate instruments calibrated by the Bureau it was agreed that this service would be rendered on a reimbursement basis.

In the conference regarding calibration services to the public, the scientific apparatus makers and others were asked to cooperate in keeping their requests to a minimum, particularly as regards secondary standards such as mercury-in-glass thermometers and volumetric glassware. The possibility of working out a system of priorities for calibration services was explored and was found to be impractical because of the very large number of items involved

and the difficulty of assessing the relative importance of different areas. It was explained that while other Federal agencies can reimburse the Bureau for services, the fees collected from the public are required by law to be deposited in the Treasury and are not available to the Bureau.

3.3. Transfer of Services to Private Agencies

At the conference with industry representatives consideration was given to the possibility of transferring some of the larger routine calibration operations to nongovernmental agencies. The matter was explored further with representatives of commercial testing laboratories, who visited the Bureau and made detailed studies of the operations. No shift seemed feasible because the diversity of items and requirements even in the larger areas was such that the work did not appear attractive as a commercial venture.

In the field of materials testing, however, it was possible to give up one operation—the testing of samples of the breath of radium workers for radon content. This test service, which the Bureau had provided because facilities were not available elsewhere, was discontinued when a university laboratory was found equipped and willing to do the work.

The Bureau divested itself of another service activity in the testing area by arranging for the American Society for Testing Materials to take over the responsibility for publishing the Directory of Commercial and College Testing Laboratories, which the Bureau had maintained since 1927. A joint announcement by the Bureau and the ASTM stated that the present edition of the Directory (NBS Miscellaneous Publication M187) would continue to be available from the Superintendent of Documents, Government Printing Office, until the revised edition in preparation by ASTM was ready for distribution by that Society.

3.4. Testing for the Public

A large number of requests for qualification and acceptance testing services were referred to commercial and college testing laboratories, usually by reference to the above-mentioned Directory. Requests from manufacturers and dealers for the evaluation of products being offered for sale to the Government were

referred to agencies that might be interested in purchasing the products. These agencies were informed that the Bureau would make the tests only on the request of another Federal agency and would furnish the results only to that agency.

The Bureau conducted a small number of tests involving the use of special or unique facilities not available in commercial or college laboratories. The fee value of such tests in fiscal year 1953 was $18,600; in fiscal year 1954 it had been reduced to $6,900.

Very few referee tests were found necessary since most of the differences that were brought to the Bureau for consideration were resolved informally. In some instances information and experience available to Bureau staff members provided the solution, while in other instances disagreements growing out of inadequate test methods led to the development of new or revised methods in cooperation with technical committees of national standardizing organizations in which the Bureau is represented. The extent of the use of the Bureau's standard samples for reconciling differences in chemical analyses was emphasized by a number of requests for new standard samples.

3.5. Testing for Government Purchase

The sample-testing of cement purchased by Government agencies amounted to more than three-fourths of all the acceptance testing done by the Bureau. In order to render prompt and efficient service in connection with major Government construction projects, work was carried on not only in Washington but also in field laboratories in Allentown, Pennsylvania; Denver, Colorado; San Francisco, California; Seattle, Washington; and Kansas City, Missouri. The Kansas City laboratory was set up on a temporary basis in connection with nearby construction projects. Since the Bureau tested the bulk of the cement purchased by the Government, it was able to effect economies made possible by operating on a large scale.

With regard to this operation the Ad Hoc Committee stated, "The acceptance testing of portland cement . . . is, in fact, only sampling and analyzing for Government agencies. Hence, it seems a legitimate function for the Bureau." The Committee, however, did not wish this approval of the cement testing program to set a

precedent for large-scale testing operations in other fields, but added, "Although the work outlined . . . above appears proper and well carried out, a word of caution is offered. As a general rule, routine repetitive testing does not add strength to the Bureau's scientific effort. Thus the endeavor should not be considered a pattern for future testing."

The sample testing of electric lamps was another area in which the Bureau continued to evaluate a large proportion of Government purchases. The cost of this operation in fiscal year 1954 was $38,700 as compared with $1,016,000 for the testing of cement.

In addition to the foregoing items, the Bureau tested a great number of other products. The significance of these tests was indicated by the number of instances in which the product failed to comply with the specification under which it was being tested. In one area, that of building materials, 137 samples out of 280 samples tested did not meet specifications.

3.6. Testing for Regulatory Agencies

The Bureau was called upon to perform a variety of testing services by regulatory agencies of the Government. The majority of the tests were carried out for three agencies as follows: (1) Tests for the Federal Trade Commission relating to incorrect labeling and misleading claims; (2) tests for the Post Office Department involving allegedly fraudulent use of the mails; and (3) examination and inspection of aircraft and aircraft parts for the Civil Aeronautics Board, often for the purpose of determining the cause of accidents. The relatively small volume of such testing in relation to the over-all Bureau program is indicated by the fact that the cost in fiscal year 1953 was estimated at $24,000, and in fiscal year 1954 at about $13,000.

3.7. Services to State Governments

In accordance with its statutory function, the Bureau continued to provide calibration services without charge for the standards used by the different States. The principal service of this kind was maintenance of the Master Railway Track Scale Depot at Clearing, Illinois, and the operation of two test cars for the calibration of master track scales. This service is important in providing a

uniform basis for agreement between buyers and sellers of commodities.

Because State universities perform important standardizing services within their States, the Bureau calibrates standards and provides them with the standard samples required for education and public service. However, inasmuch as many State universities now act as contractors for Federal agencies, the Bureau asked that services required in the capacity of a contractor be requested directly by the sponsoring Federal agency so that the Bureau could be reimbursed for the cost of the work.

3.8. Standard Samples

The Ad Hoc Committee stressed the importance of the Bureau's standard sample program, stating, "This is a proper function for the Bureau and one that within its resources it has performed well." The Committee stated (at the beginning of fiscal year 1953) that it had not been possible for the Bureau to increase the numbers of standard samples or even to maintain its former position. This statement was still applicable throughout fiscal years 1953 and 1954. The Committee also noted the frequent use of standard samples in refereeing questions between buyer and seller. The extent to which standard samples were used by industry for this and other purposes is indicated by the fact that sales to the public in 1954 amounted to $99,000 while the total value of the samples furnished to all Federal and State agencies combined was $20,000.

3.9. Relations With the General Services Administration

The Bureau and the General Services Administration have many common interests in the area of testing and specifications. The General Services Administration is assigned broad responsibility for purchasing supplies and services required by the Federal Government together with related functions including specifications, inspection, and testing. The Bureau, for its part, is authorized to develop test methods; to test materials, supplies, and equipment, including items purchased for Government use; and to cooperate with other governmental agencies in the development of specifications. The functions of the two agencies when viewed broadly are supplementary, and it is in the interest of the Govern-

ment that they work closely together. To facilitate effective cooperation a Memorandum of Understanding (Appendix, page 131) was developed between the two agencies. The memorandum deals particularly with the assignment to the Bureau of responsibility for specifications for general test methods and for individual products in the area of its competence, and with the conduct of qualification and acceptance testing.

3.10. Services in Specific Areas

Services in specific areas within the scope of the various technical divisions of the Bureau are summarized in the following paragraphs.

Electricity. Since 1924 the Bureau has conducted annual qualification tests on various types of dry cells and batteries as a basis for their purchase by Government agencies. Similar tests on special batteries for use in hearing aids were continued for the Veterans' Administration. Testing of standard measuring apparatus for manufacturers, electric power companies, State Public Utility Commissions, university laboratories, and private testing laboratories as well as for many agencies of the Federal Government continued at a constantly rising level. During the 2-year period calibrations were furnished on 2,352 standards of electrical resistance, inductance or capacitance, 1,256 electrical measuring instruments and related apparatus and 1,181 standard cells.

Optics and Metrology. The calibration of standards included such items as incandescent, fluorescent, and mercury-vapor lamp standards of luminous intensity, luminous flux, and color temperature; standards for checking the reliability of spectrophotometers and for referencing the 100 percent reflectance values; colorimetric and photometric standards for television tubes, signal glassware, and petroleum products; and glass or vitreous enamel standards of color, reflectance, opacity, gloss, and luminance. Also included were miscellaneous items submitted for calibration such as ruby mica, Lovibond glasses, and exposure meters. In all, approximately 500 standards were calibrated in the 2 years. Over 14,000,000 incandescent, fluorescent, and photographic flash lamps were sample tested.

Testing in the field of photometry and colorimetry included paints and varnishes, glass, luminous tape, cotton standards, road

signs, signal devices, mirrors, sunglasses, smoke signals and luminosity filters, and standards of luminous flux, color temperature, reflectance and gloss. This work was done for many Government agencies and included approximately 250 items. Approximately 600 airplane cameras, photographic objectives, telescopes, binoculars, goggles, and spectacle lenses were tested. Approximately 1,120 samples of film were tested for residual sodium thiosulfate content for numerous agencies of the Federal Government as well as for State governments, universities, and for industry. Also, two samples of new types of film base were tested for compliance with NBS standards for permanent record use.

A total of 32 samples of photographic films, 7 samples of plates, 49 samples of papers, 16 samples of sensitized tracing cloth, 46 samples of diazo papers, and 6 samples of developers were tested for the General Services Administration for compliance with Federal specifications. Several determination of silver content in fixing baths were made for other agencies in connection with the reclamation of silver. A total of approximately 3,800 NBS Microcopy Resolution Test Charts, used in testing microcopying cameras and films, and several hundred copies of instructions for their use were furnished to Government and State agencies, to universities and to industry.

During the past 2 years the Bureau tested or calibrated 24 length standards, 251 base-line invar tapes and wires, 447 steel tapes, 2,908 haemacytometer chambers, 23,593 cover glasses for haemacytometers, 344 sieves, 3 precision graduated circles, and other miscellaneous items. This work included the highly precise calibration of several length standards with probable errors ranging from 2×10^{-6} to 4×10^{-6} inch, and circles calibrated to the nearest second.

The quantity of testing or calibration of gages and related items has remained at a high level throughout the period. Among the API gages tested was a large number of master and references gages for use in foreign countries; also three sets (38 pairs) of regional master cable drilling tool joint gages were recalibrated for the first time in about 25 years. Measurements were made of errors in planeness of 24×36 in. granite surface plates intended to be flat within a range from a true plane to 0.00005 in. convex.

Heat and Power. A total of 4,532 liquid-in-glass thermometers, 249 resistance thermometers, 71 optical thermometers, and 859

thermocouples and thermocouples materials were calibrated. Calibrations of 533 deep sea reversing thermometers were made for the Navy Hydrographic Office. Of 66,589 clinical thermometers tested, 56,662 represented a sampling of over 566,620 thermometers purchased by the Veterans' Administration and the Department of Agriculture. Tests and calibrations were made on several special types of thermometers and thermometric devices.

One hundred fifty-six viscometers were tested and 1,614 standard viscosity samples were supplied to other laboratories for use in the calibration of viscometers. Seventeen gasolines and fuel oils, 2 standard reference fuels, 23 lubricants, and 59 miscellaneous materials were tested for various Government agencies. Heats of combustion were measured for 36 samples of jet engine fuels. One hundred thirty nonroutine tests on aircraft electrical network equipment and 138 nonroutine tests of high-pressure pneumatic devices and equipment were conducted for the Navy Department. Eleven engine-generator sets were tested for the Engineer Research and Development Laboratory and one automobile was inspected for the Federal Bureau of Investigation. Heat capacity measurements were made on a number of standard materials for the Calorimetry Conference Program. The heat capacities of samples of brass and plexiglass were determined for the Navy.

Atomic and Radiation Physics. More than 1,750 radioactive standards were issued including RaD–E, C^{14}, Na^{22}, P^{32}, Co^{60}, Sr^{90}, Y^{90}, I^{131}, Ti^{204}, radium, radon, alpha-ray standards, and radium, uranium, and thorium rock standards. The Bureau measured and certified 2,766 radium, mesothorium, and cobalt preparations. Fifteen alpha-ray and 13 miscellaneous gamma-ray sources were calibrated. Over 1,700 breath and air samples were tested for radon content while 589 ores and sludges and 267 water samples were tested for radium content. Twenty-one mercury-198 lamps (a new length standard developed by NBS) were distributed to universities, Government institutions, and private industry. Neutron measurements of 16 radium-beryllium sources and more than 1,900 chemical and isotopic analyses were carried out. Two thermal neutron fluxes were calibrated and 32 thermal neutron dosimeters were calibrated at the request of the AEC.

Tests and calibrations were made on the following items: 66 r-meters, 328 ionization-chamber pocket dosimeters, 535 phosphor

glass dosimeters, 50 photographic dosimeters, 80 special radiation instruments, 19 radiographic chemicals, 135 pieces of lead glass, 8 lead-lined building blocks, 3 protective aprons, and 28 miscellaneous X-ray units and accessories.

One-hundred and six lamps that serve as fundamental standards of total radiant energy were calibrated and issued; these are the only standards of this type in the United States. About 100 eye-protective lenses were tested for various industrial and Government laboratories for compliance with Federal specifications. Approximately 25 photoelectric and photoconducting cells were calibrated for spectral sensitivity and 20 tungsten filament lamps for spectral emissivity. In addition 6 standards of spectral radiant energy, 1 photoelectric photometer, 4 thermopiles, 59 samples of welding glass, and 4 special lamps were calibrated. Four paint samples and 23 samples of safety glass for eye protection and for windshields were tested. In addition about 200 samples of glass and 125 samples of plastic were tested for other laboratories within the Bureau.

Chemistry. About 5,000 samples of a great variety of materials, including paints and varnishes, soaps and detergents, metals and alloys, carbon paper and typewriter ribbons, and reagent chemicals, were analyzed or tested, either for compliance with purchase specifications or in connection with research projects or regulatory investigations. Calibrations in the field of chemistry included 16 polarimeters for the assay of sugar and 88 quartz plates used as secondary standards to check these instruments. The calibration of Magne-gages, formerly done by the Bureau, was taken over by the instrument manufacturer. The NBS standardizing service essential to the use of these instruments is now provided in the form of specimens of plated metals with coatings of certified thickness. The number of these standard samples issued was 16,700.

About 48,000 standards of certified composition or purity were issued. One new standard was added—a chromium-nickel alloy used for electrical heating. Thirty standards were renewed during the year—13 steels, 3 bronzes, 2 cast irons, a ferroalloy, a zinc-base alloy, melting-point lead, melting-point copper, and potassium dichromate. Sixteen benzoic acid thermometric standards were issued, bringing to 96 the total of these calibrating devices issued since this service was begun about 7 years ago.

Mechanics. Sound absorption tests on 143 samples of acoustic material and sound transmission loss tests on 17 wall structures were made for other government agencies, industry, and the public. Calibrations were performed on 37 microphones, sound level meters, and earphones, about 200 pressure measuring instruments, 89 anemometers for measuring wind velocity, 1,011 elastic calibration devices, including proving rings, dynamometers and aircraft weighing cells, 11,355 weights, 18 balances, 28 master railway track scales, 721 other railway track scales, 112 scale testing cars, 172 other types of scales, 1,402 water current meters, 1,827 hydrometers, 61,545 burets and pipets, 6,135 flasks, 322 other measures of volumetric capacity, and 27 flow meters.

Tension, compression, bending, torsion, hardness, and other mechanical tests were made on a variety of specimens submitted by other Government departments, State institutions and private organizations to determine mechanical performance and compliance with specifications. Specimens included reinforcing steel, aluminum and copper conductors, wire and fiber rope, expansion, joint filler, hand tools, pole top pins, crossarm pins, upset spool bolts, insulator wire holders, pencils, crayons, signal flares, electric fans, and other articles. Precise density determinations were made on 118 samples of liquids and solids.

Organic and Fibrous Materials. The present test method for evaluating pneumatic tires requires a combination of laboratory and road-service tests. Not only does the inability to control conditions in a road test present difficulties but such tests are costly and time consuming. To overcome the deficiencies of the road test, the Bureau is developing a new tire tester under the sponsorship of the Army Ordnance Corps.

The stiffness of paper is an important property in such practical uses as wrapping papers, sanitary tissues, playing cards, and others. While several methods have been proposed in the past for measuring this property, all have met objections and none has been generally accepted. A new apparatus for measuring the stiffness of papers of all kinds has been developed by NBS. This apparatus will measure stiffness ranging from very light and flexible tissues to cards and light paperboards.

Typical materials tested for various Government agencies in 1953 and 1954 were alkyd diisccyanate radome foams, cordage of

various types, hose, tanning materials, floor coverings, beltings, expansion joint materials, treated duck, flags, various leather and paper products, solid rubber tires, and water and stain repellents. In conjunction with the American Dental Association Research Fellowship maintained at the Bureau, a number of dental materials were tested for compliance with ADA Specifications. Dental materials and equipment were also tested for the military services and the Veterans' Administration. The demand for the nine standard samples for rubber compounding ingredients continued to be large.

Nearly 900 textile mills and other organizations in the United States and abroad have obtained light-sensitive paper from the Bureau for calibrating the carbon arc lamps used in testing color fastness of textiles. The paper, produced in the paper mill at the Bureau, is now being prepared in booklets of standard faded strips. The NBS "Master" lamp used to standardize the paper was replaced with new improved equipment during 1954. The paper standards are now sold through the NBS Standard Sample Service.

Metallurgy. Various metallurgical tests were made for such agencies as the Coast Guard, Federal Trade Commission, Army Engineers, Department of Justice, Post Office Department, and General Services Administration. About 2,570 pieces were heat treated for other Government agencies and other units of the Bureau. Castings with a total weight of 17 tons were made in the experimental foundry for other agencies of the Government. The eight steels developed for the International Cooperative Investigation several years ago are still in demand by research laboratories as standards for use in the determination of oxygen and nitrogen in steel by vacuum fusion.

Mineral Products. Federal agencies engaged in construction activities requested tests on more than 52,000 samples representing 26 million barrels of portland cement. The tests, both physical and chemical, were carried out in five separate field stations established for this purpose as well as at the central laboratory in Washington. A statistical study has been made to determine the minimum number of samples and amount of testing required to give adequate information regarding the quality lot of cement. Closely related to this work is the program of the Cement Reference Laboratory, which inspects, when requested, the apparatus and

test methods of cement testing laboratories throughout the United States. The Cement Reference Laboratory is located at the National Bureau of Standards and is jointly supported by the Bureau, the Public Roads Administration, U. S. Corps of Engineers, and the American Society for Testing Materials. Twelve thousand vials of standard fineness samples of cement were prepared and 4,000 were distributed to various laboratories.

Tests were conducted on soils, aggregates, pozzolans, oxychloride cements, water, concrete and related materials. Refractory items such as fire-clay bricks, air-setting mortars, insulating refractory bricks, and refractory castables were tested for compliance with Federal Specifications. Tests were conducted for various States on safety glass compliance with the American Standards Association Code for Glazing in Motor Vehicles. A substantial volume of crucible grade natural flake graphite was tested prior to its storage in the National stockpile.

Building Technology. Structural tests were made on 178 samples of brick and concrete, 216 masonry units, 188 units of pipe, 85 samples of tile, 16 samples of calking compounds, 12 samples of natural building stone, 30 standard samples of limestone blocks, and 60 other miscellaneous building materials. Approximately 60 tests of fire extinguishers and equipment were performed. A total of 29 fire-resistance tests were made on floors, walls, columns, beams, or roof assemblies. Fifty-eight investigations of fire hazard of materials were made, including 10 tests for fabric flammability, 12 tests on paint flammability, 16 flammability tests of interior finish materials, and 20 tests of spontaneous ignition hazard. Thirty-nine miscellaneous fire studies, including tests for mail hazards on marine flares, and on matches, were performed. Seven air-conditioning units were tested.

Thermal-conductivity tests were conducted on 79 samples including lightweight concrete slabs, roof insulation, building board, mineral wool, and lightweight concrete blocks. Performance tests were made on 9 impingement air filters and on 5 electrostatic air cleaners. A total of eight miscellaneous household items such as venetian blinds, flush valves, faucet aerators, substitute heating duct materials, and refrigeration components, were tested. An electric map heater was tested for the Army Map Service. Design approval tests were performed on four elevator buffers.

Performance tests of refrigerators for storing whole blood were made for the Military Operations Subcommittee of the U. S. Congress. Three large walls with reinforced mortar facing were tested for the Federal Civil Defense Administration to determine their resistance to transverse loads. Performance tests on air cleaners were made for the Navy Bureau of Ships and the Public Buildings Service. A total of 3,866 samples of bituminous road materials were tested for the Government of the District of Columbia, and 164 miscellaneous bituminous materials for other Government agencies.

Radio. In the high-frequency region, 186 instruments and devices of 15 types were calibrated and 23 dielectric samples were measured for industrial and Government laboratories. The instruments consisted of attenuators, standard capacitors, filters, field strength meters, a test oscillator, audiofrequency bridge, amplifier, slotted line, vacuum-tube voltmeters, and voltage generators The dielectric properties of materials such as iron and ferrite field plastics, polyethylene, soil, Bentorite, high temperature laminates, ceramics, ferrites, antenna housing materials, fused quartz, barium titanate, cesium iodide, araldite, teflon, alundum, glass, and indian lava were measured as well as the radiofrequency properties of a large number of capacitors, resistors, and inductors. A thorough examination of the complex permeability versus frequency behavior of the majority of commercially available as well as of some experimental ferrites was made. Causes for relaxation behavior were investigated as were effects of aging and climatic changes. A comprehensive program of powdered iron core properties was about 75 percent completed utilizing measurements on over 6,000 cores with approximately 15,000 sets of data. Important properties of such materials available in this country will be known after completion of the tests. A precise measurement of the loss characteristics of the core material exhibiting the lowest known losses in 1 to 10 megacycle region was made and about 25 standard samples of this material were distributed to interested manufacturers and laboratories.

In the microwave region, calibration service was made available for attenuaters in two additional waveguide sizes. A number of the attenuation calibrations were made on directional couplers, indicating a trend toward the use of this device for a very stable

type of attenuation standard. Requests reveal a definite trend toward demands for calibrations at many discrete frequencies, making the calibrations much more involved. In 1953 very extensive calibrations were made of nine waveguide attenuators for a large defense department program. Over 60 frequency meters were calibrated, the majority being in the X-band region. Calibration of power meters continues to be on an experimental basis and is confined to the UHF region and a narrow portion of the X-band region. Although a service is offered to calibrate power meters up to a level of 10 watts in the UHF region, an effort is being made to extend the range for X-band power meters from several milliwatts up to at least 5 watts. This is being accomplished by using calorimetric methods.

4. Cooperative Activities

The active participation of the Bureau's staff in projects of professional societies and standardizing bodies greatly enhances the dissemination and utilization of the results of NBS research, development, standardizing, and testing activities. At the same time, staff members are able to keep in close touch with technical and scientific advances elsewhere and to coordinate the standards and specifications used in industry with those employed by the Government.

The extent of this activity is indicated by the fact that in Fiscal Year 1953 Bureau staff members took an active part in the work of 681 technical committees of more than 100 national societies, serving in 182 positions as chairman or secretary of a committee. For example, NBS personnel serve as President and Editor of the Optical Society of America, President of the Instrument Society of America, and a director of the American Chemical Society. They also participated actively in 52 international committees and served as chairman or secretary of 21. These figures do not include numerous assignments to task forces or minor ad hoc committees.

This cooperative activity led to the promulgation of 15 national codes in 1953 dealing with various subjects ranging from protection against fire, lightning, and radiation to plumbing and building construction. Also promulgated during the same period were 214 Federal Specifications based on the work of technical committees

of the Federal Specifications Board in which Bureau staff members took an active part. Many of these specifications were based on investigations conducted at the Bureau.

The Fiscal Year 1954 marked a transition from the committee method to the assigned-agency method for the preparation of Federal Specifications. Under the new plan the General Services Administration assigns agencies such as the Bureau the responsibility for specifications in their fields of competence. Although the former interagency technical committees have been abolished, Bureau staff members have found it helpful to make extensive use of these committee contacts for coordinating the specifications being developed with Government and industry.

Projects for the development of new and improved methods of test were conducted in all of the Bureau's technical divisions. These methods related to a very wide variety of subjects, including standard procedures for realizing thermometric fixed points; methods for measuring the characteristics of X-ray tubes; techniques for evaluating talking books for the blind; general methods for testing rubber, leather, textile, paper, and plastic products; and procedures for the application of statistics to sampling, inspection, testing, and the design of experiments. In 1953, 203 test methods were published and 53 more were issued in unpublished reports.

During the past 2 years, Bureau services ranged from the provision of an original and effective method for analyzing California smog to recommended building maintenance procedures that will result in substantial savings to the Defense Department. Advice and assistance was rendered to Congressional committees in such areas as the use of bagasse as newsprint and the preparation of legislation limiting the distribution and sale of hazardous and highly flammable fabrics. In the field of mathematics a large computation program involving the determination of temperature rise in certain nuclear reactors was carried out for university and industrial contractors of the Atomic Energy Commission. An electron tube information and testing service was established to serve the Bureau, other Government agencies and industry. This service endeavors to answer questions on the characteristics, performance, instructions, and availability of electron tubes. Some 800 requests for advice were received from agencies of the Department of Defense, the Federal Trade Commission, the War Munitions Board, and the Office of International Trade. Other forms which the

Bureau's cooperative activities assume are indicated in the following paragraphs.

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

Improved instruments for measuring basic physical magnitudes are vital to advances in the physical sciences and their applications. Yet until recently the problem of designing instruments to measure different quantities and for use under different conditions has been largely left to the individual scientist or engineer working in his particular technical field. However, it is coming to be more and more widely recognized that the problems met with in designing various kinds of scientific instruments have much in common and that the designer of an instrument for a specific purpose can often benefit from the experience gained by others with instruments built for quite unrelated purposes. The coordinated planning of research on instrumentation as a science in itself makes it possible to take advantage of ideas and developments originating in various technical fields that have a bearing on basic instrumentation problems.

The technical work of the Office of Basic Instrumentation has two principal objectives: (1) Systematic analysis of available methods and devices in terms of their performance and characteristics, and (2) research on new applications of principles and materials leading to the development of instruments and techniques not now available. This program is carried out largely through the assignment of instrumentation research projects to those NBS laboratories that are best qualified to conduct research in the particular field of science involved. Examples of such work include the high-resolution micromanometer, barium titanate accelerometer, and optical image feedback system, reported upon elsewhere in this document. The Office of Basic Instrumentation also maintains a small laboratory staff for investigation of special

problems and a group of specialists in instrumentation literature who are developing a reference and consultation service to aid in the solution of instrumentation problems.

Weights and Measures. The translation of the national standards of length and mass, and of the derived standards of capacity, to the channels of industry and trade is a matter of great economic importance to the producing, manufacturing, processing, and distributing agencies of this country and to all purchasers of commodities and services. Congress has left to the individual states the regulation of commercial weighing and measuring devices. The National Bureau of Standards serves in a technical advisory and coordinating capacity largely by virtue of its custody and maintenance of the national standards and of its related calibration services. To aid in this work the Bureau maintains an Office of Weights and Measures.

The over-all functions of the Office of Weights and Measures are to assist in increasing the uniformity of weights and measures throughout the United States, and to provide means and methods for making measurements consistent with the national standards of measurement. Commerce and industry have become increasingly aware of the importance of weights and measures administration. Because of this the demand made upon the Bureau for assistance and advice in this field has continued to increase during this period. A definite program of assistance to State and local departments, as well as to business and industry, in the several phases of weights and measures supervision, was planned and successfully pursued.

The Bureau's major medium of cooperation with weights and measures officials, equipment manufacturers, and associated interests is the National Conference on Weights and Measures. The director of the Bureau is President of the Conference, and the chief of the Bureau's Office of Weights and Measures is the Secretary of the Conference. The 38th and 39th meetings of this organization were held in Washington in May 1953 and 1954. In 1953 the official delegate registration was 430, including 201 weights and measures officials from 39 States and the District of Columbia, 95 representatives of manufacturers of weighing and measuring devices, 75 representatives of associations, business, industry, and railroad, and 53 persons from Federal agencies. The 1954 total registration was 455, including 211 weights and measures officials

representing 39 States and the District of Columbia, 110 representatives of manufacturers of weighing and measuring devices, 78 representatives of associations, business, industry, and railroads, and 51 persons from Federal agencies.

One of the technical standing committees of the Conference, in which the Bureau has been especially active, is the Committee on Specifications and Tolerances. This committee is charged with the responsibility of developing the technical requirements for commercial weighing and measuring devices. After research and development the requirements are presented to the Conference for adoption and then to the several States for promulgation.

Actions of the 38th National Conference included the following: Adoption of further specifications and tolerances for commercial weighing and measuring devices; adoption of the Committee on Methods of Sale of Commodities; recommendations on several commodities; adoption of the Committee on Legislation's recommendations on certain labeling and package-marking requirements.

Included in the actions of the 39th National Conference were: Adoption of modifications to codes of specifications and tolerances for linear measures, taximeters, liquid-measuring devices, grease-measuring devices, scales, and the tentative code for farm milk tanks in final form; adoption of recommendations of Committee on Methods of Sale of Commodities relative to certain commodities and their packaging; adoption of the Report of the Committee on Weights and Measures Education dealing with the activities and salaries of weights and measures departments and officials.

Radiation Protection. The National Committee on Radiation Protection, an advisory group made up of experts in various phases of the radiation field and sponsored by NBS, continued work at a high level of activity. The Committee prepares recommendations for safe operating and handling procedures for radioactive substances and other sources of radiation for use by industry, the medical profession, and research workers. The reports of the Committee are published as NBS Handbooks; four were published during the 2-year period and three others were in press.

Research Associate Program. An important area of cooperation between the National Bureau of Standards and American industry is defined by the Bureau's Research Associate Plan. This plan is an arrangement whereby technical, industrial, and commercial organizations can support work at NBS on projects which are of

special interest to them, yet of sufficient general interest to justify use of Government facilities.

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

Since the Research Associate Plan was established in 1920, more than 175 organizations and individuals have supported cooperative research at the Bureau. At present 16 groups are supporting some 42 research associates at NBS. Included are cooperative projects on pyrometric cones, bone char, sugar research, electrodeposition, trailer plumbing systems, dental materials, cement, porcelain enamel, X-ray diffraction methods, masonry mortars reinforced concrete, fire resistance, and asphalts. Research Associate Plans active during the 2 years are as follows:

Sponsor	*Field of Activity*
American Dental Association	Dental research
American Electroplaters Society	Porosity of electrodeposits
American Gas Association	Metering gas flow
American Iron and Steel Institute	Reinforced concrete
American Society for Testing Materials	Cement reference laboratories
American Society of Mechanical Engineers	Elevator research
Asphalt Roofing Industry Bureau	Asphalt roofing research
Bone Char Research, Inc.	Research on adsorbents for sugar refining
Calcium Chloride Association	Hydration of portland cement
Edward Orton Ceramic Foundation	Temperatures of pyrometric cones
McPherson Foundation for Sanitary Research	Trailer plumbing systems
National Research Council	Masonry research and fire resistance
Porcelain Enamel Institute	Test methods for porcelain enamels
Portland Cement Association	Cement research
Sugar Research Foundation	Chemistry of calcium phosphates
Joint Committee of Chemical Analysis X-ray Diffraction Methods (ASTM & Am. Crystallographic Assoc.)	Standard X-ray diffraction powder patterns

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

Radio Propagation Service. One of the most important services of the Bureau is its continuous appraisal and advance warning of ionospheric disturbances which disrupt radio communication. During 1953 and 1954 the radio disturbance warning and forecast services were modified and extended. Concurrent with the move of the Central Radio Propagation Laboratory to Boulder, Colorado, the North Atlantic service was consolidated at Ft. Belvoir, Virginia. Advance forecasts from 1 to 24 days ahead were initiated semiweekly and medium term forecasts for 24 hours ahead were made once a day. Short term forecasts are now issued regularly every 6 hours and are broadcast on WWV. Many reports of ionospheric, solar, geomagnetic, and radio wave propagation data were regularly mailed, telephoned, or telegraphed to such government agencies as the Army, Navy, Air Force, Civil Aeronautics Administration, Federal Communications Commission, Central Intelligence Agency, and the Department of State, as well as to commercial users such as Press Wireless, Radio Corporation of America, Radio Free Europe, and Aeronautical Radio, Inc. Foreign recipients include agencies of the British, Canadian, Australian, and French governments. The regular exchange of ionospheric data was continued with a large number of countries participating in the worldwide program of ionospheric observations.

At the request of the U. S. Senate Committee on Government Operations, studies and recommendations were made concerning the choice of transmitter sites for the International Administration of the State Department. A member of the staff participated in a polar flight with the Air Weather Squadron to determine proper frequency usage to ensure reliable communications in that region. Advice was given to the U. S. Naval Research Laboratory on the monitoring for position fixes of radiosonde balloons which are allowed to travel with the winds at heights of 30,000 feet for dis-

tances up to 8,000 miles. Training in interpretation of ionospheric records was given to U. S. communication personnel, both military and civilian, as well as to foreign government personnel. Information was given to the U. S. Air Force on probable range of maximum usable frequencies for sky-wave transmission during a sunspot cycle for use in antenna design, and to the Federal Communications Commission on methods of predicting sunspot numbers. Daily-hourly tabulations of ionospheric data from Puerto Rico were furnished to the U. S. Army Signal Corps for use in a study of possible correlation between the state of the ionosphere and the development of hurricanes in the Caribbean.

At the request of the Department of Defense, NBS staff members joined a special group of radio propagation experts in an investigation of unusual reports of extended range tropospheric propagation in mountainous regions. It was found that under certain conditions mountain obstacles directly in the path of VHF transmissions could greatly enhance the received signal over that which would have been obtained if the mountain obstacles were not present. A theoretical explanation for this enhancement was advanced and plans were made to take advantage of this effect in future VHF point-to-point applications. Advice was also furnished the Federal Communications Commission Radio Propagation Advisory Committee, relative to appropriate means for predicting the transmission loss to be expected on transmission paths typical of a television broadcast service.

International. Under authority of the Department of Commerce and several educational exchange programs of the Department of State, such as the Mutual Security Act of 1951, Foreign Economic Assistance Act (Smith-Mundt Act), the Fulbright Act, and others, the Bureau conducts visitor and trainee programs which permit foreign scientists and technicians to work, study, and visit at the Bureau. These activities also permit the National Bureau of Standards to keep more closely in touch with scientific developments in other countries. Services to foreign countries take the form of tests, calibrations, and exchange of standards and publications. An example of an advisory service rendered to a foreign country is shown by the service given to Costa Rica under the Point IV program. A staff member has been conducting a survey to determine the "standards" requirements of Costa Rica and to make recommendations for the establishment of a standards

research agency. This service will be supplemented by a program for training personnel in the United States for work in such an institution. Plans are also being drawn for assistance to Brazil in establishing a modern paints, varnishes, and lacquers laboratory.

Bureau members attended meetings of the following organizations: International Electrochemical Commission, International Civil Aviation Organization, International Committee on Optics, International Commission on Illumination, International Astronomical Union, International Scientific Radio Union, International Commission on Radiological Protection, International Union of Pure and Applied Chemistry, International Union on Pure and Applied Physics, International Committee for Uniform Methods of Sugar Analysis, International Congress for Applied Mechanics, International Association of Dental Research, and International Organization for Standardization. At many of the meetings Bureau members presided over sessions and served as chairmen of the U. S. delegation or as officers of the organization. For example the International Association for Dental Research, composed of members from 25 countries, is the leading technical organization in the field of dental research. Its presidency is held by a member of the NBS Dental Research Associate Group sponsored by the American Dental Association. Through representation in this organization the dental research group at the National Bureau of Standards receives and gives valuable assistance to the advancement of organized dental research in the United States as well as assisting in the dissemination of information to advance the dental profession's service to the public.

During 1953, the International Association and the Research Council of the American Dental Association worked out a program for making better use of the technical knowledge of manufacturers, schools, and NBS in dental materials specifications. This is the first technical committee on dental materials that includes the three groups: dental profession, Government agencies, and manufacturers. Close liaison between all the elements in the dental field has thus been established so that the consumers and producers can assist each other in standardizing procedures for evaluating the materials used by both civilian and Federal dentists. This program, typified by the work already begun on dental amalgam and chrome-cobalt casting alloys, should be of great value to both civil and military dental service.

During the 2 years extensive investigations were carried out in collaboration with the standardizing laboratories of the United Kingdom and Canada with a view to establishing international standards of the radioactive nuclides in general use in medicine and research. Only by such means can the clinical and experimental results obtained in one country be compared with those obtained elsewhere. As part of this program the Bureau distributed samples of radioactive carbon-14, phosphorus-32, cobalt-60, and iodine-131 to the National Physical Laboratory and to Atomic Energy of Canada, Limited. The National Physical Laboratory, on its part, distributed to the National Bureau of Standards and Atomic Energy of Canada, Limited, samples of radioactive strontium-90 in equilibrium with its radioactive daughter product yttrium-90 and of gold-198. The latter is very short-lived, decaying to half its intensity in only 2.7 days, so that the most precise planning had to be undertaken to assure the success of the intercomparison. The results obtained in these international comparisons have been so satisfactory that international standards have already been proposed of a number of the radioactive nuclides. The question of establishing secondary means of standardization, to allow the shorter-lived standards to be preserved, is now under discussion.

Intercomparisons were carried out during 1954 between the British and United States primary radium standards and the Canadian National radium standard at the National Physical Laboratory in Teddington, England, the National Research Council of Canada laboratory in Ottawa, and the National Bureau of Standards. During the past year the Bureau actively participated in international conferences dealing with radiation protection and radiation standards. At meetings of the International Commissions of Radiological Units and Radiological Protection, in Copenhagen, a new unit of dosage was adopted for use with high-energy radiations. International agreement was also reached on a much wider scale than ever before in matters of protection from radiation. Recommendations developed by the National Committee on Radiation Protection, which is sponsored by the Bureau, formed the principal basis of the new international recommendations. A permanent organization was established for future intercomparison of standards of radiation dosage and protection.

Also, a primary X-ray standard ionization chamber of the National Bureau of Standards was compared with the National Physical Laboratory standard. As a result, there is now good agreement between these X-ray standards, on which therapeutic use of X-rays depends.

5. Appendices

5.1. Organization of the National Bureau of Standards *

ALLEN V. ASTIN, *Director*

Associate Director for Chemistry
WALLACE R. BRODE

Associate Director for Physics
ROBERT D. HUNTOON

Associate Director for Testing
A. T. MCPHERSON

Associate Director for Administration
NICHOLAS E. GOLOVIN

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY AND ELECTRONICS

F. B. SILSBEE, *Chief*

Resistance and Reactance	—	J. L. THOMAS
Electron Tubes	—	C. P. MARSDEN, JR.
Electrical Instruments	—	F. M. DEFANDORF
Magnetic Measurements	—	R. L. SANFORD
Process Technology	—	L. P. TUCKERMAN
Engineering Electronics	—	P. J. SELGIN
Electronic Instrumentation	—	C. STANSBURY
Electrochemistry	—	W. J. HAMER

OPTICS AND METROLOGY

I. C. GARDNER, *Chief*

Photometry and Colorimetry	—	K. S. GIBSON
Optical Instruments	—	F. E. WASHER
Photographic Technology	—	R. DAVIS
Length	—	L. V. JUDSON
Engineering Metrology	—	I. H. FULLMER

* As of October 1954 .

HEAT AND POWER

F. G. Brickwedde, *Chief*

Temperature Measurements	—	F. G. Brickwedde
Thermodynamics	—	C. W. Beckett
Cryogenic Physics	—	R. P. Hudson (*actg.*)
Engines and Lubrication	—	J. F. Swindells (*actg.*)
Engine Fuels	—	F. L. Howard

ATOMIC AND RADIATION PHYSICS

L. S. Taylor, *Chief*

Atomic Physics Laboratory

Spectroscopy	—	W. F. Meggers
Radiometry	—	E. K. Plyler
Mass Spectrometry	—	F. L. Mohler
Solid State Physics	—	R. G. Breckenridge
Electron Physics	—	L. L. Marton
Atomic Physics	—	L. M. Branscomb

Radiation Physics Laboratory	—	H. O. Wyckoff
Nuclear Physics	—	U. Fano
Radioactivity	—	W. B. Mann
X-rays	—	H. O. Wyckoff
Betatron	—	H. W. Koch
Nucleonic Instrumentation	—	L. Costrell
Radiological Equipment	—	S. W. Smith
Radiation Instruments Branch, Atomic Energy Commission	—	R. L. Butenhoff

CHEMISTRY

E. Wichers, *Chief*

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

MECHANICS

W. Ramberg, *Chief*

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

ORGANIC AND FIBROUS MATERIALS

G. M. Kline, *Chief*

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

METALLURGY

J. G. Thompson, *Chief*

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

MINERAL PRODUCTS

I. C. Schoonover, *Chief*

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

BUILDING TECHNOLOGY

D. E. Parsons, *Chief*

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

APPLIED MATHEMATICS

F. L. Alt, *Acting Chief*

Numerical Analysis	—	J. Todd
Computation	—	M. Abramowitz (*actg.*)
Statistical Engineering	—	C. Eisenhart
Mathematical Physics	—	E. W. Cannon

DATA PROCESSING SYSTEMS

S. N. Alexander, *Chief*

Components and Techniques	—	A. W. Holt
Digital Circuitry and Devices	—	R. D. Elbourn
Digital Systems	—	A. L. Liener
Analog Systems	—	H. K. Skramstad (*actg.*)

OFFICE OF SCIENTIFIC PUBLICATIONS—

Wallace R. Brode, *Chief*

OFFICE OF WEIGHTS AND MEASURES—

W. S. Bussey, *Chief*

OFFICE OF BASIC INSTRUMENTATION—

W. A. Wildhack, *Chief*

ADMINISTRATIVE DIVISIONS

Accounting	—	G. D. Horsburgh
Personnel	—	G. R. Porter
Administrative Services	—	H. P. Dalzell
Shops	—	F. P. Brown
Supply	—	C. B. Kipps (*actg.*)
Management Planning Staff	—	Ivan Asay
Budget	—	W. W. Bolton, Jr.
Internal Audit Staff	—	P. McClenon (*actg.*)
Plant	—	C. A. Dieman

BOULDER LABORATORIES

F. W. Brown, *Director*

CRYOGENIC ENGINEERING

R. B. Scott, *Chief*

Cryogenic Equipment— B. W. Birmingham (*actg.*)
Cryogenic Processes — P. C. Vander Arend (*actg.*)
Properties of Materials— M. M. Reynolds (*actg.*)
Gas Liquefaction — V. S. Johnson (*actg.*)

RADIO PROPAGATION PHYSICS

R. J. Slutz, *Chief*

Upper Atmosphere Research — T. N. Gautier (*actg.*)
Ionospheric Research — R. Bateman
Regular Propagation Services— W. B. Chadwick

RADIO PROPAGATION ENGINEERING

K. A. Norton, *Chief*

Frequency Utilization Research — K. A. Norton (*actg.*)
Tropospheric Propagation Research— J. W. Herbstreit

RADIO STANDARDS

H. A. Thomas, *Chief*

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

ADMINISTRATIVE DIVISION— S. W. J. Welch

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

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

Anchorage, Alaska	Point Barrow, Alaska
Guam	Puerto Rico
Narsarssuak, Greenland	Puuene Maui, T. H.
Panama Canal Zone	

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

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

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5.2 Fiscal Data on NBS Program

PROGRAM AND SOURCE OF FINANCING	Obligations Incurred	
	Fiscal Year 1953	Fiscal Year 1954
SUPPORTED BY NBS APPROPRIATIONS		
Operating Programs:		
Research and Testing	$3,954,847	$2,992,239
Radio Propagation and Standards	2,677,267	1,941,084
Operation and Administration	776,000	750,000
Total	7,408,114	5,683,323
Construction and Facilities Programs:		
Operation and Administration	404,444	238,554
Construction of Laboratories	214,403	568,841
Emergency Facilities, Radiation Physics Laboratory	130,798	.....
Total	749,645	807,395
Total, NBS Appropriations	8,157,759	6,490,718
SUPPORTED BY OTHER AGENCIES		
Department of Defense and AEC:		
Ordnance & Missile Development Programs [1]	24,518,053	3,328,121
Other Programs	14,325,526	14,396,391
Total	38,843,579	17,724,512
Other Agencies	1,240,700	937,670
Total, Other Agencies	40,084,279	18,662,182
Total Program	48,242,038	25,152,900

[1] Programs transferred to the Department of Defense, September 27, 1953.

5.3. Advisory Committees

STATUTORY VISITING COMMITTEE

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

Dr. Detlev W. Bronk, President, National Academy of Sciences (1955)
Professor J. H. Van Vleck, Dean, Division of Applied Science, Harvard University (1956)
Dr. M. J. Kelly, President, Bell Telephone Laboratories, Inc. (1957)
Dr. Clyde E. Williams, President, Battelle Memorial Institute (1958)
Dr. Crawford H. Greenewalt, President, E. I. du Pont de Nemours & Co. (1959)

[Members whose terms expired during reporting period.]

Dr. Robert F. Mehl, Head, Metals Research Laboratory, Carnegie Institute of Technology (1953)
Dr. Donald H. Menzel, Director, Harvard Observatory (1954)

AD HOC COMMITTEE FOR THE EVALUATION OF NATIONAL BUREAU OF STANDARDS

[Appointed at request of Secretary of Commerce from members of nine scientific and technical societies.]

Dr. Mervin J. Kelly of Bell Telephone Laboratories, Chairman of the committee, representing the National Academy of Sciences
Dr. Lee A. DuBridge of California Institute of Technology, representing the American Institute of Physics
Dr. Kenneth S. Pitzer of the University of California, representing the American Chemical Society
Dr. William L. Everitt of the University of Illinois, representing the Institute of Radio Engineers
Dr. James W. Parker of The Detroit Edison Company, representing the American Society of Mechanical Engineers
Dr. Clyde E. Williams of Battelle Memorial Institute, representing the American Institute of Mining and Metallurgical Engineers
Dr. Abel Wolman of Johns Hopkins University, representing the American Society of Civil Engineers
Dr. Guy Suits of the General Electric Company, representing the American Institute of Electrical Engineers
Dr. J. Barkley Rosser of Cornell University, representing the Policy Committee for Mathematics

Committee's Major General Conclusions

[Page 20 of committee report]

1. The National Bureau of Standards is of vital importance to national strength.
2. It is an organization with a splendid record and tradition, internationally recognized and respected.
3. It is, in general, staffed with professional men of competence, integrity and loyalty to the Bureau's functions and objectives.

4. With the increasing range and depth of technology, the need for the services of the National Bureau of Standards becomes even more important and its functions more complex. The accurate determination of physical constants, the properties of materials, standards and standard practices, and testing and evaluation procedures are all essential services for our industrial society.
5. Since the close of the war the technology of the nation has shot rapidly forward. The Bureau's basic programs expanded until 1950 but at a rate beneath that justified by the needs. Since 1950 the decrease in basic programs must be considered as tragic. The ground lost since 1950 should be regained in the next two fiscal years and the programs then expanded as detailed studies by the Director and his advisory committees find necessary.
6. Scientific and technical services to other agencies of Government are important responsibilities of the Bureau. In general, the Bureau has discharged these responsibilities well.
7. The Department of Defense and the Atomic Energy Commission have made broad and significant use of the Bureau. Their use of the Bureau in areas other than development of weapons is of value to the Bureau in its basic programs and should be encouraged.
8. The volume of weaponry development work has become large in comparison with all other activities of the Bureau. Its relative size and its effects on the other Bureau programs make its transfer from the Bureau desirable.
9. Other agencies of the Government do not make as large use of the services of the Bureau as might well be expected. The Committee believes that an increase in the use of the Bureau by other agencies of Government should be encouraged.
10. If the recommendations of the Committee are followed, the Bureau should be in a position to perform its authorized functions in balance at the minimum level for the nation's needs within a four-year period.

AD HOC COMMITTEE ON BATTERY ADDITIVES OF THE NATIONAL ACADEMY OF SCIENCES

[Appointed to evaluate NBS Program in battery additive testing.]

Zay Jeffries, Chairman, Vice President (retired), General Electric Company
Elmer K. Bolton, Director of Chemical Department (retired), E. I. du Pont de Nemours and Co.
William G. Cochran, Professor of Biostatistics, Johns Hopkins University
J. P. Fugassi, Professor of Physical Chemistry, Carnegie Institute of Technology
John G. Kirkwood, Professor of Chemistry, Yale University
Victor K. LaMer, Professor of Chemistry, Columbia University
Lewis G. Longsworth, Member, Rockefeller Institute for Medical Research
Joseph E. Mayer, Professor of Physical Chemistry, University of Chicago
Fred E. Terman, Dean, School of Engineering, Stanford University
Samuel S. Wilks, Professor of Mathematical Statistics, Princeton University

NBS TECHNICAL ADVISORY COMMITTEES

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

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

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

INSTITUTE OF RADIO ENGINEERS

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

AMERICAN INSTITUTE OF PHYSICS

Professor F. Seitz, University of Illinois
Professor J. W. Beams, University of Virginia
Professor D. M. Dennison, University of Michigan
Dr. E. M. Purcell, Harvard University
Professor J. A. Bearden, Johns Hopkins University
Dr. M. Deutsch, Massachusetts Institute of Technology
Dr. Hale Sabine, Celotex Corporation
Professor R. B. Lindsay, Brown University
Dean R. A. Sawyer, University of Michigan

POLICY COMMITTEE FOR MATHEMATICS

Dean Mina Rees, Hunter College
Professor Philip M. Morse, Massachusetts Institute of Technology
Dr. Edward Teller, University of California
Professor David Blackwell, Howard University
Professor A. H. Taub, University of Illinois
Professor Mark Kac, Cornell University

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

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

AMERICAN CHEMICAL SOCIETY

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

AMERICAN CERAMIC SOCIETY

Mr. Ray Birch, Director of Research, Harbison-Walker Refractories Company
Dr. K. C. Lyon, Technical Manager, Indiana Glass Company
Mr. E. P. McNamara, Cambridge Tile Company
Dean Elburt Osborn, Pennsylvania State University
Mr. Wayne Deringer, A. O. Smith Corporation
Dr. Allan Bates, Portland Cement Association

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

John P. McBride, Director of Standards and Necessities of Life, Boston, Mass.
W. M. Harks, Bowser Inc.
Burns H. Dreese, Hobart Manufacturing Company
Alvin V. Hokanson, National Association of Retail Grocers
Charles M. Fuller, Sealer of Weights and Measures, Los Angeles, California
Harry J. Kennedy, Continental Oil Company

AMERICAN SOCIETY OF CIVIL ENGINEERS

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

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 years 1953 and 1954.

RECIPIENT	HONOR	SOURCE
Appel, William D.	Honorary Master of Science	Lowell Textile Institute
	Honorary Professorship	
	Olney Medal	American Association of Textile Chemists & Colorists
	Exceptional Service Award	U. S. Department of Commerce
Astin, Dr. A. V.	Honorary Doctor of Science	Lehigh University
Bailey, E. C.	Meritorious Service Award	U. S. Department of Commerce
Bailey, W. H.	Meritorious Service Award	U. S. Department of Commerce
Bekkedahl, Dr. N. P.	Meritorious Service Award	U. S. Department of Commerce
Bennett, J. A.	Meritorious Service Award	U. S. Department of Commerce
Blum, Dr. William (retired)	Elliott Cresson Medal	Franklin Institute
	A. W. Hothersall Medal	Institute of Metal Finishing (London, England)
	Honorary Doctor of Science	University of Pennsylvania
Bright, H. A.	Meritorious Service Award	U. S. Department of Commerce
Brode, Dr. W. R.	Election to Membership	National Academy of Sciences
Broida, Dr. H. P.	Awarded Fellowship	John Simon Guggenheim Memorial Foundation
Campbell, W. R.	Award in the Engineering Sciences	Washington Academy of Sciences
Carwile, N. L.	First Prize in Eighth Photographic Exhibit	American Society for Testing Materials
Clabaugh, W. S.	Meritorious Service Award	U. S. Department of Commerce
Coblentz, Dr. W. W. (retired).	Second Annual Award	Society for Applied Spectroscopy.
Connor, Mary P.	Meritorious Service Award	U. S. Department of Commerce
Cordero, Fidel	Meritorious Service Award	U. S. Department of Commerce
Craig, D. N.	Meritorious Service Award	U. S. Department of Commerce
Craig, N. C.	Awarded Fellowship	National Science Foundation
Cryogenic Engineering Laboratory.	Exceptional Service Award	U. S. Department of Commerce
Denison, Dr. I. A.	1954 Willis Rodney Whitney Award.	National Association of Corrosion Engineers.
Douglas, C. A.	Meritorious Service Award	U. S. Department of Commerce
Dunmore, F. W. (retired)	Annual Pioneer Award	National Conference on Airborne Electronics.
Geller, R. F.	Honorary Membership	Keramos (honorary fraternity)
Genensky, S. M.	Awarded Fellowship	Brown University
Gilford, S. R.	Meritorious Service Award	U. S. Department of Commerce
Goldberg, Dr. H.	Exceptional Service Award	U. S. Department of Commerce
Haas, P. H.	Excellence in Mechanical Design for r-f Permeameter.	Editors, DESIGN NEWS
	Meritorious Service Award	U. S. Department of Commerce
Hartman, C. C.	Meritorious Service Award	U. S. Department of Commerce
Henry, R. L.	Arthur S. Flemming Award	Junior Chamber of Commerce
	Award in the Engineering Sciences	Washington Academy of Sciences
Hermach, F. L.	Meritorious Service Award	U. S. Department of Commerce
Hoats, Earle D.	Meritorious Service Award	U. S. Department of Commerce
Holt, A. W.	Meritorious Service Award	U. S. Department of Commecre
Hubbard, Dr. D.	Meritorious Service Award	U. S. Department of Commerce
Hughes, L. L.	Meritorious Service Award	U. S. Department of Commerce
Humphreys, C. J.	Meritorious Service Award	U. S. Department of Commerce
Insley, Dr. H.	Exceptional Service Award	U. S. Department of Commerce
Kalmus, H. P.	Exceptional Service Award	U. S. Department of Commerce
Kanagy, Dr. J. R.	Alsop Award	American Leather Chemist Assn.
	Meritorious Service Award	U. S. Department of Commerce

5.4. Awards and Honors (*Continued*)

RECIPIENT	HONOR	SOURCE
Kingsbury, D. E.	Meritorious Service Award	U. S. Department of Commerce
Kline, Dr. G. M.	Award of Merit	American Society for Testing Materials
	Exceptional Service Award	U. S. Department of Commerce
Lamb, Dr. V. A.	Meritorious Service Award	U. S. Department of Commerce
Levedahl, W. J.	Awarded Fellowship	National Science Foundation
Lyons, Dr. H.	Award in the Physical Sciences	Washington Academy of Sciences
Maxwell, Dr. E.	Meritorious Service Award	U. S. Department of Commerce
McLane, Dr. C. K.	Selection as a Fellow	John Simon Guggenheim Memorial Foundation
Meggers, Dr. W. F.	Elliott Cresson Medal	Franklin Institute
	Election to Membership	National Academy of Sciences
Miscampbell, J.	Meritorious Service Award	U. S. Department of Commerce
Modular Design of Electronic Equipment (group award)	Exceptional Service Award	U. S. Department of Commerce
Mong, L. E.	Meritorious Service Award	U. S. Department of Commerce
National Bureau of Standards	Blue Ribbon Award for Exhibit Depicting Services to Science and Industry (Jointly Shared by NBS & Presentation, Inc.)	Advertising Club of Washington
Newman, Dr. S. B.	Meritorious Service Award	U. S. Department of Commerce
Parker, L. L.	Meritorious Service Award	U. S. Department of Commerce
Parsons, D. E.	Award of Merit	American Society for Testing Materials
Pellam, Dr. J. R.	Arthur S. Flemming Award	Junior Chamber of Commerce
	Award in the Physical Sciences	Washington Academy of Sciences
	Meritorious Service Award	U. S. Department of Commerce
Piper, W. M.	Meritorious Service Award	U. S. Department of Commerce
Projector, T. H.	Excellence in Mechanical Design for Searchlight Focusing Device	Editors, DESIGN NEWS
Rabinow, J.	Excellence in Mechanical Design for Conveyor Belt Sorter	Editors, DESIGN NEWS
Reid, M. A.	Awarded Fellowship	National Science Foundation
Roeser, W. F.	Meritorious Service Award	Sigma Tau (honorary engineering fraternity)
Rosenberg, S. J.	Meritorious Service Award	U. S. Department of Commerce
Scal, R. K-F.	Meritorious Service Award	U. S. Department of Commerce
Schrodt, J. P.	Meritorious Service Award	U. S. Department of Commerce
Shafer, M. R.	Meritorious Service Award	U. S. Department of Commerce
Sommer, H.	Meritorious Service Award	U. S. Department of Commerce
Souder, Dr. W.	Citation and Medal	Indiana University
Sparks, C. M.	Special Citation	Goucher College
Stewart, C. L.	Meritorious Service Award	U. S. Department of Commerce
Tallerico, F.	Meritorious Service Award	U. S. Department of Commerce
Taylor, L. S.	Henry Harrington Janeway Award	American Radium Society
Tener, R. F.	Meritorious Service Award	U. S. Department of Commerce
Thompson, G. N.	Exceptional Service Award	U. S. Department of Commerce
Wagman, D. D.	Meritorious Service Award	U. S. Department of Commerce
Wall, Dr. L. A.	Fellowship for Study in Laboratoire de Chimie Physique, Paris	Fulbright Act
Watstein, D.	Wason Medal	American Concrete Institute
Weaver, E. R.	Exceptional Service Award	U. S. Department of Commerce
Weir, C. E.	Meritorious Service Award	U. S. Department of Commerce

5.5. Memorandum of Understanding

Memorandum of Understanding Between the General Services Administration and the National Bureau of Standards With Regard to Specifications and Testing

The General Services Administration in accordance with its responsibilities under Public Law 152, 81st Congress, as amended, Federal Property and Administrative Services Act of 1949, and its Administrative Order No. 113, dated December 14, 1951, titled, "Payment of Fees for Testing Articles and Commodities," and the National Bureau of Standards in accordance with its responsibilities under its basic law as amended in Public Law 619, 81st Congress, mutually agree to the following assignment of responsibilities for specifications and testing:

1. Specifications. The General Services Administration will endeavor to assign to the National Bureau of Standards specification projects for general methods of test and for end products which come within the scope of the technical competence and interest of the Bureau. All consultative and advisory services and those laboratory studies having to do with the development of specifications for general methods of test will be financed by the National Bureau of Standards within the limitations of funds available for this purpose. The laboratory investigations or tests in connection with development of specifications for commodities will be financed by the General Services Administration either from appropriated funds or through funds from other sources within the limitation of such available funds.

The National Bureau of Standards will undertake to compare the quality of products procured under specifications in which it is interested with the quality of products on the open market, using for this purpose its own test results, test results made available by the General Services Administration, and pertinent information from other sources.

The General Services Administration will obtain technical advice and assistance on an individual agency or Ad Hoc arrangement for group meetings to reconcile technical differences when the nature and scope of the problem necessitates such consultation.

2. Testing. When qualification tests are called for by a specification or are required by Federal Supply contracts in connection with procurement under a specification prepared by the National Bureau of Standards, the General Services Administration will designate the Bureau as the laboratory to make the tests. The Bureau will be reimbursed for the cost of such testing by the General Services Administration either from appropriated funds or from charges to the suppliers of the products concerned.

The National Bureau of Standards will undertake to perform acceptance testing of samples submitted to it by the Regional Offices of the General Services Administration in accordance with prearranged agreements. The General Services Administration will make every reasonable effort to send to the Bureau for acceptance testing a portion of the samples of those products for which the specifications have been assigned to the Bureau. The Bureau will be reimbursed for the cost of such testing by the General Services Administration.

The National Bureau of Standards will undertake to conduct a program of interlaboratory testing to aid in maintaining a uniform high quality of acceptance testing on the part of all laboratories concerned with Government procurement that are willing to participate. The Bureau will establish any reference samples that may be required in this program, and will finance the program within the limitations of funds available for the purpose.

3. Effectuation of Agreement. In order to effectuate the policy set forth in this document, the Federal Supply Service, GSA, and the National Bureau of Standards will from time to time as conditions and operations warrant develop supplemental arrangements and procedures involved in establishing the detailed responsibilities and functions covering the assignment of Federal and Interim Federal Specifications for methods of test and end products. Further arrangements and procedures may be made to achieve and maintain effective and efficient materials acceptance testing operations. Such supplemental understandings or arrangements will be consistent with the principles stated herein.

Clifton E. Mack,
Commissioner, Federal Supply Service.

January 29, 1953.

A. V. Astin,
Director, National Bureau of Standards.

January 5, 1953.

5.6. Publications

Publications in the Bureau's Series

Journal of Research. The *Journal*, issued monthly, presents research papers in various fields of physics, mathematics, chemistry, metallurgy, and the engineering sciences. (Annual subscription: domestic, $4.00; foreign, $5.25.) Research Papers published from July 1952 to June 1954, inclusive:

Volume 49, July–December 1952

2336. Fine structure in some infrared bands of methylene halides. Earle K. Plyler and W. S. Benedict.
2337. Overlapping dissociation constants of 4,4′-diaminobenzophenone from spectral-absorbency measurements. Elizabeth E. Sager and Iris J. Siewers.
2338. Calibrating wavelengths in the region from 0.6 to 2.6 microns. Nicolo Acquista and Earle K. Plyler.
2339. Long-tube method for field determination of sound-absorption coefficients. Earle Jones, Seymour Edelman, and Albert London.
2340. Refractive uniformity of a borosilicate glass after different annealing treatments. Leroy W. Tilton, Fred W. Rosberry, and Florence T. Badger.
2341. Solution of systems of linear equations by minimized iterations. Cornelius Lanczos.
2342. Heats of hydration and possolan content of portland-possolan cements. Edwin S. Newman and Lansing S. Wells.
2343. Infrared properties of cesium bromide prisms. Earle K. Plyler and Nicolo Acquista.
2344. Titanium dioxide rectifiers. R. G. Breckenridge and W. R. Hosler.
2345. Infrared spectra of noble gases (12000 to 19000 A). Curtis J. Humphreys and Henry J. Kotkowski.
2346. A viscometric study of the micelles of sodium dodecyl sulfate in dilute solution. Lawrence M. Kushner, Blanton C. Duncan, and James L. Hoffman.

2347. Absorption spectrum of water vapor between 4.5 and 13 microns. W. S. Benedict, H. H. Claassen, and J. H. Shaw.
2348. On calculating the zeros of polynomials by the method of Lucas. Herbert E. Salzer.
2349. Effect of moisture on compressibility of natural high polymers. C. E. Weir.
2350. Thermodynamics of some simple sulfur-containing molecules. William H. Evans and Donald D. Wagman.
2351. A correlation of pollarized light extinctions with crystal orientation in 70 nickel-30 copper alloy. H. C. Vacher.
2352. Magnesium-rich side of the magnesium-zirconium constitution diagram. J. H. Schaum and H. C. Burnett.
2353. A study of the diphenylamine test for aliphatic nitrocompounds. Kivi Grebber and J. V. Karabinos.
2354. Influence of prior strain history on the tensile properties and structures of high-purity copper. William D. Jenkins and Thomas G. Digges.
2355. A description of the arc and spark spectra of rhenium. William F. Meggers.
2356. Hydraulic resistance effect upon the dam-break functions. Robert F. Dressler.
2357. Ultraviolet radiant energy from the sun observed at 11,190 feet. Ralph Stair.
2358. Mass spectra of the tetramethyl compounds of carbon, silicon, germanium, tin, and lead. Vernon H. Dibeler.
2359. Determination of planeness and bending of optical flats. Walter B. Emerson.
2360. Index of refraction of magnesium oxide. Robert E. Stephens and Irving H. Malitson.
2361. Refractivity of potassium bromide for visible wavelengths. Robert J. Spindler and William S. Rodney.
2362. On approximate solutions of systems of linear inequalities. Alan J. Hoffman.
2363. Deuterium and hydrogen electrode characteristics of lithia-silica glasses. Donald Hubbard and Given W. Cleek.
2364. Calorimetric properties of polytetrafluoroethylene (Teflon) from 0° to 365°. George T. Furukawa, Robert E. McCoskey, and Gerard J. King.
2365. Analytical and experimental studies with idealized gas turbine combustors. Fillmer W. Ruegg and Howard J. Klug.
2366. Corrosion of galvanized steel in soils. Irving A. Denison and Melvin Romanoff.
2367. Corrosion of low-alloy irons and steels in soils. Irving A. Denison and Melvin Romanoff.
2368. Loading of quartz oscillator plates. Leland T. Sogn and Philip A. Simpson.
2369. Effects of moderate biaxial stretch-forming on tensile and crazing properties of acrylic plastic glazing. B. M. Axilrod, M. A. Sherman, V. Cohen, and I. Wolock.
2370. Mass spectra of fluorocarbons. Fred L. Mohler, Vernon H. Dibeler, and R. M. Reese.
2371. A method of computing exact inverses of matrices with integer coefficients. J. Barkley Rosser.
2372. Effect of water on the induction period of the polymerization of methyl methacrylate. I. C. Schoonover, G. M. Brauer, and W. T. Sweeney.
2373. Transmittancy of commercial sugar liquors: dependence on concentration of total solids. V. R. Deitz, N. L. Pennington, and H. L. Hoffman, Jr.

2374. Extension of the first spectrum of rhodium (Rh I). Robert J. Murphy.
2375. Heat generation in the setting of magnesium oxychloride cements. Edwin S. Newman, John B. Gilfrich, and Lansing S. Wells.
2376. Stiffness of paper. F. T. Carson and Vernon Worthington.
2377. A convenient small osmometer. G. A. Hanks and S. G. Weissberg.
2378. Low even configurations of the first spectrum of molybdenum (Mo I). Richard E. Trees and Marion M. Harvey.
2379. Methods of conjugate gradients for solving linear systems. Magnus R. Hestenes and Eduard Stiefel.

Volume 50, January–June 1953

2380. The sixth series in the spectrum of atomic hydrogen. Curtis J. Humphreys.
2381. National Bureau of Standards mobile low-level sounding system. P. D. Lowell, W. Hakkarinen, and D. L. Randall.
2382. A simple calculation of dielectric loss from dielectric dispersion for polar polymers. Paul Ehrlich.
2383. Struve function of order three-halves.
2384. Spectral energy distribution of the International Commission on Illumination light sources A, B, and C. Raymond Davis, Kasson S. Gibson, and Geraldine Walker Haupt.
2385. The constants in the equation for atmospheric refractive index at radio frequencies. Ernest K. Smith, Jr., and Stanley Weintraub.
2386. Tables of complete elliptic integrals. J. M. Hammersley.
2387. Assembled polygon for the calibration of angle blocks. Clyde E. Haven and Arthur G. Strang.
2388. On the spectrum of energy in turbulent shear flow. C. M. Tchen.
2389. Beryllium-uranium system. R. W. Buzzard.
2390. Pulsed light system for multiple-cell ultracentrifuge rotor. M. Wales, P. G. Sulzer, and L. C. Williams.
2391. Damping of elastically supported element in a vacuum tube. S. Levy, E. V. Hobbs, W. D. Kroll, and L. Mordfin.
2392. Calorimetric determination of the half-life of polonium. D. C. Ginnings, Anne F. Ball, and D. T. Vier.
2393. Determination of molecular weights of dextrans by means of alkaline copper reagents. H. S. Isbell, C. F. Snyder, N. B. Holt, and M. R. Dryden.
2394. An interferometer procedure applied to the study of the chemical durability of silicates, enamels, and metals. Robert G. Pike and Donald Hubbard.
2395. Transitions and phases of polytetrafluoroethylene (Teflon). Charles E. Weir.
2396. Hydrodynamic effects of gales on Lake Erie. Garbis H. Keulegan.
2397. Twisted square plate method and other methods for determining the shear stress-strain relation of flat sheet. Walter Ramberg and James A. Miller.
2398. Stress-strain relation in shear from twisting test of annulus. Walter Ramberg and James A. Miller.
2399. An intersystem transition in the first spectrum of beryllium. W. R. Bozman, C. H. Corliss, W. F. Meggers, and R. E. Trees.
2400. Synthesis of lactose–1–C^{14} and lactobionic–1–C^{14} delta lactone from 3-β-D-galactopyranosyl–α–D–arabinose. Harriet L. Frush and Horace S. Isbell.
2401. Surface areas of cottons and modified cottons before and after swelling as determined by nitrogen sorption. Florence H. Forziati, Robert M. Brownell, and Charles M. Hunt.

2402. Measurement of multimegohm resistors. Arnold H. Scott.
2403. Temperature dependence of compression of natural rubber-sulfur vulcanizated of high-sulfur content. Charles E. Weir.
2404. On a recursion formula and on some tauberian theorems. N. G. de Bruijn and P. Erdos.
2405. Pyrolysis of styrene, acrylate, and isoprene polymers in a vacuum. S. Straus and S. L. Madorsky.
2406. Tabulation of an integral arising in the theory of cooperative phenomena. Michael Tikson.
2407. A new method for determining linear thermal expansion of invar geodetic surveying tapes. Peter Hidnert and Richard K. Kirby.
2408. Transmission of near-infrared energy by some two- and three-component glasses. Jack M. Florence, Francis W. Glaze, and Mason H. Black.
2409. Refinements in radioactive standardization by 4π beta counting. W. B. Mann and H. H. Seliger.
2410. A new technique for the mass spectrometric study of the pyrolysis products of polystyrene. Paul Bradt, Vernon H. Dibeler, and Fred L. Mohler.
2411. Contributions to the theory of Markov chains. Kai Lai Chung.
2412. Titanium-uranium system in the region 0 to 30 atomic percent of titanium. R. W. Buzzard, R. B. Liss, and D. P. Fickle.
2413. Nonquantized frequency-modulated altimeter. Henry P. Kalmus, John C. Cacheris, and Herbert A. Dropkin.
2414. Infrared spectra of pentachlorofluoroethane, 1,2-dichlorotetrafluoroethane, and 1-bromo-2-fluoroethane. Delia Simpson and Earle K. Plyler.
2415. Modified 1913 reference tables for iron-constantan thermocouples. Robert J. Corruccini and Henry Shenker.
2416. Epitaxial deposits of metals evaporated on salt substrates. Olive G. Engel.
2417. Torsion of anisotropic elastic cylinders by forces applied on the lateral surface. Harold Luxenberg.
2418. On methods for obtaining solutions of fixed end-point problems in the calculus of variations. Marvin L. Stein.
2419. Electron microscopy of synthetic elastomer latices. Robert R. Stromberg, Max Swerdlow, and John Mandel.
2420. Second-order transitions of rubbers at high pressures. Charles E. Weir.
2421. Thermodynamics of the rubber-sulfur system at high pressures. Charles E. Weir.
2422. Laboratory measurement of the corrosion of ferrous metals in soils. W. J. Schwerdtfeger.
2423. Effect of temperature on the electrical resistance and voltage departures (errors) of glass electrodes, and upon the hygroscopicity of glass. Donald Hubbard.
2424. On the numerical solution of parabolic partial differential equations. Gertrude Blanch.
2425. Thermal properties of some butadiene-styrene copolymers. George T. Furukawa, Robert E. McCoskey, and Gerard J. King.

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2426. Fabrication of radio-frequency micropotentiometer resistance elements. Lewis F. Behrent.
2427. Properties of some masonry cement. D. N. Evans, A. Litvin, A. C. Figlia, and R. L. Blaine.
2428. Subsieve particle-size measurement of metal powders by air elutriation. Rolla E. Pollard.

2429. Eigenvectors of matric polynomials. Murray Mannos.
2430. The system barium oxide-boric oxide-silica. Ernest M. Levin and George M. Ugrinic.
2431. Errors introduced by finite space and time increments in dynamic response computation. Samuel Levy and Wilhelmina D. Kroll.
2432. Heat capacity, heats of fusion and vaporization, and vapor pressure of tetrafluoroethylene. George T. Furukawa, Robert E. McCoskey, and Martin L. Reilly.
2433. Hydrothermal preparation of some strontium silicates. Elmer T. Carlson and Lansing S. Wells.
2434. Ultraviolet spectral radiant energy reflected from the moon. Ralph Stair and Russell Johnston.
2435. Phase equilibria in the system MgO-TiO_2. L. W. Coughanour and V. A. DeProsse.
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