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1. General Review

During the last year, a total of 630 unclassified projects were conducted at the National Bureau of Standards. The fields represented by these projects included the physical sciences and engineering. Most of the bureau's effort occurred in physics, mathematics, chemistry, metallurgy, and engineering (electronic, electrical, mechanical, ceramic, chemical, and structural engineering). A considerable amount of work was done of direct interest to the medical, biological, and dental sciences; these activities are concerned with physical problems: radiation measurement and protection, X-rays, physical and chemical properties of blood plasma substitutes, and various instruments.

Within the physical sciences, the Bureau was engaged in basic and applied research, development, calibration and testing, and a variety of scientific services. Subsequent sections of this report present representative aspects of this work. As in recent years, however, the bulk of the Bureau's effort has been directed to research and development for defense. The major programs in this area have been concerned with advanced electronic defense (including proximity fuzes) and guided missiles as well as atomic energy. These programs were sponsored by various agencies of the Department of Defense and by the Atomic Energy Commission. The details of such programs are necessarily classified.

Most of the Bureau's work was conducted in its Washington, D.C., laboratories. However, a growing amount of activity characterized the operations of the other three principal laboratories—at Corona and Los Angeles, California, and at Boulder, Colorado. The NBS Institute for Numerical Analysis, located on the campus of the University of California, Los Angeles, continued its well-established program in mathematical research (particularly numerical analysis), computational services, and electronic computer machine development and operation. The Corona laboratories, acquired during the preceding year from the Navy and suitably equipped, were in full operation with a staff totaling some 400 by the end of the year. The principal interests of this laboratory were missile projects of interest to the Navy and ordnance work of interest to the Army, along with work in electronics (e.g., automatic computers) and optics (e.g., infrared spectroscopy). At Boulder, a major cryogenic engineering facility was constructed for the Bureau by the Atomic Energy Commission. The installation was in full operation by the middle of the year. Meanwhile, a contract had been let for a major radio laboratory, to be erected in the Bureau's Boulder site and scheduled for completion by the spring of 1954.
Typical activities during the year included the following: Thin, high-strength skin for high-speed aircraft was developed. The performance of extremely large orifice meters was studied. A new titanium dioxide rectifier was developed which has promising properties. A new method was devised for sorting out atoms of unequal masses and accurately determining extremely small differences in their atomic masses. A semi-portable radioactive cobalt source was developed for checking radiation instruments in the field. Various radioactive sugars and sugar derivatives were developed. The properties of blood plasma substitutes were studied—particularly critical molecular weight. The properties of self-curing dental resins were investigated. Progress was made in the electrodeposition of aluminum and molybdenum. Improved ceramic dielectrics, important in electronics, were developed. The physical and structural properties of cellular concrete were studied. Methods of solving large sets of algebraic equations were studied. Studies of advanced, automatic electronic computers were underway. The National Bureau of Standards Eastern Automatic Computer (SEAC) was in operation 24 hours per day, 7 days per week, through the year on important mathematical and scientific problems. The Bureau of Standards Eastern Automatic Computer (SWAC), after undergoing a test and proving-in period now operating on a one-shift basis.

As a result of the rapid expansion of the radio frequency spectrum during the war, considerable effort has been placed on exploring the nature of radio waves at the higher frequencies, important for defense communications and for such civilian applications as television. Regular service like the broadcast of radio frequency standards by the Bureau's static transmitter WWV (Maryland) and WWVH (Hawaii) and the issuance of monthly radio propagation predictions (3 months in advance), have been continued. A North Pacific Radio Warning Service was established during the year for the Arctic regions; operating 24 hours per day, 7 days per week, this service is necessary for reliability of radio communications in those regions. Extensive studies of the properties of radio waves between 94 and 1,000 megacycles have been conducted at the Bureau's Cheyenne Mountain Station. A new phenomenon of radio propagation by the ionosphere at the higher frequencies has been discovered and is being intensively studied.

Reflections from the moon were used to send a radio telegraph message. A number of advances were made in the field of basic standards science. Last year was the first full year in which the new NBS atom standard of length was available to industry and other laboratories: mercury-198 lamps were distributed. Wavelengths were determined provide infrared standards, hitherto unavailable, important in analyzing compounds, production control, and detection. Colorimetric specification for a set of color standards for judging petroleum products were prepared to replace the current obsolete standards. Considerable work was done on the standardization of safety colors. The calibration of a 24-sided polygon for calibrating in turn master angle blocks of industry, was completed.
One of the important services of the Bureau to business, industry, and government laboratories is the comparison of working standards with the national standards of measurement. More than 56,000 calibrations were performed by the Bureau. Typical of this activity were the following calibrations: 388 static calibration devices (proving rings, aircraft weighing cells, Amsler boxes, etc.), 743 water current meters, 474 timepieces, 8540 standard weights, 2000 flasks, and 2500 hydrometers. Calibration and testing for the Government included the calibration of more than 20,000 clinical thermometers (sampled from 200,000 purchased) and the sample-testing of 15,800,000rels of cement and 6,700,000 light bulbs. Approximately 30,000 standard samples (substances of known composition) were distributed to industry and private laboratories during the year while the Government itself used 4000 units.

The total funds appropriated by Congress for the Bureau's basic program were 8.6 millions, consisting of 6.9 million for the technical activity and 1.7 millions for administration, shops, plant maintenance and laboratory renovations, etc.

Several organizational changes were made in the Bureau's technical division structure during the last year (see the end of this report for a list of visions and sections). An Associate Director was appointed to coordinate the Bureau's calibration and testing activities. The growth of the ordnance gram made it advisable to form three new divisions in place of the one previous division, and an Associate Director was appointed for this activity. A cryogenic engineering section, part of the Heat and Power Division, was established at Boulder, and a section concerned with the structure high polymers was established in the Organic and Fibrous Materials Division.

The rest of this report presents some of the activities of an unclassified nature of the Bureau during the year. Sections 2 through 16 contain brief reports of representative projects in research and development. Section 17 summarizes the Bureau's work in calibration, testing, and the preparation and issuance of standard samples. The cooperative and advisory activities of the Bureau—within the Government, nationally, and internationally—are outlined in section 18. The list of scientific and technical divisions and sections, noted above, appears in section 19.

2. Electricity

The work in electricity is primarily concerned with the development and improvement of standards and methods of electrical measurement, and studies of properties of materials that are important in electricity and magnetism. The Electricity Division is also responsible for the dissemination of the improved standards to scientific and industrial laboratories. The quantities measured in the course of this work include electrical resistance, current, voltage, inductance, capacitance, energy and power. During 1952
considerable manpower was diverted to projects requested by the Department of Defense. These included the determination of the electrical magnetic properties of materials under extreme or unusual conditions required for the development of new military devices.

Transfer Instruments for A-C Measurements

Higher audio frequencies have been steadily adopted for use in aircraft, induction furnaces and heating, and in certain important electronic developments. One phase of a program to increase the range and accuracy of electrical measurements at these audio frequencies was completed in 1952. Improved transfer thermal converters and associated equipment will enable the Bureau to meet rapidly growing demands for the accurate standardization of ammeters and voltmeters at frequencies higher than previously.

Thermal converters have long been used in thermocouple instruments of moderate accuracy. The Bureau’s study shows that converters which meet special requirements can be used for a-c measurements by transfer methods with an accuracy approaching 0.01 percent. In the transfer method, the instrument is calibrated with direct current, in terms of the fundamental current standards, immediately after each measurement with alternating current. Instruments may be designed for such service, as were these thermal transfer instruments, to obtain increased precision of reading with little dependence on long-time stability and other secondary characteristics. Of fundamental importance, however, is the a-c-dc difference or transfer accuracy. Careful experimental studies of different types and ranges of available thermal converters and a detailed intercomparison of converters with other types of transfer instruments disclosed a number of factors which may limit the transfer accuracy of converters at audio frequencies. Theoretical evaluations of these factors were correlated with actual measurements so that it is now feasible to specify design characteristics needed for the required accuracy.
Good progress has been made on the construction of an air capacitor of this design that its capacitance in electrostatic units can be computed with high accuracy from measurements of its physical dimensions. Supplementary capacitors have been built for stepping up values based on these computations by a factor of several hundred. These can then be compared with values obtained in electromagnetic units by measurements based on our standards of resistance and frequency. This work, when completed, will have two purposes: first, a determination of the ratio of the electrostatic to electromagnetic units which should be a measure of the velocity of light, second, assuming that the velocity of electromagnetic waves is the same at these low frequencies as at the frequency of light waves, an independent method for measuring the unit of electrical resistance in absolute ms.

3. Optics and Metrology
The activities of the Optics and Metrology Division include photometry and colorimetry, refractometry, optical and photographic technology, and applications of metrology which are most dependent upon optical methods. Calibration of line standards, interferometric measurements of length, and measurements of the coefficient of linear expansion are part of this work. Noteworthy work of the division included an international com-
parison of photometric standards which showed the measurements by the NBS to be gratifyingly near the mean of the results of five participating national laboratories. The division established color standards for petroleum products and a dictionary of color names. Initiation of a program measuring the index of refraction of optical glass and crystals over the spectral range within which they are transparent, important applications of an interferometer with optical planes 10 inches in diameter, a new cedure of sensitometry applicable to photographic papers, and a new more convenient method for measuring the coefficient of expansion of veyors’ tapes were also part of the division’s work.

Color Standards for Petroleum Products

Crude oil is black and nearly opaque; as it is refined the color changes through reddish black, dark reddish brown, orange, and yellow to clear. The degree of refinement can thus be judged by color, and measurement plays an important part in the purchase and sale of partial refined oils. For more than 20 years the petroleum industry has depended upon a set of 12 glass color standards from abroad, which imperfectly cated by nonuniform steps this range of oil colors. At the request of the American Society for Testing Materials, the division developed colorimetric specifications for a set of color standards adjusted precisely to the visual color range of petroleum products, covering this range in 16 uniform steps. Also determined were the thicknesses of glass components of American manufacture required in combination to meet these colorimetric specifications.

Dictionary of Color Names

Great dependence is placed on color names by commerce and industry. These names run into the thousands and have their origins in diverse and technologies. Some names identify wide ranges of colors, others intended to pin-point a single color. Existing dictionaries of color names defining each by an actual color swatch have limited usefulness in industry because they fail to show the extent of the color range indicated by the name.

By making use of a method of designating colors by 21 common generic terms (red, yellow, green, light, dark, and so on) developed at the Bureau in 1939, this defect has been overcome. All possible colors are divided into 267 groups, each identified by combinations (such as dark red or green) of these generic terms. A dictionary, prepared at the Bureau under the cooperation of the Inter-Society Color Council, lists alphabetically all 10,000 color names. It coordinates all the published information on color names used by American science and industry including mass-market names, the color names used in textiles and plastics, those used by Federal agencies in the purchase of paint, those used in interior decoration, those used for colors of rocks and soils, and those used in biology, botany, horticulture, philately. Translations from one color language to another (such as Viridis (biology) = Serpentine (fashion) = Mint Green (mass market
\[ t \text{ green (ISCC-NBS) } \] are thus easy, and confusion and misunderstanding may be avoided.

**Fundamental Refractometry**

Techniques were developed for the measurement of indices of refraction strategically important optical media over their entire useful ranges including the near ultraviolet, visible, and infrared regions of the spectrum. The methods for the different regions are now as nearly the same as is feasible considering the differences in the radiations and the different expedients must be employed for their isolation and detection. In particular, the only sensitive method of minimum deviation can now be employed, and consistent data can be obtained for adjustments by dispersion equations. Indices of reflection of optical glass, lithium fluoride, potassium bromide, cesium bromide have been determined and published either in final tentative form. The refractive uniformity of samples of annealed boro-silicate optical glass was precisely determined by interferometric methods found to be as good as \[ \pm 1 \times 10^{-6} \] regardless of the annealing temperature employed within the limits \[ 490^\circ \text{ to } 530^\circ \text{ C} \].

**Spectrophotometers**

Thousands of spectrophotometers are now in daily use in industrial and analytical laboratories as research and analytical tools in physics, chemistry, engineering, and technology. For many years the National Bureau of Standards has prepared and issued permanent glass standards of various types for use in checking the calibration of spectrophotometers in the visible spectrum. Such glass standards are unsuitable in type for use in the ultraviolet, however, and are not permanent in that region.

After several years of work the Bureau has completed measurements on an alkaline solution of potassium chromate, which will serve as a spectrophotometric standard in the ultraviolet. The solution may be readily prepared from the specified composition. It will enable the users of spectrophotometers in the ultraviolet region to check the reliability of the instrument’s photometric scale and to detect important errors resulting in wavelength inaccuracies, stray light, or excessive slit widths.

**Comparison of Secondary Standards**

Forty-five sets of intercomparisons of a group of ten of the Bureau’s interfer bars were made, each bar being compared with all the others. The deviations were reduced by the method of least squares, and the probable error obtained from the comparisons was \[ \pm 0.03 \] micron. Computations were made using only 25 and then 30 sets in the reduction, and it was found that the computed lengths of the standards varied by a maximum of 0.04 micron from those lengths computed from 45 sets of direct comparisons. This indicates that a lesser number of direct observations need be taken, that a high degree of accuracy can still be maintained.
Standard Angles

The calibration of a 24-sided polygon constructed at the National Bureau of Standards has been completed. The polygon has been used to determine the values of the angles of master angle blocks of 15°, 30°, and 45° as each angle block can be compared with a number or a set of 24 angular intervals on the polygon corresponding to the angle of block, it has been possible to determine the angles of these master blocks with probable error not greater than 0.1 second.

Optical Measurements on the Interferometer

A large interferometer which transmits a beam of light 10 inches in diameter has been completed and used for a variety of tasks. The mechanical design is such that this forms a universal instrument of which the components can be combined to form any one of several well-known types of interferometer. The instrument has proved an indispensable tool for the investigation of large disks of optical glass. It has been used to measure the variation of index of refraction within such a disk along a diameter. This interferometer has also been used to test large photographic objects for airplane cameras. In connection with the testing of these large specimens, the Bureau is now equipped to grind and polish disks as large as 30 inches in diameter.

Sensitometry of Photographic Papers

A new method of sensitometry, termed the bar-gamma method, application to photographic papers has been devised. The method provides a simple, rapid means for evaluating papers with respect to their exposure scale and contrast (bar-gamma), and yields results which are reproducible with high precision. An ASA standard dealing with sensitometry of photographic papers based on this method has recently been adopted. A proposed Federal Specification for photographic papers and cloths, embodying this method of sensitometry, is now being prepared.

Coefficient of Expansion of Surveyors' Tapes

A new method was developed for determining the coefficients of linear thermal expansion of geodetic tapes. Coefficients of expansion of 50-meter tapes were derived from measurements of the electric resistance versus ambient temperature (temperatures from 0° to 50° C) and of the linear expansion versus electric resistance (on heating the tapes to various temperatures by passing direct current through the tapes). The new method promises to be more rapid than the old, which required observers to work in uncomfortably hot ambient temperatures.

Thermal Expansion

A long series of measurements of the coefficients of thermal expansion of selected aluminum alloys was completed and a number of papers published. Part of the work consisted of investigating the relationship between chemical composition and thermal expansion.
new type of interferometer (p. 8) used to measure the variation of index of refraction in large glass disks.

4. Heat and Power

To provide a fundamental basis for precise measurements of heat and power, the Bureau has established and maintains a scale of temperature over most of the range from the lowest obtainable to the highest temperatures of incandescent bodies and flames. NBS-calibrated platinum resistance thermometers, thermocouples, and optical pyrometers are used as standards in industrial and university research laboratories. This calibration service represents the only effective way of ensuring that the various laboratories are employing the same temperature scale.

The work includes the determination of quantities of heat by calorimetry; temperature regions extending over a large part of the scale and the thermal properties of solids, liquids, and gases (measured over a wide range of temperatures and pressure)—e.g., heat capacity, heats of vaporization and sublimation, vapor pressure, and thermal conductivity. Coordinate theoretical programs relate the thermal properties to molecular structure and involve the calculation and compilation of tables of thermal properties on the basis of NBS and other data.

From these fields of research the work branches into engineering applications: automotive and aircraft engines and accessories, high pressure pneumatics, and cryogenic engineering. Basic lubrication studies are conducted the characteristics of fluids and bearings for use in mechanical equipment. The Bureau is also responsible for determining and maintaining standards of viscosity and for certifying the viscosities of fluids used for calibrating flowmeters. It maintains the primary standards for the determination of octane numbers of automotive and aviation fuels. Research is con-
ducted to increase the accuracy of these standards and to develop proved measuring instruments and apparatus.

Isotopic Determination of Water Content

A method which uses heavy water to determine the total water content of biological tissues and other materials was developed. This work was part of a program of basic instrumentation sponsored by the Department of Defense and the Atomic Energy Commission. Based on a spectroscopic measurement of the ratio of ordinary to heavy water in a solution containing the sample, the new method can be applied to a large number of same with rapidity and convenience. Recent experiments at the Bureau have shown that it saves considerable time in determining the water of hydration of inorganic crystals and proteins, the extent of hydration of the human body, and the water content of bacterial cells. Other applications to which the technique has been applied include studies of water exchange in and out of water transport through human capillaries, determination of moisture in the atmosphere, and the identification of unknown organic molecules.

A known amount of the material to be analyzed is dissolved in a mixture of deuterium oxide (heavy water) and hydrogen oxide, and the result change in the ratio of deuterium oxide to hydrogen oxide is determined spectroscopically. From the difference in this ratio before and after addition of the sample, the water content of the sample, which is assumed to contain no deuterium oxide, is computed. The analysis takes advantage of the wavelength separation of the emission lines of hydrogen and deuterium oxide to the isotopic shift. By means of a high-frequency electrodeless discharge, water vapor from the sample is dissociated into H and OH and into D and OD. The ratio of excited hydrogen to deuterium, which is a function of the ratio of hydrogen oxide to deuterium oxide, is then determined by measuring the relative intensities of the H line (4861.3 Å) and the D line (4860 Å).

Properties of Gases

The systematic study and preparation of tables of thermal properties of a group of wind tunnel gases, fluorine compounds and, more recently, deuterium compounds has been undertaken. The compilation and calculation of tables of thermodynamic and transport properties of wind tunnel and engine gases including oxygen, nitrogen, hydrogen, carbon dioxide, carbon monoxide, argon, and steam were completed. In all, 100 tables were calculated giving the compressibility, density, heat capacity, entropy, enthalpy, specific heat ratio, sound velocity, viscosity, thermal conductivity, and vapor pressure from low temperatures and pressures to 3,000° K and 100 atmospheres. Particular attention was directed to the properties of air; charts and tables were issued extending the known properties to pressures of 5,000 pounds per square inch.

Reports were issued on a comprehensive investigation of thermodynamic and related properties of fluorine and deuterium compounds.
nal water content of biological tissues and other materials is determined by an opic method (p. 10). A discharge tube (left) is scanned by a monochromator (center), and the photoelectric recorder (extreme right) indicates the change in the ratio of ordinary to heavy water (deuterium).

Entropy, enthalpy, and free energy functions of ten simple fluorine compounds were calculated and reported from 100 to 5,000° K. Theoretical analyses of the molecular data of several groups of related fluorine-containing molecules are in progress. This work is complementary to an experimental program on the same class of materials. The measurements include determinations of the heat capacities of such substances as the fluor polymer, the refrigerants Freon-12 and perfluoropropane, and three important fluorine compounds. The ultimate objective of the experimental and theoretical programs is to obtain a complete ensemble of thermal, molecular, and related properties of all simple and some of the more complex compounds. The accumulation of such data should facilitate the solution of many problems arising from diverse uses of fluorine-containing materials. These materials exhibit an extraordinary range of properties, e.g., they include some of the most stable as well as the most reactive and corrosive all known chemicals.

High-Pressure Pneumatics

A pneumatics laboratory has been established with the cooperation of the Bureau of Aeronautics to further the development and technical evaluation of pneumatic systems and equipment. The need for greater economy in the utilization of weight and space in aircraft has led to new developments in the pneumatics field. For example, although compressed air has been used for years, the trend is toward much higher storage and working pressures as well as greater actuation speeds. Systems are now being designed for storage pressures of 3,000 pounds per square inch and actuation speeds of a few milliseconds. Preliminary calculations indicate that storage pressures of 800 psi are justified and that perhaps even higher pressures may yield further savings in weight and space, but with diminishing returns.
The pneumatics laboratory has placed in operation high-pressure, high-capacity facilities and developed instrumentation to study the pneumatic phenomena of high-pressure, short duration, transient flow. It is now engaged in technical evaluation of airborne pneumatic systems and individual components such as actuators, pressure reducers, special purpose valves, storage reservoirs, and other related equipment. The laboratory is also conducting parallel theoretical and experimental investigations on the physical phenomena associated with the thermodynamics and mechanics of fluid flow.

Low-Temperature Physics

During the past year the National Bureau of Standards low temperature laboratory expanded its research program to include the investigation of magnetic properties of paramagnetic salts. Research on superconducting and properties of liquid helium was continued. Facilities were prepared for the production and storage of liquid helium in large quantities and the attainment of extremely low temperatures by means of adiabatic demagnetization. The liquefier designed at the NBS produces helium at the rate of 15 liters per hour. An improved transfer and storage method permits the storage of liquid helium in large dewar vessels for long periods of time; the total available storage capacity is about 200 liters.

The attainment and measurement of temperatures of the order of a few thousandths of a degree Kelvin are now possible at the National Bureau of Standards through the installation of a large electromagnet, a precise inductance bridge, and associated apparatus. This program provides a method for extending the NBS temperature scale down to the region of few hundredths or thousandths of a degree on the absolute scale. The equipment, utilizing the cooling effect of demagnetization, was designed by the Bureau.

In the field of superconductivity, investigation of the isotope effect continued and developed along several lines. The discovery of this phenomenon in 1950 demonstrated a connection between the isotopic constitution of a superconductor and the superconducting transition temperature. It was shown that the heavier isotopes of a given element become superconducting at lower temperatures than the lighter ones. This knowledge has led to a better understanding of the nature of the superconducting state and has stimulated theoretical physicists to suggest new and promising theories of superconductivity. Special apparatus and precise techniques developed for this work were used to complete a study of thallium isotopes. The results have been in general agreement with those obtained earlier with tin isotopes.

The investigation, in collaboration with the Argonne National Laboratory, of thermal wave propagation in a 4-percent mixture of the rare isotope helium 3 in ordinary liquid helium 4 contributed new results. Temperature measurements, carried out by means of the NBS-developed technique,
yleigh disk method, showed wave velocity of the thermal wave to be increased by the presence of the helium 3 impurity, down to the lowest temperature of 0.9° K. This result is of fundamental significance to the role played by statistics as absolute zero is approached. The disk observations also provided measurements of the kinetic energy density of thermal propagation, showing a marked reduction due to presence of helium 3, as predicted. The torque determinations with the disk also provided the first specific heat measurements for the mixture, in good agreement with the theoretical values.

Lubrication Studies
In many applications the oil fed to a journal bearing serves a dual purpose. While its primary function is to act as a lubricant in the development of a load-carrying film, it also is called upon to carry away the heat generated in the bearing. As a consequence, the rate of flow of oil through the bearing is an important consideration in bearing design and operation. Recently a simplified method of analysis for the rate of oil flow in plain journal bearings was developed from data obtained on the NBS four-bearing friction machine.

The problem of lubricating bearings and the reduction gears in turbo-encop engines operating at extremes of temperature is of considerable interest to the military services. To determine the properties of these lubricants, the Navy Bureau of Aeronautics sponsored a project to investigate the use of the Modified SAE and the McKee Extreme Pressure Lubricants Testing machines for determining the antiwear and the load-carrying properties of turbo-prop lubricants. These machines use two contacting cylindrical test cups which are rotated under load at different speeds to give combined rolling and rubbing action typical of gear teeth. Methods were developed which show promise for controlling the anti-wear and load-carrying properties of turbo-prop lubricants. Thirty-five lubricants were tested. With
regard to low viscosity at low temperature, high load-carrying capacity, wear, and good stability at high temperatures, some of the additive-synthetic oils are superior to mineral oils and appear to be suitable for as turbo-prop lubricants.

Cryogenic Engineering Laboratory, Boulder, Colorado

This year saw the completion of the construction and putting into regular operation of the world's largest liquid hydrogen plant and cryogenic laboratory on the Bureau's site in Boulder. The capacity of the plant is 320 liters of liquid hydrogen per hour. The hydrogen liquefiers and the purifiers for the hydrogen are in duplicate so that the plant can be operated continuously without shutdowns. The hydrogen liquefiers and purifiers were designed and constructed by the Bureau. The liquid hydrogen plant is supplied with liquid nitrogen from two 10,000-liter storage containers which are filled by two liquid nitrogen generators each producing 250 liters per hour.

The liquid hydrogen and liquid nitrogen plants are housed in one building having a floor area of 14,000 square feet. There is also a separate laboratory building with 20,000 square feet of floor space. Both buildings are provided with many safety and anti-explosion features to minimize the hazards of working with liquid hydrogen in large quantities. There is a staff of engineers manning the plant and laboratory buildings.

The Cryogenic Engineering Section was organized to operate the liquid hydrogen and nitrogen plants and to conduct engineering research and development to make the handling of liquid hydrogen in large quantities safer and more convenient. This new section will also determine engineering data for cryogenic equipment.

Jet Engine Fuels

In a reciprocating engine, the power developed is dependent mainly on the compression ratio, but raising the compression ratio tends to increase the knocking tendency of the fuel; high-octane fuels have a lower tendency to knock than ordinary fuels; hence the compression ratio of the engine may be raised and the power increased. However, for jet fuels there is a single critical property comparable to octane number. These fuels should burn fast, leaving a minimum of smoke, and should have a high heat combustion in relation to their weight.

A project is nearing completion in which several hydrocarbons having different structures were synthesized and studied to determine which type of compound satisfied the requirements of a jet fuel to the greatest extent. In complementary studies the compounds prepared were used in the Cleveland Laboratory of the National Advisory Committee for Aeronautics in study of the mechanism of flame propagation. Precise physical constants were measured at NBS; in several cases the unusual structure of the compound warranted measurement of its thermodynamic properties.
Almost every conceivable type of aliphatic hydrocarbon has been repre-
tated in these syntheses. These compounds were purified by fractionation
procedures which resulted in products of very high purity. Some of the
compounds were unknown prior to this work, and several new methods and
niques in organic syntheses were developed.

5. Atomic and Radiation Physics

The results of atomic and nuclear research are of importance to research
atories, medical institutions, industry, the military services, and other
ment agencies. The program of the Atomic and Radiation Physics
vision is primarily concerned with studies of (a) fundamental particles
as atoms, nuclei, neutrons, and electrons (beta-rays), (b) properties
radiations, particularly gamma- and X-rays and ultraviolet, visible and
ared light, and (c) the interactions between such radiations and par-
les. Emphasis is placed on the fundamental research and development
The NBS Cryogenic Engineering Laboratory, Boulder, Colorado, was complete (p. 14). Top: nitrogen liquefier room. Bottom: hydrogen liquefier room.
ecessary to meet the ever-increasing demand in these branches of physics new standards, more accurate values of atomic and nuclear constants, able data on the properties of high-energy radiations, new and improved methods of measurement, and the calibration of sources of radiation and instruments used for detecting these radiations.

A major example of the increased service which the Bureau has given to the Atomic Energy Commission, other Government agencies, and the public is in its calibration program on cobalt 60. As recently as 1949, radioactive cobalt of mass number 60 was of interest to only a few workers engaged in nuclear research. In July through December of that year, less than 1,000 millicuries of cobalt 60 were measured and certified by this Bureau. From January through June 1952, over 250,000 millicuries were measured, requests for an additional two million had to be rejected, and only one million were awaiting test. In addition to the programs for which the Bureau has primary responsibility, many investigations were performed for the Atomic Energy Commission, the Department of Defense, and other Government laboratories. Typical programs included the studies of protection against radiation, the development of radiation detecting instruments, research on semiconductors and solid state electronics, and the development of new techniques in electron physics and mass spectroscopy.

Titanium Dioxide Rectifiers

A major problem in the electrical industry is the conversion of alternating to direct current. This may be done in a number of ways; where moderate amounts of power are needed, such as in a radio or television set or in the electroplating industry, the most convenient method uses a metal rectifier. At present, the most satisfactory devices of this nature use the element selenium. There are, however, two practical difficulties with the use of selenium: (1) the rectifiers cannot operate satisfactorily at temperatures much above 100° C and (2) selenium is currently in acute short supply.

Investigations of the semiconductor titanium dioxide led to the discovery of a new unit that has considerable promise, particularly for high temperature operations. These new rectifiers are made by heating titanium metal in water vapor at temperatures around 600° C. This treatment produces a tightly adherent coat of semiconducting titanium dioxide on the mium-metal base. A second electrode is then electroplated on the oxide layer. Laboratory tests on the electrical properties of these units show that they have some advantages although they are at present not the equal of the selenium rectifiers in some respects. In particular, their rectification is not good at 150° C. The comparative simplicity of their preparation suggests that it may be possible to produce commercial units.

Measurement of Atomic Masses

A new method has been devised for sorting out atoms of unequal masses by accurately determining extremely small differences in their atomic
This is accomplished by measuring the time-of-flight of particles passing through crossed electric and magnetic fields. The method effectively combines the principle of resonance, as utilized in a cyclotron for acceleration of particles to high energies, with the conventional analyzer mass spectrometer for separating atomic masses. The resulting instrument has distinct advantages over either a mass spectrometer or cyclotron because it surmounts several limitations which restrict the accuracy attainable by using either method separately. The measurement of heavier masses has in the past been especially difficult and severely limited in accuracy; the new method appears to be most effective for heavier masses and demonstrated greater power to separate atoms of very slight mass-differences than any previous mass spectrometer.

The utmost precision in determining atomic masses is essential for the development of atomic energy programs and for future research in nuclear theory. The importance of mass values arises from the basic equation used in calculating the amount of energy released in a nuclear reaction or in checking theories of the internal structure of the nucleus. An indication of the degree of accuracy required in measuring these values can be obtained by considering the uranium atom. An error or uncertainty only four parts per million in the value used for the mass of the uranium nucleus results in an uncertainty of one million electron-volts in the calculation of the energy of a nuclear reaction involving uranium.

Solid State Physics

An important new method for studying imperfections in crystals was devised. Crystals are usually considered to be perfectly regular threedimensional arrays of atoms, but it has been realized within the last two years that a great many of the most important electrical and mechanical properties of solids depend on the presence of irregularities, such as missing atoms or atoms trapped in the wrong place in the ideal crystal structure.

Because of the great practical importance of the effects of these imperfections (e.g., in the sensitivity of photographic plates, electrical properties of transistors, chemical catalytic behavior, oxidation of metals, and fluorescent screens on television and radar tubes), there have been many efforts to devise methods for the accurate measurement of the numbers of these defects. Although the presence of the defects could be clearly demonstrated, no method was found that could measure directly the number of defects or give a clear indication of the type of imperfection.

Work at the NBS led to the recognition that these imperfections should influence the absorption of mechanical energy by the crystal, and preliminary tests completed about a year ago showed that the effect could be observed. During the past year a new instrument that makes these measurements rapidly and precisely was devised and placed in operation. The principle of the method is simple; the crystal, in the form of a bar mounted on nearly frictionless supports, is set in vibration and the time requi
new method has been devised for sorting atoms of unequal masses (p. 17). The analyzer of the new mass spectrometer now under construction is partially moved for inspection.

r the vibrations to die away is measured. From studies of the decay oscillation at various temperatures, it is possible to obtain considerable formation about the number and properties of the lattice defects. Measurements thus far completed on a crystal of rock salt have not only revealed many expected features but much new detail that will require extended theoretical study. This method of investigation promises to become a valuable approach to the study of crystal imperfections.

**Helium Scattering**

Until quite recently helium-ion beams were not available with the energy solution and intensity required for the study of the scattering of alpha particles of different energies in helium. Work along these lines had to be done with natural radioactive alpha emitters and hence low intensity and poorly resolved beams. Recent developments in radio-frequency ion sources have made it possible to obtain high intensity helium-ion beams from electrostatic generators. Such sources were recently installed in the two generators of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, and alpha-particle scattering was one of the first problems attacked in cooperation with that Institution. The energy region from 200,000 to 3 million volts has now been covered. This investigation has bridged the unexplored gap in energy between the extremely low energies, where nuclear effects are negligible, and the energies where some of the older work with natural alpha emitters had been carried out in England.
Cobalt-60 Source

Radiation instruments for the detection of gamma rays are now in production for use by the military services and in civil defense. The accurate calibration of these instruments is essential, and it must be possible to check the meters under field conditions. The most direct means for accomplishing this is through the use of a compact source of radiation, and it has been decided that radioactive cobalt will be satisfactory in this connection. Since the quantities of cobalt are large, serious problems of handling and protection arise during its use. A semi-portable radioactive cobalt source combined with the accessory devices for the calibration of instruments has been developed by the NBS. It contains a 9-curie cobalt slug (the quantity of radiation from such a slug is comparable to the largest radium sources used for therapeutic purposes before the war). Basic requirements of the equipment included portability for handling under field conditions, suitability for use on truck, shipboard, laboratory, or on the ground, adequate shielding, compliance with the ICC shipping and storage regulations, and minimum weight and maximum ruggedness consistent with the above requirements. Several prototypes have been constructed and put into use; the equipment is now going into quantity production for the military services.

Betatron Program

To keep pace with the new developments and the application of very high-energy radiations to physics, medicine, and industry, the National Bureau of Standards has procured two electron accelerators for production X-rays in the multimillion-volt region. A 50-million volt betatron and 180-million volt synchrotron are now installed in a specially constructed building designed for obtaining experimental results under a wide variety of working conditions. X-rays from the betatron have been utilized in research since January 1, 1952, and facilities for the removal of the electron beam from this machine are now in the testing stage. Magnetic field measurements and component testing of the synchrotron are virtually completed, and X-rays up to 180 million electron volts should be available for research during the coming year.

The applications of multimillion-volt accelerators in the fields of medical therapy, industrial radiography, and nuclear physics research are increasing rapidly. These applications of high-energy radiations have made it necessary for the Bureau to undertake a broad program of measurement and instrumentation and the determination of safety and operational requirements needed by laboratories and industrial organizations.

Radiometry of Fluorescence

The extensive adoption of fluorescent lighting during the last 15 years for household, recreational, commercial, and industrial uses has aroused interest in its relationship to colors, e.g., in paints, fabrics, chemical reactions, and even the appearance of food. The spectral quality of the radiant
ergy from the lamp determines its usefulness and suitability in a particular application. Experiments conducted during 1952 resulted in the development of a method and associated equipment for use in precise evaluation of the spectral energy distribution of fluorescent lamps.

**Reflection of Gamma Rays**

Accompanying the increased use of radioactive materials in industrial research and medicine is a growing concern for the harm radiations from these materials can inflict on personnel. To aid in reducing these dangers to a minimum, the National Bureau of Standards, in cooperation with the Atomic Energy Commission, has been conducting a theoretical and experimental investigation of radiation shielding devices. This particular program is devoted largely to studies of the distances radiations travel from their sources and the transformations they undergo during the process. The experimental phases of the work are intended to yield information that is essentially general in nature but which can be readily adapted to specific problems. Whenever possible, the experiments are carried out on a small scale or on a model. In this way, a wide variety of investigations can be made of the protection problems associated with devices such as very large nuclear reactors. Ultimately, the accumulated data will form a basis from which radiation barriers of the correct thickness and material may be designed for economical and safe protection.

**Geographic Film Dosimeter**

A compact film badge was developed by the NBS for industrial safety programs and for monitoring in civilian defense. The development resulted from investigations of X-ray effects on photographic film emulsions. Studies involved the effects of high-energy X-rays—ranging from those produced by constant exciting potentials of 50 kv to the radiation from a 100 Mev betatron—and included a determination of the sensitivity and energy dependence of the photographic emulsions.

**Attenuation Data**

The NBS report *X-Ray Attenuation Coefficients from 10 Kev to 100 Mev*, published in May 1952, constitutes the first of a contemplated series of books and tabulations of information on various problems of radiation physics. Radiation physics has grown from a branch of basic atomic research into an important element of all atomic-energy activities and of large areas of biology and medicine. This broad range of application emphasizes the need for tabulations of radiation data, supplemented by elementary expository statements of the principles underlying the phenomena under consideration. Moreover, the preparation of adequate tables of numerical data often requires much new research. X-ray attenuation coefficients were tabulated from 23 materials including water, and concrete. The most commonly used materials were chosen for ablation. However, it is possible to obtain coefficients for an element
Installing the "doughnut" of the new 180-million-volt synchrotron. Magnetic field measurements and component testing of the synchrotron are virtually complete (p. 20).

of any atomic number to a good accuracy by interpolation from the tabulated quantities. The energy range of the incident radiation, 10 Kev to 100 Mev, was covered in 33 approximately equal intervals in a logarithmic scale; that coefficients may be obtained readily at all other energies in this range by graphical interpolation.

A knowledge of the scattering of photons and electrons is essential for applications of radiation theory to research and medicine and is to a large degree dependent upon calculations using the complicated Klein-Nishina formula. Such calculations, presented in graphical form, have now been completed for radiations over the energy range from 10 thousand to 10 million electron volts.

Wavelengths for Infrared Standards

A particularly urgent problem has existed in the spectral region of maximum response for photo-conducting cells recently developed for infrared detection. Wavelengths were known only to one part in one hundred; hence the cut-off of filters could not be determined with any greater accuracy. For this reason, the Office of Naval Research has been supporting a program for the standardization of wavelengths in this region of the infrared spectrum. To date some 300 lines and bands have been measured. For some of these the wavelengths have been determined to a high degree of accuracy with a probable error of one part in 250,000.

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plex Spectra

The analysis of complex spectra supplies the physicist, the chemist, and astronomer with atomic data that are needed in the interpretation of various laboratory and stellar problems. During 1952 the Bureau practically completed three such analyses that have been in progress for more than thirty years. In the first spectrum of chromium, Cr I, more than 100 characteristic radiations were measured for wavelength, their intensities were estimated, and the behavior of many of them in high magnetic fields was studied. Similar results were worked out for more than 2,000 radiations that constitute the second spectrum of chromium.

These data were used to derive, for the neutral and singly ionized chromium atoms, the energy states upon which the designations of the radiations are based, and the amount of energy required to detach, respectively, a valence electron from the atom and ion. In the first spectrum of molybdenum, data on wavelengths, intensities, and magnetic lines have been compiled for nearly 9,000 characteristic radiations. Since molybdenum is chemically a homologue of chromium, their spectra should be similar and, in general, this was found to be the case.

Infrared Spectroscopy

A major research and development program in infrared spectroscopy related topics is underway at Corona, sponsored by the Department of Defense. One of the results of general interest obtained in this work is the development of a new method of characterizing the sensitivity and behavior of photoconducting detectors. The procedure provides a practical means for predicting the effect of certain optical and electronic design changes on the over-all operating characteristics of infrared detection systems. Studies were also made of physical properties of photoconducting detectors, and several new experimental methods were developed—e.g., automatic scanning device for the photographic presentation of sensitivities, a high-speed rotating mirror device that generates sharp contours, a high-speed scanning of the spectrum of objects for use in time-constant studies, and a method for determining the efficiency sensitivity of photoconductors as a function of wavelength.

An important investigation of the atomic spectrum of hydrogen was completed. This study resulted in the discovery of the first member of the Pfund series and the second member of the Pfund series.

6. Chemistry

A wide range of research is conducted in physical, analytical, organic, and inorganic chemistry. Special laboratories are devoted to organic photochemistry, detergents and absorbents, carbohydrates, metals and their compounds, pure substances, electrodeposited coatings, gases, and acid-base indicators and pH standards. Representative activities included the development of new methods of chemical analysis, studies of the nature and
causes of chemical reactions, determination of the physical constant of substances of interest to science and industry, and development of specifications for commodities used extensively by the Government. Most of the NBS standard samples, critical in industrial quality control and in research, originate in the Bureau’s chemical laboratories. There was a marked increase during the year in the research conducted for the Department of Defense. Also increasing effort had to be given to the standard service and to consultative and advisory services for other Government agencies.

**Structure in Detergent Solutions**

One of the most interesting and widely investigated problems in colloid chemistry is that of the determination of micelle size and shape in detergent solutions. Although a program of study of structure in detergent solutions is intended primarily to advance understanding of detergents and the detergent process, the results of such investigations are applicable to a large extent to a host of other industrially important surface-active substances. In addition, detergents can be considered as one of an increasingly important group of materials—the water-soluble polymers. During 1951 Chemistry Division concluded a viscometric study of dilute aqueous solutions of dodecyl sulfate. This work lends support to the view that micelles in this system are spherical.

**Labeled Sugars and Sugar Derivatives**

Sugars labeled in specific positions with radioactive carbon 14 have been sought by research workers in the fields of biology, medicine, and chemistry. A project, begun at the NBS in 1951 and sponsored by Atomic Energy Commission, has yielded a large group of these valuable research tools. Labeled sugars, which are chemically indistinguishable from normal sugars, will be particularly useful in biology, where scientists are interested in discovering the mechanism by which a molecule becomes a source of energy or contributes to the structure of living cells. cause these sugars have an atom of carbon 14 precisely placed in the structure, they can be traced through the complicated chemical reactions that are vital to animal and plant life.

During the current year methods were perfected for the preparation of 12 more C\(^{14}\)-labeled sugars and sugar derivatives. Substantial quantities of these substances were distributed for research in biology and medicine. Methods were published for the preparation of glucose-1-C\(^{14}\), mannose-1-C\(^{14}\), fructose-1,6-C\(^{14}\), and lactose-1-C\(^{14}\). Significant improvements were made in methods for the preparation of d-arabinose-1-C\(^{14}\), d-ribose-1-C\(^{14}\), d-fructose-1,6-C\(^{14}\), D-glucuronic acid-6-C\(^{14}\), D-glucose-6-C\(^{14}\), and D-arabinose-5-C\(^{14}\). Simple methods were developed for the assay of C\(^{14}\) in the term positions of reducing sugars. The value of reaction with radioactive cyanide for the determination of minute quantities of reducing sugars was indicated and analytical procedures were devised.
Bureau is investigating the use of dextran as a blood plasma substitute (p. 27). Dextran solubility in methanol-water solutions is tested by dropping methanol burette into water solutions of dextran. Right: equilibrium ultracentrifuge (center) used in study of blood plasma substitutes and other high polymers.

Organic Compounds

Organic chemistry is assuming increasing importance because of the adoption by industry of many new inorganic compounds. Particularly in the field of metals, where new uses and shortages have driven potential users to seek substitutes and new materials, more detailed knowledge of the chemistry of newer metals is needed. Continuing work is needed to expand the knowledge of metals like titanium, a light metal which is strong as steel and corrosion resistant, and zirconium, a strong heat-resistant material used in atomic piles. Several contributions were made in this field by the Bureau during 1952. One was to the analytical chemistry of titanium, zirconium, silicon, barium, strontium, calcium, magnesium, aluminum, and iron through the development of a reliable method for mining the chemical composition of titanate dielectrics. An outstanding feature of the method was the discovery of an extremely sharp separation of barium from strontium. This same reaction effected the preparation of strontium-free barium salts and of barium-free strontium salts.

The discovery that silver can be precipitated in metallic form from ammoniacal silver solutions by hydrogen peroxide made available a longed-for laboratory method not only for the purification of silver but also for reparation in a finely crystalline state.

A new method for preparing cobalt-free nickel salts made available for first time nickel salts suitable as standards for measurement of magnetic susceptibility, spectrochemical analysis, and for developing testing methods for nickel salts as reagent chemicals. In this connection the potentiometric determination of cobalt in nickel salts by means of ferricyanide was extended to entities as small as 2 micrograms in the presence of one million times as much nickel.

A method was devised for freeing zirconium of common impurities and preparing zirconium sulfate and oxide.
Dissociation Constants

In connection with the Bureau’s program for establishing pH standards, a procedure was developed for the resolution of overlapping dissociation constants of polybasic acids and, hence, for determining the concentrations and pH values of solutions of salts of these acids. The method has been applied successfully to the determination of the constants of d-tartaric acid and, in modified form, to phosphoric acid over the range of temperatures ordinarily encountered in pH measurements. These acids and salts are widely used as constituents of buffer solutions for the regulation of acidity. The determination of accurate values of their dissociation constants is expected to be of practical as well as of theoretical application.

Chemical Thermodynamic Properties

In the continuing project on the collection and critical evaluation of chemical thermodynamic properties of substances, which has received partial support from the Office of Naval Research, a milestone was passed with publication of a 1,200-page Circular (C500) entitled Selected Values of Chemical Thermodynamic Properties. This volume contains values of heat and free energy of formation, entropy, heat capacity, and heats of temperature of transition, fusion, and vaporization for all inorganic compounds and of certain organic compounds (those containing not more than two carbon atoms), where such data were available. Complete references to the original literature are given. Loose-leaf tables to supplement data in the circular and also to give high-temperature thermodynamic properties of chemical substances are being prepared and distributed.

Pure Substances

The evaluation of purity of chemical substances that are “nearly” pure has been less successfully handled in the past than the analysis of mixtures or the assay of extremely pure compounds. Even in the latter case, little indication is usually attained about the nature of impurities. Recent developments in the area of nearly pure substances have yielded far more precise information on the kind of impurities that are present. An apparatus for the fractional melting of completely frozen material is used. As the frozen material melts, the less pure portions are withdrawn first, successive portions tend to wash away that which has preceded them, and the entire sample is melted and divided into separate containers. During the entire operation the system is sealed so that there is no contact with or other modifying influences. Fractions obtained in this way are immediately subjected to purity evaluation by standard procedures. Cryoscopic estimations of purity combined with mass spectrographic analysis have been especially valuable. Present uses have been confined to projects of defense nature, but potential applications occur in the entire range of chemical and industrial fields. The procedure is similar to fractional distillation in that total fractionation is attained and no portion is wasted.
Plasma Substitutes

An increased stockpile of blood plasma and "substitutes" for use either in the armed services or in civilian defense is urgently needed. The Naval Research Council is coordinating a nation-wide research program to assist in the creation of a stockpile adequate in quantity and quality. The Bureau is participating in this program by making a study of the properties of extran, a polysaccharide of high molecular weight derived from the fermentation of sugar. For clinical use, a narrow molecular weight range of extran is required, the lower limit being governed by the permeability of capillary membranes and the upper limit by the tendency of high molecular weights to promote clumping of the red blood cells. The Bureau studied various methods for evaluating molecular weight distributions, including the chemical measurement of end groups, light scattering, ultra-centrifugal methods, solubility in solvent-nonsolvent mixtures, and viscosity. The relations between viscosity, molecular weight, and molecular shape were studied for dextran produced by a method developed by the Northern Regional Research Laboratory (Department of Agriculture). Procedures for characterization of the molecular weight distribution by a combination of fractional precipitation and light scattering, already embodied in a military specification, have been improved in collaboration with the Department of Agriculture and with industry. Copper reducing values of dextran were used to determine number-average molecular weights. This method is based on the postulate that a molecule of dextran has the same reducing power as a molecule of isomaltose. Comparative studies were made of the determination of reducing end groups by several methods. Optical rotations, active indices, and densities were measured on clinical dextran from a variety of sources. A study of the branched structure of the material was made in which the 1,6, 1,4, and 1,3 linkages are determined by olate oxidation and isotope dilution methods.

7. Mechanics

Research work in the field of mechanics includes fundamental mechanics of solids, liquids and gases, improvements in the precise measurement of physical quantities such as density, mass, force and pressure, investigations in the field of aerodynamics, acoustics, structures and hydraulics, and the development of instrumentation and apparatus. Investigations in progress include architectural acoustics, measurement of sound pressure at low frequencies, and precise measurement of pressures up to 200,000 psi (for application in military work and the chemical industry) and of pressures below 1,000,000 psi for aeronautical and laboratory use. Other studies include the measurement of turbulence with hot-wire anemometers at speeds below and above the speed of sound, the impact experienced by an airplane landing, the measurement of backflows of salt water along the beds of...
Sonic Measurement of Physical Properties

With the increasing use of automatic process controls by industry, methods for measurement of physical properties are needed. Two instruments reported last year continued under development during 1964. One is an instrument for measuring, by an acoustic technique, the viscosity coefficients of gases; the other is a device for measuring and recording continuously the velocity of sound in a liquid. A by-product of these investigations was a very fast blocking oscillator, having a rise time of less than 0.02 microsecond and a duration of less than 0.06 microsecond.

Sound Reverberation

The recording correlation meter was improved and applied to study in detail the degree of randomness of the sound field used in making reverberation room measurements. It was found that the measured relation agrees with the theoretically predicted value, with the possible exception of high frequencies, where the researches are being continued.

Viscosity of Gases

Several measurements of the viscosity of gases, sponsored by the Natick Advisory Committee for Aeronautics, were made on apparatus developed in previous years. Measurements were made on a sample of gaseous combustion products at a temperature in excess of 2,000° F at atmospheric pressure. Almost no reliable data on the viscosities of g
his and higher temperatures are available. They are particularly useful in developing aircraft engines in which both the temperatures and gas velocities are high. Measurements conducted on dry air under pressures to 300 atmospheres and temperatures up to about 600° F and on moist air over a less extensive range of temperature and pressure agree closely with values believed to be the best previously available.

**Wire Anemometers at High Speeds**

Because the cooling of a fine heated wire responds quickly to changes in speed, the hot-wire anemometer has proved to be more useful for the estimation of turbulent motions in air than any other known device. Sponsored by the National Advisory Committee for Aeronautics, the Bureau is now exploring the possibilities of this instrument in the transonic and supersonic speed range. Anemometer wires can have a diameter no greater than a few microns if there is to be any hope of adequate frequency response. As the most critical problem has been to find a suitable wire material with sufficient strength. Tungsten, used until very recently, has several disadvantages and cannot be procured in sufficiently small diameters. Within the past few months, rhodium-platinum alloy wires in diameters down to 0.2 microns have been investigated and found to be successful. While still thinner wires can be drawn, it is not yet known whether they will withstand wind loads.

**Fatigue Strength of Structures**

Much of the research on the failure of structures by fatigue under fluctuating loads has been directed toward determination of the behavior of the materials by using carefully finished specimens and testing them to failure under fluctuating loads of constant amplitude. Fatigue strengths so determined are greater than safe design stresses for machine elements and primary structural members because of the absence of stress raisers, such as holes, notches, change of section, etc. The discrepancy between these two stresses depends not only on the shape of the part but also on the material and method of fabrication.

The relationship between the fatigue strength of the basic materials and the fatigue strength of aircraft structures is of particular importance because limitations make the efficient use of materials essential. At the request of the Bureau of Aeronautics, a program of tests designed to determine the relation between fatigue life of a simple structure and that of coupons made from the same material has been completed. Seven simple beams, constructed by an aircraft manufacturer, were subjected to notched bending loads in a specially designed machine. This machine permitted varying the deflection of the middle of the beams with respect to the center to produce failure in from 1,200 to 500,000 cycles. Stresses in the range were computed from the measured loads required to deflect the beams. Both coupons of the material used in the beams were tested over the same range under repeated axial load and the corresponding stress-life relation-
ship determined. The results showed that the beams were about half as strong as the basic material for failures at the same number of cycles in the range from 1,200 to 500,000 cycles.

Another difficulty in predicting the behavior of structures in service results obtained in standard laboratory fatigue tests is due to the unfluctuating loads of constant amplitude in the standard test, where service the maximum load varies widely from cycle to cycle. An airplane, for example, usually has many cycles of low loads with only occasional of high load associated with landing, taxiing, maneuvering or flight during unusual weather conditions. At the request of the NACA, the effect axial load fatigue life of smooth aluminum-alloy sheet coupons subject to two stress amplitudes was measured in special testing machines. Data on several hundred smooth specimens of two aluminum alloy sheet materials over a wide range of stresses and numbers of cycles indicate that for stress levels the linear cumulative damage theory can be used to predict life with an accuracy of 40 percent in the worst case. In the above it is assumed that the damage in terms of life at any stress level is equal to the number of cycles applied at the level divided by the number of cycles required to cause failure at that level. When the sum of the damage equals unity, the specimen will fail.

Stiffened Skin for High-Speed Aircraft

In order to achieve high aircraft speeds, the wings of our most modern airplanes are made extremely thin to reduce drag. At these high speeds the wings are heated considerably by the friction of the air flowing over them, and their strength is thereby reduced. At the request of the National Bureau of Aeronautics, a combination of sheet and stiffening material of small total thickness and high strength was developed. This construction consists of two plates separated by bar-type stiffeners to form a sandwich. The plates and stiffeners are assembled by long rivets passing through the stiffener and both plates of the sandwich. An advantage of such a construction is that it can be readily tapered in both width and thickness to fit the needs of a particular aircraft.

An experimental check was carried out to determine if this type of construction is strong enough to carry the extremely large edge-loads for which it was designed. Seventeen specimens were tested under compressive load simulating conditions in the upper wing surface; two specimens were tested under tensile loads simulating conditions in the lower wing surface. The experimentally determined strength was in good agreement with the strength predicted by proposed design methods.

Tests were conducted to determine the effect of temperature on strength and distortion of wing panels of the above sandwich type and other high-strength types. It was found that, at a uniform elevated temperature, the strength was 20 to 30 percent below the strength of the panel tested at room temperature. Temperature gradients through the panel thickness were found to cause some warping of the specimens but to leave
limit-load gages (circled) installed on the underside of the wing of a F8F "Bearcat" (p. 31). (Photo courtesy of United States Marine Corps.) Idle: side view of partially assembled NBS limit-load gage showing its three or components: the arm (A), cam (B), and gage points (C and D).

-all strength relatively unchanged from that corresponding to the rage temperature.

Limit-Load Gage

A limit-load gage recently developed by the NBS provides a simple means determining whether basic structural components of operational air-
ft have been stressed beyond safe limits. Designed and developed for Navy Bureau of Aeronautics, the gage indicates visually when wings other structural elements have been subjected to loads equal to or greater n a predetermined load beyond which permanent damage may occur.
general the imposition of such loads, which are unpredictable, may be used by rough air, landings, or a sudden change in flight attitude. The ge has been extensively tested for use by high-speed aircraft, and its ess there suggests its use on other types of aircraft and possibly on bridges d similar structures. The limit-load gage is extremely simple and consists y of an arm, a cam, and gage points. Overload is indicated when the a, initially cocked above the cam, flips past it.
Pressure Drops in Oxygen Flow Systems

The pressure drops during gas flow through the components of a system containing tubing, fittings, and orifices must often be computed when systems are being designed. Any such calculation of pressure drop involves many uncertainties and estimates. A theoretical study has been made for the Aero Medical Laboratory of the Air Force of the pressure drops in oxygen equipment systems. Methods of computation for various components for the various flow regimes were developed into uniform form. These methods, with obvious modifications, are applicable to gases.

Laboratory Centrifuges

An ultrahigh centrifuge has been completed. This centrifuge is capable of producing an acceleration of 60,000 g on a 1-lb weight. Prior to development of this equipment, stresses of this magnitude could not be produced in laboratories. A second centrifuge has been developed to handle heavy items. This centrifuge will produce acceleration forces of 10,000 g on equipment weighing 100 lb. This centrifuge allows testing of complex units.

Four-Inch Air Gun

Information about stresses due to acceleration is frequently needed in scientific laboratories. An air gun having a 4-in. diameter has been constructed at the Bureau. This air gun is 96 ft long and is operated by high-pressure air to impel the specimen through the air gun. The specimen received in a catcher box which can be filled with various materials to produce varying values of deceleration. The NBS air gun is a departure from the usual methods of measuring acceleration stresses: such guns have usually been activated by high-pressure air to produce the desired acceleration stress on acceleration of the specimen; in the new gun, low-pressure gradually accelerates the specimen, the desired stresses being produced by deceleration of the specimen as it hits the catcher box.

High-Capacity Load Calibrating Devices

The calibration of four 3,000,000-pound-capacity compression dynamometers for use in calibrating large testing machines has been completed. These dynamometers can be used together to measure forces up to 12,000,000 lb. Prior to the development of these dynamometers, which make use of attached wire resistance strain gages as a part of their load-indicating systems, the highest load which could be accurately measured was approximately 2,600,000 lb. It is expected that the new dynamometers will be used to calibrate a considerable number of the larger testing machines at reduced cost and a saving in time.

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: Dam-Break Problem

The classical solution of the Saint-Venant problem for the flow of water over a dry bed resulting from the breaking of a dam disagrees with experimental results by as much as 50 percent, owing to neglect of the hydraulic stance effect. In investigating this problem the Bureau found a new type of boundary-layer phenomenon, or “tip effect.” This tip effect will be sent not merely in the specific dam-break flow but more generally wherever a positive wave advances along a dry channel. The aerodynamic interpart of this hydraulic problem has also been analyzed, which is case of a gas escaping into a vacuum (as, for example, in a vacuum-supersonic wind tunnel). The problem also has been further generated to encompass a pipe with variable cross-section. Experiments are being conducted to parallel the theoretical investigations of the hydraulic problem. One purpose of the experimental work is to check the mathematical results; another is to amass data to determine the extent of applicability of the Chezy resistance law (which is a steady-flow formula) to highly steady flows.

Density Currents

This project, reported last year and supported by the Office of Chief of Engineers (Department of the Army), has been continued. The emphasis has been placed on the problem of salt-water intrusion from a tideless sea on a rectangular channel in which fresh water flows toward the sea, thus diluting a river mouth. Three series of tests were completed in investigations of the effect of the densimetric Reynolds number (Reynolds number multiplied by a density ratio): effect of channel width and slope on propagation of the saline wave front in the fresh water, form of the wave front, configuration of the wave front when its motion has been arrested by fresh-water current. Each series of tests was carried out with six different salt-water densities and with nine different river velocities for each density used.

8. Organic and Fibrous Materials

The Bureau investigates rubber, plastics, textiles, leathers, and papers. As natural and synthetic materials are considered nondepletable resources and are of great importance to the national economy. The textile industry is the nation's second largest while the comparatively new field of plastics has already assumed fifth place in size and is still growing. These organic materials have certain common characteristic properties due to the long, chain-like structure of their molecules. The complex molecular structure of high polymers, combined with their refusal in many cases to obey the laws of classical physics, has made it very difficult in the past to gain definite fundamental knowledge of their properties. In recent years, however, rapid progress has been made in the science of high polymers, and techniques have been developed for measuring their properties and...
studying their reactions. Many of the new techniques—such as X-ray fraction, infrared spectroscopy, and electron microscopy—are being employed by the Bureau to obtain a better understanding of the fundamental properties of high polymers, both natural and synthetic.

The research program has included studies of rheological properties of synthetic polymers, physiochemical structure of fibers, chemical nature and structure of human tooth enamel and dentin. Applied research on polymeric materials included efforts to make papers and plastics having properties outside the range of those previously thought possible. Significant contributions have been made in applications of polymeric materials to windows on aircraft, structural laminates reinforced with fiber, self-curing resins for dentures and dental fillings, and sole leather, to improve abrasion and fungus resistance. Research was also undertaken to extend the uses of organic materials to replace metals and other substances that are in even shorter supply. The reopening of the Government synthetic rubber plants greatly increased the demand for standards of rubber samples and called for investigations leading to better methods of quality control.

**Deformation of Elastomers**

A knowledge of the fundamentals of deformation and flow behavior of elastomers is valuable in developing new mechanical uses of this rapidly growing class of materials. Since polyisobutylene can be regarded as a prototype linear elastomer, an extensive investigation of its deformation and flow properties has been undertaken. The studies showed that the temperature dependence of retarded elasticity follows the same law as the temperature dependence of viscosity. The logarithm of the viscosity is observed to vary linearly with the inverse square of the absolute temperature and the slope of this relationship is found to be independent of molecular weight.

**Structure and Composition of Collagen**

Only within recent years has the art of tanning started to develop on a truly scientific basis, since tannins and hide alike are such complex chemical structures that adequate methods for studying them were not previously available. The Bureau is using some of these modern methods in study the composition of collagen, the most important constituent of hide and leather-making purposes. By application of chromatographic techniques the polar amino acid content of collagen, hide powder, and gelatin was determined. The glutamic acid content of these materials was also estimated by conversion of this amino acid to pyrrolidone carboxylic acid.

**Structure of Cotton Fibers**

The extent to which the available surface of cotton increases when contact with water is believed to influence the behavior of the fiber during processing and use. As a part of an investigation on the structure of cotton...
rs, surface area measurements were made on a number of cottons that have been stabilized, in the expanded condition resulting from swelling in er, by a process of solvent exchange. Surface areas, calculated from quantities of nitrogen adsorbed at low temperature by the expanded cot- tons, ranged from 4 square meters per gram for a partially methylenated on to 148 square meters per gram for a mercerized cotton of low ma-
ty. Purification and mercerization resulted in increases in the surface ilable after swelling, methylenation produced a decrease, ethylamine atment had no effect. The results indicate that the method will prove ful in evaluating the effects of various treatments on cotton and other ulose fibers.

Structure of Tooth Enamel and Dentin

Great differences exist in the resistance of the teeth of different individ-
to decay, and these differences are thought to be associated in some way h the manner in which the hard, calcified tooth structures are deposited. learn more about the problem, the Bureau, in cooperation with the rican Dental Association, has been investigating the structure of teeth a variety of physical and chemical techniques. For many years it has n known that human teeth fluoresce, emitting visible light when irradi-
d with ultra-violet light. Since in general the fluorescence of a substance very sensitive to small differences in structure or composition, it was felt t a thorough investigation of the fluorescence of enamel and dentin might ng out details of structure not made apparent by other methods.

Certain developmental or growth lines in the tooth were revealed clearly fluorescence photomicrographs obtained from very thin tooth sections minated with high-intensity ultraviolet radiation. Fluorescence spec-
scopy methods were used to study the differences in composition of the rious areas of teeth. Crystallographic methods were used to investigate position of the carbonate content of tooth structures. Many different bonate apatites were synthesized and studied by means of X-ray diffraction methods and by petrographic microscope examination to determine the xts of including carbonate in the apatites. The discovery of a particle proximately 50 Angstrom units in size in enamel and bone by low angle ray scattering and line broadening methods gives additional evidence to ort the theory that the carbonate content of tooth structures is present nclusions rather than as an integral part of the structure.

f-Curing Dental Resins

Self-curing dental resins are of interest to the armed forces because y can be used for direct insertion into cavities and in making artificial utures without special heating equipment. In cooperation with the rican Dental Association, the Veterans' Administration, and the artment of Defense, an investigation of the properties and clinicalavior of these resins has been carried out. The shrinkage of the self-
ing resins was found to be several times that of any other direct filling

35
material. This large shrinkage and the high coefficient of thermal expansion, about 8-10 times that of tooth structures, form probably the greatest disadvantage. The opening and closing of the space around resin filling, resulting from the difference in expansion of the resin and the tooth structure, produces a seepage of oral fluids in and out of the space as the tooth is alternately cooled and warmed. This exchange of fluids may establish conditions favorable for tooth decay. Tests for other properties gave both good and poor results, but clinical studies show that experimental dentures in service up to 2 years have been satisfactory in most cases.

Glass-Fiber Reinforced Plastics

The use of glass-fiber reinforced plastics has increased greatly in the last few years. The armed services have found this type of material adaptable to scores of applications, such as radomes and other parts of aircraft, containers, boats, prefabricated shelters, skis, and toboggans. The variety of applications requires many data on design and production quality control. Under the sponsorship of the NACA and the Wright Air Devel
sheet of aircraft glazing, stretch-formed in the shape of a hat, is removed from vacuum forming vessel (p. 38). Right: apparatus used for determining the testing strength of leather (p. 37). Plungers used in the tests are on the machine.

ent Center, many investigations of this material have been undertaken at the Bureau. It was shown that close control of the many variables involved in production makes possible the fabrication of reinforced plastics with more uniform quality, greater strength, and improved electrical properties.

Stiffness of Paper

The stiffness of paper is a property of importance in a wide variety of uses, such as case liners for shipment of military materials, cards for use in mechanical punched-card systems, and currency paper. Heretofore there has been no very satisfactory method for measuring this property. A new instrument for determining this property has therefore been developed at the Bureau. In the NBS device, the specimen is bent through a given angle, and its stiffness is measured as the torque in a wire suspension. By varying the size of the supporting wires and the angle through which the specimen is bent, papers having a wide range of stiffness can be tested without difficulty in whatever dimensions they happen to be available. The NBS Stiffness Tester is also expected to prove useful in testing the stiffness of such materials as thin plastic sheets and textiles.

urst Test for Fibrous Sheet Materials

For many years the Mullen tester has been used for measuring the bursting strength of fibrous sheet materials, particularly paper and leather. Yet the use of this device has been continually accompanied by difficulties. During the year two research projects intended to obviate such difficulties were completed. In the paper industry, the use of the device is so widespread that it seemed preferable to try to overcome the difficulties, retaining the use of the Mullen tester, while in the leather industry it seemed
practicable to develop a better method with different apparatus. It was found in a device having a cylindrical steel plunger with a hemispherical tip, adaptable for use with a testing machine of 2,000 pounds capacity.

**Multiaxially Stretched Plastic for Aircraft Canopies**

Transparent acrylic plastic is used for aircraft canopies rather than glass because it can more readily be formed to the streamlined shapes required and is lighter in weight. However, this material has a tendency to form tiny cracks or fissures. On some pressurized military airplanes a laminate made of a soft vinyl butyral plastic sandwiched between two outer layers of the acrylic plastic is used to obtain greater protection against shatter of the enclosure when struck by shrapnel. However, the laminate is characterized by increased weight and a greater tendency to craze. We recently conducted at the Bureau showed that by hot-stretching the acrylic laminar sheets the material is made essentially craze-resistant and takes on laminar structure which gives it the improved impact characteristics of an acrylic-vinyl laminate.

**Recovery of Asbestos**

At the request of the Bureau of Ships, the Bureau studied the reclaimed asbestos fiber from various kinds of molded and cloth insulation discarded in large quantities during the repair and refitting of ships. The study involved the removal of extraneous materials and the reduction of the clear cloth to fiber form. It was found that the asbestos could be reclaimed digesting the insulation in either dilute acid or alkali and reducing the clear cloth to fiber form in a paper pulp beater. The recovered fiber was adaptable for making paper and molded compounds. The industry is interested in the use of the reclaimed asbestos as a filler in molded plastic compounds, paper products, and molded lagging (insulation). The recovery of asbestos from the discarded pipe insulation will aid in relieving the shortage of this critical material.

**9. Metallurgy**

Research and development activities in physical metallurgy include the preparation of metals and alloys by melting, casting, hot and cold working, and heat treatment. They also include the determination of structural properties, and behavior under normal and abnormal conditions of use. In general, this program is directed toward a better understanding of metals in order that new or improved metals and alloys may be developed. Since 1950 the basic and applied studies in physical metallurgy have been greatly stimulated by the defense effort. Studies this year have covered the mechanism of the deformation and failure of metals, the effect of adding small amounts of magnesium to cast iron, and the development of several devices designed to speed metal fatigue tests. Considerable effort was devoted to the study of corrosion of metals, as part of a continuing study.
rrosion

Studies of the corrosion of metals have been intensified because of the increasing awareness of the loss to the national economy from this source. Current NBS efforts to reduce this loss include studies of the basic mechanisms of corrosion, determinations of the relative merits of known materials, studies of the basic mechanisms of corrosion, determinations of the relative merits of known materials, and evaluation of protectiveatings and protective devices.

Additional data were secured on the underground corrosion of metals from exposure sites maintained throughout the country; new theories of the mechanism of the corrosion of metals underground and of protection against this corrosion were developed; and experimental confirmation of the importance of these theories was obtained. The theoretically derived value of $-0.85$ volt for the cathodic protection of steel in underground service has been confirmed experimentally, and it has been demonstrated that the rate of corrosion of metals underground can be determined in situ without disturbance. Studies were completed on the corrosion of galvanized iron and of low-alloy irons and steels after underground exposures up to 17 years.

Stress-corrosion cracking, caused by the combined action of stress and corrosion, can be responsible for the spontaneous service failure of objects ranging from brass cartridge cases to stainless-steel coffee urns. Although the problem is an important one, much remains to be learned about the mechanism of stress-corrosion cracking. Corrosion is generally considered to be an electrochemical phenomenon, involving the flow of minute electrical currents between areas of different potential. When most metals are exposed to ordinary atmospheres, a thin oxide film is quickly formed that tends
to protect the metal from further corrosion. According to the most generally accepted theory, which the NBS study tends to confirm, stress-corrosion cracking starts with a scratch or break in this protective film. When protective film is broken through, the freshly exposed metal is more and (more negative) than the surrounding film-covered surface, and if moist is present an electric current flows that causes the metal to be removed from the exposed area.

**Deformation and Failure of Metals**

The failure of metals due to fatigue under stress begins as a brittle crack which spreads until the remaining metal can no longer carry the load. A sudden and complete fracture then occurs. The Bureau is attempting to learn more about the mechanism of this process.

A valuable and useful property of ductile metals is their ability to become stronger and harder by cold-drawing or other cold-working. This increase in strength is usually accompanied by a decrease in toughness, especially when specimens are tested in tension at the same temperature as that used in cold-working. Investigation at the NBS of the creep of high-purity copper was extended to include cold-drawn copper. Specimens were tested for their creep characteristics at 110°, 250°, and 300° F with constant loads in tension. At each test temperature, the cold-drawn copper was markedly superior to the annealed copper in resistance to creep and fracture. This superiority in strength, however, was accompanied by considerable loss in elongation at fracture; for equivalent second-stage creep rates and temperatures, reduction of area at fracture was about the same for both forms of copper.

The mechanism of the deformation and failure of metals at various temperatures and under different kinds of deforming stresses was the subject of several investigations during the year. Short-time tests at high temperatures showed that strain aging at about 300° F and irregularities in ductility at 500° to 700° F are encountered in high-purity nickel. A similar investigation of the fatigue of metals at ordinary temperatures showed that understressing reduces incipient fatigue damage and makes the metal less sensitive to the detrimental effect of notches. Recent results showed that when ingot iron is deformed at low temperatures, slowly in tension rapidly in impact, a shock wave is not essential to the formation of deformation twins and the newly formed twins are as ductile as the parent metal. These findings are contrary to recently proposed theories.

**Structure of Metals**

Addition of small amounts of magnesium to cast iron has received increasing attention recently because it imparts desirable ductile qualities to the iron. It was shown during the year that the nodular graphit produced by the action of magnesium on molten cast iron has the same structure as the flake graphite normally found in cast iron. The improved properties of the nodular iron therefore are due primarily to the shape...
The study of the deformation and failure of metals at low temperatures resulted in findings contrary to proposed theory (p. 40). A specimen submerged in a bath of liquid air is being tested under a 50,000-pound-capacity testing head.

The graphite particles, not to their composition or internal structure. Structural studies showed that certain microstructural constituents can be identified more easily and rapidly by optical microscopy with polarized light than by previously used procedures such as X-ray diffraction.

The solubility of chromium carbides in 18 chromium-10 nickel stainless steel was shown to be much lower than was previously believed. This means that only those steels that have been “stabilized” by titanium or columbium can be relied upon for immunity to intergranular embrittlement under severe conditions of service.

**Metal Fatigue Tests**

Several devices recently constructed at the National Bureau of Standards are proving valuable in speeding metal fatigue tests. The new auxiliary equipment includes devices for stopping the testing machine when a small crack forms in a specimen, apparatus for the uniform polishing of
fatigue test specimens, and a machine for fatigue-testing thin sheet specimens in bending. Because metal fatigue, or fracture under fluctuating stress, is the principal cause of service failure of machine parts, the laboratory study of fatigue of metals is of major importance. The continuing fatigue studies at NBS rely largely on commercially available test machines. Occasionally, however, it is found necessary to supplement these machines with specially-designed equipment such as the present new device.

10. Mineral Products

Research and development in the field of the nonmetallic inorganic mineral products is concerned with the determination of the constitution, structure and physical properties of these minerals with a view to their more efficient utilization for defense purposes and for civilian use. Such products include ceramic oxides, glass, refractories, porcelain enamels, building and concreting materials, lime and gypsum. During 1952 the Bureau conducted investigations pertinent to the development of atomic energy. The development of refractories for jet engines continued, and improvements were made in ceramics with piezoelectric properties for special ordnance applications. The synthesis of useful silicates, especially asbestos, received increasing attention. Detailed work on the structure of specific crystalline compounds of interest in cement technology proceeded satisfactorily. Progress was made in the development and standardization of test methods for cement and concrete. Pioneer work was undertaken in a study of the elastic and plastic properties of single crystals of ceramic oxides. Further progress was made in a study of the constitution of glass, especially with regard to surface properties and phase relationships at high temperatures.

Refractory Concretes

Refractory concretes are composed of aggregates consisting of calcium fire-clay or crushed used firebrick and bonding material of high-alumina hydraulic cement. While it is known that this type of refractory material has important advantages over other types in moderately high temperature installations such as incinerators or heat-treating furnaces in steel plan little is known of the properties in the transition zone of intermediate temperatures. At low temperatures strength is obtained from the hydraulic bond; at high temperatures a ceramic bond is developed. An investigation of properties was carried out by weight-loss determinations at various temperatures, by differential thermal analysis, and by strength determinations at a number of different temperatures. Strength decreases were found to be associated with losses of water from the hydraulic cement at temperatures below 300°C. In the range between this temperature and that at which the ceramic bond was developed (about 1200°C), there was little change in strength. Although the maximum loss in strength exceeded 3 percent, at no time was the residual strength insufficient for the loads encountered in the types of installations for which they are intended.
stitution of Glass

Measurement of the physical and chemical properties of simple glass-forming systems is providing the experimental basis for a much needed theory on the constitution of glass. For example, a recently completed study of the properties of liquids in the system BaO-B₂O₃-SiO₂ (of importance in the manufacture of optical glass) indicates by measurements of refractive indices and other properties that such glasses are not simple solutions of the oxides. New apparatus for the accurate measurement of index of refraction of glasses, simple in construction and obviating the use of ground and polished samples, has been developed as a byproduct of this study. The index of refraction can be determined within ±1 in the fifth decimal place with the new apparatus. One of the important uses of the instrument is in controlling the index of refraction of optical glass: the sample can be prepared and measured in a few minutes.

Investigations of properties of simple glass-forming systems have been extended to include alkali borates. The introduction of alkali oxides into boric acid is accompanied by strong attractive phenomena, shown by a volume contraction of the boric oxide. At low alkali oxide concentrations there is a change in surface tension with temperature is roughly the same as that for pure boric oxide. This is an indication of the strong attraction of the boric oxide for the alkali. The attractive force varies inversely as the square of the alkali ion, the small lithium ion being pulled away from the surface five times more than the larger sodium or potassium ion.

Ceramic Dielectrics

The assurance of an adequate supply of ceramic dielectrics, essential for the development of electronic devices, is extremely important. Heretofore the formulation of bodies to duplicate the performance of useful ceramics required much time and effort, but analytical techniques perfected in the chemistry Division have greatly simplified this problem. On this basis, commercial ceramic bodies made at the Bureau proved to be the equal of those that have been developed in commercial ceramics with respect to dielectric constant and were superior in power factor and temperature-capacitance characteristics.

Life tests of direct-current volume resistivity of ceramics at 200°C reveal exceptionally good insulation properties of dielectrics made from calcium titanate and from mixtures of titania with oxides of rare-earth elements, such as neodymium and lanthanum. A resistivity of more than 10¹⁰ ohm-cm was maintained by these ceramics at 200°C during the schedule in which an increase of 5 volts per mil was made at 7-day intervals for the range of 0 to 30 volts per mil. This behavior necessitates a modification in the concept currently held that all titanates have poor insulation properties when subjected to 5 volts per mil or more at elevated temperatures.

Ceramics for Atomic Energy

Refractory ceramics with favorable nuclear properties are of interest to the Atomic Energy Commission for a great variety of high temperature applica-
Radioactive cobalt is used as a tracer to study the adherence of porcelain enameled steel (p. 45). The specimen is placed in “lead pig” (left), which contains a Geiger-Müller tube. Radioactivity detected by the tube is counted on scientific equipment (center).

Fundamental data concerning the thermal stability, compatibility, and other properties are being obtained for oxides, metals, and carbides. The importance of this connection is highlighted. For this work, a special inductively-heated furnace and a metal-resistance furnace were designed and constructed. Specimens may be heated in these furnaces at very low absolute atmospheric pressures (as low as $5 \times 10^{-5}$ mm of mercury at the beginning of a test) or in a neutral gas in which oxygen is believed to make up less than 1 part in a million. The behavior of these materials in combinations, when heated at temperatures between $800^\circ$ and $2,500^\circ$C, is being evaluated by means of X-ray diffraction techniques, chemical analysis, visual observation, and study of their microstructure. For example, the fundamental phase equilibria have been investigated for four binary systems—$\text{UO}_2-\text{Al}_2\text{O}_3$, $\text{UO}_2-\text{Be}$, $\text{UO}_2-\text{MgO}$, and $\text{UO}_2-\text{SiO}_2$.

**Ceramic Coatings for Electrical Uses**

Specialized ceramic coatings were developed to replace a scarce grade of mica in electronic components. Investigation revealed that unconventional alkali-free coatings were superior to commercial-type porcelain enamels when electrical insulation at elevated temperatures was required. Simulated service tests of ordnance components indicated that several of the developed coatings could successfully replace mica for the intended application.
herence of Porcelain Enamels

An effective ceramic or porcelain-enamel coating must adhere to the metal it is designed to protect. Cobalt oxide effectively promotes adherence of porcelain enamel to iron, and for this reason has long been added to enamel ground (first) coats. Despite a great deal of research, however, the mechanisms by which cobalt oxide promotes adherence are not fully understood. Consequently the fundamental study of adherence of porcelain enamel ground coats to iron, sponsored by the National Advisory Committee for Aeronautics, was continued throughout the year. An investigation of the correlation between roughness of interface and adherence between a cobalt-bearing porcelain enamel ground coat and iron revealed that roughness of interface is a necessary but not sufficient condition for the development of good adherence. Further studies proved that the roughness contributing to adherence is produced during firing by selective corrosion of the iron and solution of iron oxide in the enamel. This selective corrosion was attributed to galvanic currents developed on contact between iron and metallic cobalt deposited from the enamel at the enamel-metal interface. Previous experiments with radioactive cobalt had shown that metallic cobalt is precipitated from the enamel and deposited on the iron during firing. Other experiments showed that galvanic corrosion can and does occur in an electrolyte of molten enamel during the short firing period. These data provided experimental evidence for support of the galvanic theory of adherence.

Another of the fundamental studies completed concerned the evolution of gases during the firing of vitreous coatings on steel. The methods used included direct microscopic observation of bubble formation in the coating during firing, analysis with the mass spectrometer of gases entrapped in the enamels, and the use of radioactive carbon to determine the source of carbonaceous gases entrapped in the enamel. The results showed that principal gases evolved during the firing were carbon monoxide, carbon dioxide, and hydrogen. The blistering that is often observed in the early stage of firing when vitreous coatings are applied to low-carbon steel was found to be caused by evolution of the carbon gases formed by the oxidation of the carbon in the steel. Evidence was obtained that the hydrogen evolved from the reaction between the dissolved water in the coating and the hot iron base slowly diffuses into the coating as the firing continues. Some of the hydrogen also diffuses into the metal. On fast cooling this hydrogen is expelled, causing bubbles to form in the coating at the interface. It was found that practically all of the bubble structure in a normally fired enamel is due to impurities in the clay mill addition. The impurity is probably organic matter adsorbed on the clay particles.

thermochemistry of Mineral Products

Because of their favorable effects on the properties of concrete, pozzolans containing active silica are added to portland cement. There is a need
for methods of test of portland-pozzolan cement to determine the amount of pozzolan which has been added as well as to determine the heat of hydration of the product. The silica renders the blended cement partially soluble in the calorimeter acid used in determining the heat of solution of portland cement. Techniques have been devised for determining the heat of partial solution of portland-pozzolan cements and have been adapted for hardened pastes, which permit the measurement of the heat of hardening of the blended cement. The fraction of the pozzolan which is insoluble in the calorimeter acid is relatively constant. The percentage of pozzolan in the blended cement can therefore be estimated from the weight of unsolved material remaining in the calorimeter at the end of the heat of solution determination. Measurements were made of the heat hardening of mixtures related in composition to the magnesium oxycarbonate cements. It was found that, per gram of MgO, the heats of hardening of all the mixtures were nearly the same and that about 80 percent of the total heat of hydration was evolved in the first 24 hours after mixing.

Cement

A study has been made of the factors which cause differences in sound values in portland cement as determined by different flame photometers. A method was adapted for determining alkalies in cement by the Beck flame photometer and recommended for adoption by ASTM Committee C-1. A proposed method for removing manganese from cement was studied and improved so that it now gives consistently good removal as well as correct calcium values following such removal. Studies have been made of the techniques involved in cement analysis in an effort to determine optimum conditions for ignition, precipitation, and washing of precipitates.

11. Building Technology

The need for economy in the construction, operation, and maintenance of buildings has been the reason in recent years for the National Bureau of Standards to undertake a critical examination of old practices and search for new practices based upon sound engineering principles. By full advantage can be taken of the kind of engineering approach that guided the rapid technological development of the electrical, automotive, and aircraft industries, the building profession must be supplied with curate standards of measurement, new testing procedures, fundamental engineering data and fundamental performance standards. No industrial organization has the facilities to obtain the needed fundamental engineering data. The building profession, therefore, depends on the National Bureau of Standards as the principal laboratory of the Government 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). In addition, the armed services call on the Bur
develop testing methods and to obtain technical information which are immediate value to them.

The fields of interest to the Bureau are those of structural engineering, building codes, safety engineering, fire protection, heating and air-conditioning, and wall, floor, and roofing materials. Typical studies underway include resistance of concrete to impact, problems of the cracking of masonry, studies of the mechanism of fire-spread, performance evaluations of various types of heating systems, measurement of the heat-transfer properties of building materials, evaluation of air-conditioning and refrigeration equipment, and development and evaluation of asphaltic materials, floor faces, and bituminous roofing. Assistance to federal, state, and municipal bodies on the development of adequate building codes and to industry and the Federal Government on the development of safety standards is continuing.

**Thermal Conductivity**

Measurements of the thermal conductivity of homogeneous materials used in building structures have been carried out for several years in the Bureau's hardened hot-plate apparatus. Evaluation of the thermal conductance of walls, floors, and roofs containing air spaces represents a special problem, in that the heat flow depends on the size of the specimen and its orientation: not only must large-scale test specimens be used, but arrangements must be made to allow rotation of the specimen around a horizontal axis, so that the conductance may be measured when the heat flow is horizontal, vertically upward, or vertically downward. To effect this, the Bureau developed the rotatable hot-box apparatus, in which specimens 5 by 8 feet in size could be tested. Building elements of various types have been tested in the rotat-
able hot box, including those with highly-reflective air spaces such as alu-
num surfaces, those with non-reflective air spaces, including surfaces pai-
with black asphalt paint, and those with air spaces of intermediate
reflectivity such as silvercote insulation. Total radiation emissivity has
measured, thermal conductances obtained for various surface emissivi-
and a generalized relationship obtained to correlate the variables.
results should make possible the evaluation of the thermal-insulating qua-
ties of constructions, insulations, and paints used in floors, walls, and ro-

Resistance of Floor Coverings

Under sponsorship of the Office of the Chief of Engineers, Depar-
tment of the Army, the effects of grease, oils, acids, alkalies, and bleaches
were determined on 40 floor covering materials from 17 manufacturers.
materials tested included various linoleums, vinyl, rubber, asphalt, pri-
enamel, and a few proprietary coverings. The softening effect of the
agents was determined by measuring the width of a scratch made wit
sharp-edged tool on the surface of the flooring after exposure of 24 ho-
to the reagent. Most of the floor coverings were damaged somewhat
by kerosene and dilute solutions of sodium hydroxide and acetic acid.
general, vinyl floorings were outstanding in resistance to grease and oil.
Some of the asphalt tiles described as “grease resistant” were softer
appreciably by grease and oils in these tests.

Cellular Concrete

Cellular concretes are lightweight building materials weighing from
to 100 lb/cu ft in which the reduction in density relative to conven-
tional concretes is accomplished by developing voids within the mix prior
to hardening. Cellular concretes have been produced as masonry units
appreciable quantities in Sweden and Germany in recent years but ha-
received comparatively little development as structural materials in t
country.

The Bureau has conducted an exploratory study of a type of cellu-
lar concrete known as “foam” concrete in which, with the aid of foam stabil-
ing agents of the types used in fire protection and rapid agitation of t
component ingredients, a foamed mixture similar in texture to a st
whipped cream is produced. By using lime or portland cement, a pozz-
anic material such as fly ash, and a foaming agent, and subjecting t
mixture to high-pressure steam curing (100 to 150 psi), materials havi-
relatively high strength to density ratios may be obtained. The use of
ash represents a potential economic advantage: it is a waste residue
powdered coal burned in many power plants and is available in lar-
quantities at low cost. Foam concretes having compressive strengths
1000 to 2300 psi have been made at the Bureau in the density range 45
55 lb/cu ft. The Bureau’s concern with this material is to obtain an
evaluate data on its physical properties in order to establish its utility
various construction applications.
Coatings for Concrete Masonry

A laboratory and field survey of commercially available protective coatings for exterior concrete masonry surfaces was made at the request of the Department of the Army. The laboratory phase of the study included the determination of spreading rate, water-vapor permeability, resistance to weather immersion, abrasion, and durability by accelerated testing. Data obtained on the resistance of some of the coatings to wind-driven rain on long-term outdoor weathering specimens prepared on four types of race. Age and condition of coatings were observed for a large number of structures on the West Coast, in the Southwest, the Midwest, and the vicinity of Washington, D. C., and problems were discussed with builders and distributors. One of the principal conclusions from this study was that proprietary portland cement paints and paints made on the job from land cement, when scrubbed into the outside surface of concrete masonry walls, give protection from leakage caused by wind-driven rain. The lamination of sand to these cementitious paints levels the finish surface of high-textured concrete masonry and improves the durability and water resistance of the coating. Such coatings are preferred for use as base coats on open-textured concrete masonry walls.

Window Air-Conditioning Units

The Bureau has undertaken a variety of projects concerned with the evaluation of refrigeration and air-conditioning apparatus. Typical of these is the evaluation of several commercial 3/4-hp window air-conditioning units for the Department of the Army. A portable, 150-cubic-foot warehouse normally used for refrigerated storage served as a calorimeter. The cooling capacity of each of the units was determined for various combinations of indoor and outdoor temperature, up to an outside temperature of 125°F. Air-circulating capacity of the evaporator and condenser fans was measured and a determination of the maximum quantity of ventilating air introduced by the unit into the conditioned space through the fresh-air imer was made. The electrical circuitry, including motor-overload protective devices, was tested under severe conditions.

Radiant Glass Heating Panels

Electrically powered radiant glass heating panels have been evaluated under various conditions of use in the NBS Test Bungalow. The tests, made with outdoor temperatures ranging from 0°F to 32°F, showed that vertical temperature differences in the living zone were moderately low, comparing favorably with most other systems previously tested. The vertical temperature variation was found to be essentially unaffected by the presence or absence of insulation in the walls and storm windows. The average horizontal temperature variation between rooms was 2.5°F less for all observations. Comparisons were made with forced warm-air heating using identical outdoor temperatures and with indoor temperatures maintained the same...
Left: resistance of various floor coverings to effects of grease, oils, alcalis, and acids is determined by scratching exposed specimens with sharp tool (under the gram mark). Width of the scratch gives measure of resistance of various coverings to different reagents (p. 48). Right: concrete cylinder (bottom center) set up for impact testing with drop hammer (p. 48).

at 30 in. above the floor. The radiant system was found to provide more radiant energy than the forced warm-air heating system and more comfort at the floor level. The panels were found to be able to resist thermal shock such as rain water trickling down over the glass panel from windowsill or cold water accidentally thrown on the panel. The results indicate that electrically-heated radiant glass panels constitute a satisfactory method of warming a basementless house from the standpoint of temperature variation in the vertical and horizontal directions, floor temperatures, and general comfort. Even with a house thoroughly insulated, however, electric heating can be expected to entail higher annual heating costs than would coal, oil, or gas in the same structure with little or no insulation because unit cost of electricity is greater than that of other common fuels in most regions.

12. Applied Mathematics

The NBS mathematics laboratories were established in recognition of the need for a centralized, national mathematical consulting and research facility equipped with high-speed automatic machinery, capable of providing analytical and computing services for other Government agencies. In this area the Bureau engages in basic mathematical research directed toward the better utilization of the new electronic computing machines and in addition acts as a service organization, particularly in the fields of engineering, statistics, and quality control, for the Armed Forces, other Government agencies, and industry.

Numerical Analysis

The study of large sets of simultaneous algebraic equations and techniques for the inversion and iteration of matrices has been called
The problem of numerical mathematics. The Method of Conjugate
Descent was investigated and appears to be a most attractive method
in finding the eigenvalues of a matrix. During the year experimental
putations were undertaken in order to test the stability of the method
in terms of round-off errors and related problems. Studies of the numerical
integration of differential equations were continued. This subject is im-
portant because of the large number of applied problems which are
hematically formulated in this manner. The Bureau is accumulating
large body of information concerning the feasibility of solving such
problems by means of large-scale computing machinery.

Research in the mathematical theory of program planning is also one
of the subjects which continued to receive the attention of the Bureau.
A large amount of theoretical work was done on this subject, including
the development of criteria for the existence of solutions for systems
of linear inequalities and investigations of various geometrical aspects of
problem of solving such large sets of linear inequalities.

A number of computational experiments on this and on other problems
were carried out. The goal of such investigations is to find practical
computational methods utilizing high-speed computing equipment. As a
product of the program, the primality of Mersenne numbers was in-
vestigated and toward the end of the year a new prime, $2^{127} - 1$, was dis-
covered. This, the fifteenth perfect number, is by far the largest prime
number to date.

Statistical Engineering

The program in statistical engineering is concerned with the application
of modern statistical inference to complex engineering experiments and
modeling problems and with the analysis of data arising in physical experim-
ents. Advances in the field of experiment design have for the most part
been stimulated by the needs of experimenters in agriculture and biology.
Experimental arrangements that are successful in these fields often
are not applicable in the physical sciences. The NBS has thus developed
even classes of experimental arrangements to meet needs of physical
scientists, and these arrangements have found application in experimental
programs in spectroscopy and temperature measurement at the Bureau.
Work on stochastic processes and on the theory of extreme values was
carried out. The Bureau is now engaged in preparing a bibliography and
guide to statistical methodology literature. Basic research has been under-

aken on distribution-free methods of statistical analysis and on properties
characteristic functions. Perhaps the most important of the theoretical
studies being carried on by the Bureau is that relating to the development of
the theory of measurement. This research is basic to studies of the accuracy
and precision of measurement processes and is directly related to activities
in other sections of the Bureau concerned with establishment and mainte-
nance of basic standards.
Computation

In addition to performing computations requested by Federal agencies, NBS works continuously to create a stockpile of mathematical tables which can be used to facilitate such computations. At the same time, an effort is made to develop new or improved techniques for numerical computation, particularly those adaptable to automatic computing machines, and to train mathematicians in the application of numerical methods. During the year the Bureau provided training in the programming and coding of problems for solution on automatically sequenced, digital electronic computers, and consultant services on the applicability of such computers to special problems.

Essential contributions to the success of Atomic Energy Commission programs were made. Computations required in many other military programs were handled, such as trajectories of various missiles, design of fire-control equipment, and studies of explosions. Major contributions were also made in connection with work for the Office of the Air Comptroller. Programs for the deployment of aircraft of various types were computed, so that there could be a proper balance between various activities of combat, reserve, and training. In this connection, computations concerning a model of the national economy, the so-called Emergency Model, have been completed. The computation of Loran navigation tables was transferred to SEAC, at a considerable saving in time compared to the manual and punched-card computing methods previously used.

13. Electronics

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

During the past year, the work in electronics consisted essentially of an intensification and intensification of the various phases of the program already underway, including new components and new techniques; the publication of a report providing complete information on the preparation and properties of the NBS Adhesive Tape Resistor over a range of resistances from 1 ohm to 10 megohms; investigation of possible methods for prediction of failure in electronic equipment; investigation of the functional behavior of cathodes and gases in electron tubes; development of testing evaluation procedures and test equipment for electron tubes; development of special-purpose electron tubes; development of an improved cuvette recording viscometer; the publication of a complete final report covering four instrumentation systems for the measuring of oil film thickness in journal bearings; the development of a vibration calibration instrument covering a range of 10 microinches to 10 mils over a frequency range of 20 to 10,000 cycles per second.

An increasing amount of technical attention was directed toward application engineering, particularly in the introduction to service of new equipment already developed by the Bureau. Examples of such work include the automatic currency counting equipment developed for the Bureau of the Public Debt, Department of Treasury, and the automatic temperature monitor and the turbine rotor position indicators developed by the Bureau of Ships, Department of the Navy.

Adhesive Tape Resistor

Printed electronic circuits—in which components and wiring are superposed directly on insulating bases—are being used increasingly because they are adaptable to mass production and facilitate miniaturization of equipment. The major disadvantage, however, has been the difficulty of incorporating satisfactory resistors in the circuits. This difficulty was largely overcome in 1951 by development of an adhesive tape resistor method, sponsored by the Navy Bureau of Aeronautics.

In this technique, circuits are first printed in narrow metallic bands on insulating bases, leaving a small gap at each point where a resistance is required; one of the self-adhesive resistors is then cut from a strip and pressed
Instrument for detecting incipient failures of electronic equipment (p. 55)

into position. Much better control of resistance values is possible with previous printed resistor methods, and higher yields of acceptable assemblies are assured. The new method thus appears to combine advantages of printed resistors and of separately manufactured resistors. The NBS tape resistor was developed to withstand the high temperature of very compact equipment and operates satisfactorily at temperatures to 200° C; in other electrical characteristics it is similar to present film-type carbon resistors. During the past year improvements were made by the development of a low-temperature curing process for the tape resistor, permitting its use on nonceramic base material, and an extension of the range of values, which now covers from 100 ohms to 10 megohms in regular production. A reliable and reproducible set-up for the measurement resistor noise has been developed, primarily to assist the tape-resistor program although the equipment can be used on resistors of any type.

Miniatuerization

Under sponsorship of the Navy Bureau of Aeronautics, the Bureau continued the development of techniques applicable to the subminiaturization of military airborne electronic equipment. Because of the importance and wide usage of air-to-ground communication from 220 to 400 Mc, and because of the unusual problems peculiar to those frequencies, miniaturization of an airborne transmitter-receiver in that range presents a difficult task. Design and construction of such a transmitter-receiver was in progress during 1952. The set will have no dimension larger than 24 inch
will be made up of individual plug-in assemblies. Also carried out during the year was the redesign and miniaturization of an airborne radar which has been selected by the Navy as standard equipment for a new class of aircraft.

**Electronic Failure Prediction**

Since most types of electronic equipment failure are preceded by gradual deterioration, the possibility exists that these deteriorations can be detected and predicted. Under sponsorship of the Office of Naval Research, the Navy has undertaken to develop equipment along this line. For shipboard or land equipment the additional circuits required for such predicting may be completely contained, but in airborne units an attachable device would be more practical. In any case the additional circuits and components must not adversely affect the over-all reliability. During the past year cycling tests were conducted which showed that a large percentage of failures are of a predictable nature. Refinements and extensions of these procedures were made and construction of an automatic testing device is begun.

**Cuvette Densitometer**

At the request of the Department of Cardio-Respiratory Diseases of the Naval Medical Center Graduate School, the Bureau has undertaken the development of special instruments to assist with their research programs. The development of this program is the Recording Cuvette Densitometer, which provides a method of making a continuous record of the rate of passage of dye in the heart chambers by observation of blood flow from a peripheral artery. From this record calculations can be made to yield the cardiac output. The NBS Cuvette Densitometer consists of two sections: the photoelectric pickup unit and the power unit. The photoelectric unit is small and compact and can be conveniently located near the patient. The power unit is line-operated, eliminating the necessity for batteries. The system has a high order of stability and absence of fatigue effects in the photocell.

**Film Thickness Indicators**

In studies of engines and engine lubricants, it is often desirable to measure parances between shafts and sleeve- or journal-type bearings during operation. It is usually difficult to obtain such measurements without affecting the operation, particularly at high speeds. A method developed at the NBS by the Navy Bureau of Ships offers a satisfactory solution of the problem. The heart of the new system is a mutual-inductance type of electrical distance-measuring element; variation of the distance of the rotating shaft from two fixed coils results in a readily measurable variation in the coupling between the coils. Three successful variations of the device were developed. The models differ in the type and number of probes used, in sensitivity, in suitability for measuring vibratory conditions, and in type of indicating device. A cathode-ray tube is used with one model to provide a
Probes of oil film thickness indicator (p. 55) are mounted at shaft entrance sleeve-type bearing. Cathode-ray tube (dial face) gives clearance between the shaft and the bearing. (Photo courtesy of U. S. Department of the Navy.)

continuous picture of shaft displacement; the other models give dial indications on a dial or meter.

Steam Turbine Rotor Position Indicator

In modern marine turbines, it has become desirable to have an exact knowledge of the clearance between stationary and moving parts. For this purpose the Navy Bureau of Ships requested noncontacting electrical precision indication devices to record these clearances. NBS first developed shipboard installations which made these measurements external to the turbine. The next phase of the development was to make these measurements inside the turbine. Instrumentation has been completed and installed on an experimental turbine at the Naval Boiler and Turbine Laboratory. This equipment has 13 points of measurement, the majority being inside the turbine. It is expected that information derived from this installation will be of assistance in turbine design. Of particular interest is the correlation between internal and external expansion measurements. As a result, data from external measurements alone may be used with confidence as to inside-turbine clearance conditions.

Vibration Calibrator

The Navy Bureau of Ships desired an instrumentation system to assist in calibrating simple vibration pickups, thereby eliminating the tedious task of individual calibration of each pickup. At the same time, it has been difficult to find standards for measuring high-frequency vibrations when the components are under test for such characteristics as noise, microphonic...
ability. To provide a suitable method for both of these fields of measurement, an instrument based on mutual-inductance micrometer techniques developed by NBS for the calibration of vibration pickups. The in-
tement measures vibrations in the amplitude range of 0.00001 inch to 1 inch over a frequency range of 20 to 10,000 cycles per second and with accuracy of 5%. The equipment is composed of two units, the probe and the electronic chassis. The probe, less than one inch in diameter, contains the mutual-inductance transducer. Provision is made for obser-
ion of the waveform on a cathode-ray oscilloscope.

**Table Gas Clean-Up in Electron Tubes**

Electron tubes filled with a noble gas have a distinct advantage over those filled with a metallic vapor because the gas density is relatively unaltered by temperature changes and gas-filled tubes have rather uniform characteristics over wide temperature ranges. This fact would make gas-filled tubes preferable in many applications except that the gas tends to disappear during operation of the tube. If the factors which determine the rate of clean-up for each of various combinations of metal and noble gases were better understood, tubes might be designed so as to minimize this effect. The Bureau has made a study of the clean-up of helium gas in a charge tube with two additional gas-metal systems: nickel in helium and niobium in helium. The metals were in the form of cylindrical-type probes. Two significant advances were made. It was observed that the clean-up effect due to ion impact is time-dependent, and measurements were modified to take this fact into account. It was also observed that pronounced sputtering was present with each of the gas-metal combinations mentioned above, and this afforded an opportunity to make some measurements on the extent of clean-up due to sputtering.

14. Radio Propagation

The National Bureau of Standards Central Radio Propagation Labora-
try serves as the primary agency of the Government for research in radio wave propagation and for the centralization and coordination of informa-
tion in this field. The laboratory is also responsible for the develop-
ment of the national primary standards for electrical quantities at radio frequencies. Comprehensive programs are undertaken in radio physics and associated geophysical phenomena of the upper atmosphere and the 
oposphere. Extensive laboratory studies are also under way dealing with properties of matter at radio and microwave frequencies and the develop-
ment of techniques for precise measurement of electric quantities in this region. In addition to such research activities, the Bureau does a large 
amount of advisory and consulting work on radio for other agencies of the 
government such as the Department of Defense, the Civil Aeronautics Ad-
ministration, and the Federal Communications Commission, and participates in an advisory capacity to the State Department in the international
Radio propagation. The work in radio propagation is divided into four branches: ionospheric research, regular propagation services, systems research, and measurement standards.

The Ionospheric Research Laboratory conducts basic research on the nature of the upper atmosphere and its ability to reflect radio waves. The laboratory uses a widely separated network of 17 ionospheric sounding stations extending over the American continents and the Pacific area. Data supplied by these observatories provide basic material for research and for determining frequencies to be used in long-distance radio communication.

In addition, a permanent radio propagation field station at Sterling, Va., and a number of temporary field stations are operated for performance of special experiments. Because of the important influence of extraterrestrial effects on ionospheric phenomena, solar and cosmic phenomena are studied. These include radio waves emitted by the sun and other celestial bodies, which also afford a new means for exploration of the universe.

The Regular Services Section is responsible for the centralizing and coordinating of ionospheric data, predictions, and advisory services. To accomplish this, data from ionospheric stations are received and analyzed to find the best frequencies for radio communication predicted. This information is disseminated by means of regular monthly publications of the data and by mail, telegram, and telephone to Government and commercial users and cooperating laboratories both in this country and abroad.

The Systems Research Laboratory applies radio propagation information to the practical problems of radio communication with particular consideration to the advantages and limitations of the types of communication systems involved. It also conducts research on the propagation aspects of various radio systems such as FM and TV, on radio noise, types of modulation systems, and practical improvements of radio predictions and radio navigation systems.

The Measurements Standards Laboratory conducts research on standards and methods of measuring electrical quantities at all radio frequencies. The principal function of this laboratory is the development and maintenance of primary standards of electrical quantities at all radio frequencies, including time and frequency standards which are broadcast continuously by the Bureau's radio station WWV at Beltsville, Maryland, and by an experimental station WWVH in Hawaii. The need, usefulness and scope of these developments of standards, instruments, and techniques of radio-frequency measurement have been increasing steadily.

Radio Astronomy

Cosmic and solar radio waves reaching the earth from outer space limit the minimum usable signal levels for FM broadcasting, television, and communication and radio navigation services in the very-high-frequency range. In recent years, the techniques of radio astronomy have been developed for receiving and analyzing these radiations from outer space. This
had made it possible to obtain information about the positions of stellar bodies and the matter in interstellar space that could not be obtained by an optical telescope.

The program of calculations attempting to account for the enhanced levels of solar radio signals by means of plasma oscillations was continued. Some progress has also been made in the development of a theory for propagation of shock waves in an ionized atmosphere with superposed magnetic field. The theory indicates a departure from a Maxwellian velocity distribution on the part of the electrons. It is hoped to apply the results to explain the fine structure of solar radio bursts and the anomalies in excitation and temperature distribution present in the solar chromosphere.

**Ionospheric Winds**

Monthly ionospheric winds measurements utilizing fading at 2.3 Mc were continued on an intensified scale. The intensified program was made possible by a device which automatically senses and records phase differences in the fading of signals received on separate antennas. A study comparing magnetic field variations with wind speed and direction variations measured in nearby localities was undertaken to ascertain to what extent local wind variations may be correlated with local magnetic variations. The theory of correlation in the fading radio field was studied with a view toward ascertaining the feasibility of measuring the true wind speed using only simultaneous measurements of the field. Plans were completed to acquire a special low-frequency correlator capable of making a complete auto- and cross-correlation analysis of fading data.

**Low-Frequency Ionosphere Recorder**

The Bureau has operated sweep recorders in the high frequency range from 2 to 25 Mc for a number of years to investigate the upper regions of the ionosphere. Until recently the complexities involved in designing a low-frequency recorder seemed insurmountable. During 1952 NBS completed and successfully operated a multifrequency, sweep-frequency, ionosphere recorder covering essentially 50 kc to 1100 kc in less than one minute. This was the first time that such a recorder had ever been operated. Its completion meant the overcoming of three major obstacles: a large operating frequency ratio, antenna ringing, and loss of effective output due to antenna inefficiency. The transmitter operates near the million watt level.

The recorder furnished daylight information about the E layer not before available. A remarkable phenomenon noted on continuous motion picture records of repeated sweeps was the formation of the regular F2 layer at sunrise. It appeared to grow out of the night F2 layer, dropping in virtual height and developing a cusp within a period of four minutes. Details of the F2 extraordinary reflections at frequencies below the gyro frequency were visible as were details of certain types of stratification.
Transmitter assembly of new ¾-million-watt low-frequency ionosphere recorder (60). Power supply (left), low level amplifiers and pulse generator (middle), amplifier (right).

Radio Navigation

A large portion of the low-frequency spectrum is allocated to radio navigation systems. To improve the effectiveness of such systems, much basic research was done on propagation. The most significant achievement of the past year is a theoretical determination of the total phase-change of a radio wave propagated over a spherical earth. Accurate methods for computing corrections to take into account the effect of mountainous terrain and changes in the atmospheric refractive index were also developed. These theoretical calculations were checked by actual measurement and show an improvement in accuracy of at least one order of magnitude over previous theoretical calculations.

Modulation Studies

Because of the scarcity of space in the radio-frequency spectrum and the necessity for more reliable communications, a study of the efficiency of various types of modulation and methods of communicating over radio paths has been undertaken. The frequency spectra, including phase information, were obtained for a large number of modulating wave forms applied as amplitude, frequency, or multiple modulation to a carrier frequency. The bandwidths necessary for satisfactory system operation were
obtained for some specific systems, such as frequency shift keying. In addition, simplified formulas were derived for the interference produced by a number of waveforms employed in both AM and FM systems. Special formulas were derived for the interference bandwidth at any specified frequency for frequency shift teletype, frequency shift facsimile, and sub-carrier frequency shift facsimile. Other work includes a review of the conditions necessary for high-frequency broadcast reception and the derivation of the formula for calculating the noise figure of an FM receiver or the minimum satisfactory input carrier for a given output signal-to-noise ratio.

New laboratory facilities were established for the modulation studies. A linear modulator which is capable of simultaneous or independent operation at different frequencies and frequency modulation was constructed. Initial operation of the equipment in conjunction with a panoramic analyzer showed good agreement with the spectrum calculations. A pulse generator capable of generating arbitrary pulse forms of finite length was completed for use in determining optimum pulse shapes and filter shapes for various applications.

VHF Propagation Research

Research was continued on the problem of allocation of radio-frequency channels to very-high-frequency communication and broadcasting services. Experimental studies were used to determine the effects of irregular terrain and of meteorological variations in the lower atmosphere in addition to the tropospheric field-strength recordings made by the National Bureau of Standards, continuous field-strength data for the current year were obtained on fifty-three paths by seven contracting groups at strategic locations throughout the United States.

Considerable progress was made in the development of two different theories of very-high-frequency radio propagation which are intended to explain the high field strengths observed at great distances beyond the horizon. One theory explains the high observed field strengths on the basis of partial reflections occurring in a horizontally homogeneous atmosphere, while the other theory attacks the problem from the standpoint of scattering from isotropic atmospheric inhomogeneities. Further work, both experimental and theoretical, is required before conclusions can be drawn.

Terrain Effects on VHF Propagation

In cooperation with the United States Army Signal Corps, a mobile radio field-strength laboratory was used to study the directivity of directive antennas over irregular terrain, at frequencies from 49 to 460 MHz. Throughout the frequency range it was found that considerable variation in apparent antenna radiation pattern existed due to variations in configuration in the intervening terrain. Theoretical studies were made to determine optimum frequencies for short-distance communications using low-powered portable equipment over irregular terrain paths.
Improved calorimeter for the precise, absolute measurement of microwave power was designed and constructed. This instrument measures wave power at frequencies in the neighborhood of 9000 Mc at a level of a few milliwatts. The techniques are not intended to supplant entional microwave power-measuring methods but rather to enable rate calibration of secondary power-standards of various types. The need for accuracy of better than one percent appears more than adequate for most present-day requirements.

**Impedance Measurements and Standards**

Further work was done on the development of impedance standards, including several types of impedance standards for waveguides. These stand-terminations to waveguides or coaxial lines have known reflection props and are very useful in the microwave laboratory. One type consists of an accurately matched and calibrated attenuator terminated by a short plate. Designs for waveguide discontinuities that are amenable to pre-mechanical construction and to theoretical calculation were selected, indicating that the technique for combining known waveguide impedances by means of H-plane T-junctions to produce new known impedances was investigated thoroughly for the case of H-plane T-junctions. Comparison tech- niques, enabling comparison of unknown with known impedances which “magic-T” junctions, were developed to a point considered adequate for the present. The resonant-line (Chipman) technique of impedance measurement was studied in both coaxial and waveguide versions.

**Interference and Noise Measurement**

A program was initiated which, if successful, will lead to the establishment of a complete calibration service at NBS for radio interference meters, including those employing rod-type antennas. The design and construction of a detector to determine the rms, peak, and quasipeak, or average value of the interference over any time interval up to several seconds was com-pleted. Preliminary investigation indicated the problem of interference standardization to be both urgent and of very large proportions. Evaluation of a standard noise source usable up to 4.2 Mc was completed in 1949, an intensified program has been carried on which now

**Microwave Standards of Frequency and Time**

Because of fluctuations and secular changes in the length of the solar day, the first atomic clock, based on the constant natural frequency associated with the vibration of atoms in the ammonia molecule, was announced by NBS in 1949, an intensified program has been carried on which now...
comprises the investigation of four different types of atomic clocks. Spectrum lines which are both very intense and sharp are required in this to secure an ultimate standard. One of the most troublesome problems found in the ammonia clock has been a Doppler broadening of the spectral line, and much study has been devoted to the possible kinds of spectral lines that could be best employed, the atomic systems involved in obtaining such spectrum lines, and the methods of excitation of these systems. The most promising results have been obtained so far through the use of magnetic resonance techniques employing atomic beams. The work of this method (considered to have the highest potential accuracy) was begun shortly after the initial work on the ammonia clock. The equipment now been completed and preliminary work done on the excitation of a spectrum line in an atomic beam using cesium. With this equipment a spectrum line having the sharpest resonance ever obtained has been excited. The measurements have furnished direct evidence indicating the possibility of measurements to better than a part in 10 billion—an accuracy consider greatly greater than that achieved in the measurement of optical waveler and about 100 times greater than present astronomical frequency and standards.

15. Automatic Electronic Computers; Information Processing

SEAC

During the past year SEAC (National Bureau of Standards Eastern Automatic Computer) has continued to turn in an excellent record of performance in its dual use for mathematical computations and for engineering design studies. The pressure for its services has made it necessary to operate throughout the year on a basis of 24 hours a day, 7 days a week. A total of over 50 different problem types have been handled on the machine. In response to an urgent request from the Atomic Energy Commission, over two-thirds of the machine's time was made available for several months and this AEC work is now continuing at the level of about one-third the total time.

In its role as an experimental tool, SEAC has been used to test improve input-output devices and memory units. A magnetic tape device has been developed which permits rapid starting and stopping of the tape by eliminating the inertia associated with ordinary reels. In this device the tape is stored in loose folds in a two-dimensional bin. To start the tape it is necessary to accelerate a few feet of the tape material itself, and not entire reel. These devices have been tested and have been put into regular operation in problem solutions. Because of the bulk of the bins in which the magnetic tape is stored, these units are not readily adaptable to loading and unloading with ease. A separate unit has been developed which makes use of spools of magnetic wire assembled into a plug-in cartridge. The cartridge does not permit the rapid accelerations of the reel-less mag.
units, but it is much more rapid and convenient for loading and unloading. It permits a new problem to be inserted into the machine in a matter of a few seconds, and results may be removed equally rapidly. Equipment has also been constructed and is in regular use which takes results inserted on this magnetic wire and prepares, independently of the central unit, a printed copy for punched cards.

The second experimental use of the SEAC system has been in the testing of electrostatic memory unit. This type of memory holds considerable promise in the design of future machines because of the rapidity with which possible to obtain information from it or write new information into it is, however, subject to certain circuit sensitivities which require very careful design if the necessary order of reliability is to be achieved for commercial or data-processing use. A full prototype memory of this design has been attached to SEAC and tests made on it show considerable promise for future. It has already been experimentally used in the solution of some mathematical problems.

Over 600 hours of useful computing time was obtained on SWAC (Naval Bureau of Standards Western Automatic Computer), and the useful rational rate by the end of the year was approximately 40 hours per day. A punched-card input was installed, permitting the memory to be fed in 6 seconds in contrast to the 5 minutes required by teletype tape. A number of studies in pure mathematics were carried out using SWAC. An example, the primality of Mersenne numbers was investigated, and at the end of the year a new prime, \(2^{1270} - 1\), was discovered. This is the largest prime number discovered in mathematics. (See page 65).

**Computers**

The first new computer is the STATAC-SCOOP, which is a serio-parallel machine of very high speed, being designed for use with a parallel electrostatic memory and intended primarily for application to large-scale computing problems such as the SCOOP project of the Office of Air Comptroller, USAF. Since actual construction is dependent on realization of a high-performance parallel electrostatic memory, the major effort has been devoted to continuation of the analysis relating to the so-called triangular cell type operations. Many of the equipment design features are being carried out in the construction of DYSEAC, particularly the new package instruction.

The second new computer, DYSEAC, is a full-scale general-purpose digital machine operating at a 1-megacycle repetition rate and containing serial acoustic delay-line memory of at least 500 words. It differs from AC in the following particulars: (1) it contains an expanded repertoire of arithmetic operations; (2) it contains provisions for annexing a greater variety of external storage and input-output devices; and (3) it is capable
SEAC operates on a 24-hour day, 7 days a week (p. 64). New reel-less magnetic tape external memory devices (right and center) which have unusually fast access time (p. 64). Insert: for loading and unloading the computer very rapidly.

of carrying out automatically, in an integrated fashion, concurrent operations involving high-speed input-output and processing of data (e.g., it be capable of receiving nonsynchronous data from telemetering sources at the same time that it is carrying out a complex program of data-processing. The last feature will make the new computer considerably more flexible and powerful than SEAC for complex data-handling operations. Because the high-speed memory of the computer is almost immediately accessible, other units of the data-handling network, the computer can be used as a storage reservoir which can be shared among the other units of the network and which can be interrogated (or recorded in) by them independently, without disrupting the course of the internal data-processing program. Final system specifications were adopted, and work is under way on the preparation of detailed plans required for construction and assembly.

Technical Services

The Bureau also acts in an advisory and consulting capacity for other Government agencies interested in acquiring automatic computers. During 1952 the Bureau accepted two computers and monitored their installation: One was delivered to the Office of Air Comptroller, the other to the Air...
Service. Computer design and procurement for the Air Force Missile Center and Willow Run Research Center (University of Michigan) continued as cooperative efforts. The Bureau is also technical representative for the Bureau of the Census, which operates a data processing machine. The Bureau has continued to serve as a clearing house for information on the potential applications of electronic digital-computer tech-
iques both for scientific problems and for the processing of business types data. NBS representatives have met with officials of many Government agencies and industry.

16. Basic Instrumentation

Since its founding, the National Bureau of Standards has carried on a large amount of research in instrumentation. However, in order to take full advantage of the Bureau's facilities and competence in the general field of physical measurements and to bring into play the ideas and developments
originating in all technical fields, a coordinated program of broad scope was needed. The NBS Office of Basic Instrumentation was established in 19 for this purpose, with the cooperation of the Department of Defense and the Atomic Energy Commission. Functions include general correlation of Bureau projects in basic instrumentation, maintenance of liaison with sponsoring agencies, arranging for cooperative work on special problems, continuing survey of instrumentation work in progress at NBS laboratories, arranging for the testing and evaluation of new instrument developments, and stimulating theoretical and experimental studies of original ideas for improved novel means of measurement. Because instrumentation cuts across all lines of technical activity and the specific projects under the general program are carried on in many of the existing divisions of the Bureau, the Office of Basic Instrumentation was established as a part of the Director's Office. The following projects represent some of the efforts of this office.

Electron Interferometer

The concept of using lamellar crystals for splitting an electron beam suggested the possibility of this instrument. Theoretical and design studies confirmed the soundness of the proposed method, and an instrument has been constructed.

This instrument, an analogue to the classical optical interferometer, expected to throw new light on the nature of the electron by providing means of measuring the length of the wave train that modern theory associates with an electron. This knowledge can also be expected to give rise to a better understanding of the process of electron emission, the phenomenon on which all of electronics is based. Moreover, since electrons of an energy...
Commonly used in electron optics have a wavelength one ten-thousandth of one of visible light, an electron interferometer provides a basis for the measurement of length down to atomic dimensions.

Noise-Free Instrument Cable

Spurious electrical signals or “noise voltages” present a problem in many cases of instrumentation work where instrument cables are subjected to mechanical forces. They interfere with measurements of pressure in underwater explosion and air-blast research and with determination of accelerations in shock and vibration studies. They also adversely affect the performance of crystal-type microphones, hearing aids, and phonograph pickups and many other high-impedance devices in the fields of communication, measurement, and control. Until now, the mechanism of the noise generation has not been well understood and has been assumed to be somehow related to piezoelectric or converse electrostrictive effects, changes in the electrical constants of the cable, or separation of electrical charges by motion.

Laboratory work in connection with piezoelectric-type accelerometers has led to the development of a “noise-free” shielded instrument cable, in which spurious electrical signals arising from mechanical motion of the cable are reduced by a factor of 500 or more relative to ordinary cables of similar dimensions and flexibility. This development appears to have rather wide application in instrumentation problems, particularly those associated with assurance, vibration, and shock measurements.

Magnetostriction Magnetometer

Laboratory work in exploring possible instrumentation and control applications utilizing the magnetostrictive sensitivity of certain materials has indicated that one promising application of this phenomenon is its use in a sensitive magnetometer. Preliminary tests show that detection of changes in the magnetic field of the order of $3 \times 10^{-6}$ oersted (one-millionth of the earth’s magnetic field) and the selection of the best-suited magnetic material may further increase the sensitivity. It is expected that random changes in the earth’s magnetic field will come into the range of measurements well before the ultimate sensitivity is reached; and the instrumentation may then be used to study these changes. It appears possible that two of the magnetostrictive rods, set up so as to cancel these fluctuations, will allow significant measurements to be made even below this range.

Ultrasonic Voltage Photomultiplier

Study of such light-emitting phenomena as those connected with single- and nuclear disintegrations require light-sensitive elements having resolving times of the order of 1 millimicrosecond. Ordinary techniques using piezoelectric cells are not capable of this resolution. Efforts to improve the performance of photomultiplier tubes have resulted in the development of techniques for intermittent tube operation in which relatively high tube
voltages and currents are used, with a resulting increase in tube performance greater than an order of magnitude. Experimental work presently under way, in which radio frequency voltages are applied to the tube elements, shows promise of equal improvement, with substantial simplification of equipment.

**Mutual Inductance Transducer**

The variation in mutual inductance between two coils in proximity to a conducting surface has been utilized as the principle of operation for a number of instruments. These devices include instruments for measuring the thickness of electrodeposited metal coatings, insulating coatings on metal and bearing oil films, the separation of metal surfaces, and the amplitude of mechanical vibrations. These instruments have good stability, high sensitivity, and are particularly adapted to measurements where optical or mechanical access is not available. It appears that an additional possible application of the principle lies in the measurement of the condition of alloys by measuring the electrical properties of the metal, for such purposes as hardness testing. (See also p. 55.)

**17. Calibration, Testing and Standard Samples**

A direct result of the Bureau’s custody of the Nation’s basic physical standards is its program of calibration, testing, and standard samples.

The NBS calibration service is of great benefit to industry and private laboratories. Thousands of instruments are yearly sent to the Bureau for calibration. Some of these are standard laboratory devices and some are master instruments used by industry to calibrate production tools. 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. Standard samples of steels help to control the quality of the steel industry’s output. 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 gases and aviation fuels, and synthetic rubber. The list of standard samples issued by NBS now includes about 500 materials.

The Bureau’s testing activities are mainly directed toward ensuring that materials purchased by the Government conform to specifications. A multitude of diverse items are tested and the results, in many cases, eventually save the Government millions of dollars. In the course of this work the Bureau also develops new instruments, new methods of measurement, and much technical data on the properties of materials.

During the year over 300,000 tests and calibrations were performed for other Government agencies and the public. In addition, about 33,000
and samples were prepared and distributed. Typical services of this included the sample-testing of over 200,000 clinical thermometers pur- chased by the Government, the life-testing of about 4,500 light bulbs (a sam- ple of nearly 7,000,000 purchased by the Government this year), the cali- bration of approximately 8,900 gage blocks, over 860 measurements of radon samples, the testing of 277 ores and sludges for radium content, the cali- bration of more than 700 water-current meters, and the calibration of 90 capacity-measuring devices.

More than 15,800,000 barrels of cement were sample-tested during the year. The increase of approximately 3,300,000 barrels over the previous year was largely due to increased Federal construction. The tests, consisting of physical and chemical analyses, were carried out at four separate field laboratories established for this purpose as well as at the central laboratory in Washington. Closely related to this work is the program of the Cement Reference Laboratory, which inspects the apparatus and test methods of cement-testing laboratories. This laboratory is located at NBS and is jointly operated by the Government and the American Society for Testing Materials.

The Public Roads Administration contributes to the financial sup- port of the project and requires that laboratories testing cement for Federal projects must be inspected regularly by the Reference Laboratory.

For many years, all radium preparations sold in the United States have been tested and certified by the Bureau. During the year 1,808 tests of materials such as radium, mesothorium, and cobalt 60 were made for the Government and private concerns. Over 1,300 radioactive standards were distributed, reflecting the constantly increasing demand throughout the country for this service by the Bureau. These included radium gamma-ray standards, alpha-ray standards, radium D+E standards, radioactive iodine, radioactive phosphorus, radioactive carbon, radioactive cobalt, radon standards, and rock samples. To protect the health and safety of workers in operations involving the handling or processing of radium, the Bureau maintains careful check over the quantity of radium ingested by such workers and over the quantity of radon present in their working areas.

Electricity

Standard apparatus was tested for manufacturers, electric power com- panies, State public utility commissions, university laboratories and private testing laboratories as well as for many agencies of the Federal Government. Work involved over 20,000 separate exact determinations. Qualification tests of dry cells and batteries were conducted. Started in 1924, these tests have provided a continuous record of the quality of dry cells and batteries manufactured in the United States over a period of 28 years, except for a brief interruption during the war. The results of these tests have been furnished to all interested Government agencies and have been utilized in connection with purchases of dry cells and batteries for the Government.
Using the new NBS vibration calibrator (p. 56) to calibrate a vibration pi of the accelerometer type.

Optics and Metrology

Approximately 1,160 standards were calibrated in photometry and cmometry. These included incandescent, fluorescent, and mercury lamp standards of intensity, flux, and color; standards for checking the photometric scale and the 100-percent reflectance curve for spectrophotometers; glass or vitreous enamel standards of color, reflectance, transmittance, opacity, and gloss. Samples from about 7,000,000 lamps were inspected; 4,567 lamps were life tested. These included incandescent, fluorescent, photoflash lamps. Those rejected on life test represented 2.0 percent those accepted on initial inspection. Over 200 cameras and photograp lenses, chiefly for photogrammetric use, were calibrated; 450 refractive in samples and various optical instruments or optical systems were tested.

A total of approximately 1,800 NBS Microcopy Resolution Test Charts for use in testing microcopying camera and film combinations were issued. The following tests relating to length were made: 10 length standards, 96 steel tapes, 96 invar base-line tapes, 373 sieves, 2,384 haemacytometer chambers, 16,100 cover glasses, 163 leveling rods, 9,158 precision gage blocks, gauges, 1,584 instruments and standardized instrument parts, and 1,584 thread measuring wires.

Heat and Power

A total of 2,657 liquid-in-glass thermometers, 85 resistance thermometers, and 404 thermocouples and thermocouple materials were calibrated. The number of clinical thermometers tested was 41,499; 20,498 of these represented a sampling of over 204,000 thermometers purchased by the Veterans Administration and the U. S. Public Health Service. Tests and calibrations were made of special types of thermometers and thermometric devices. Fifty-six viscometers were tested or inspected, and 691 standard viscos
cles were supplied to other laboratories for use in the calibration of meters. Calibration tests were made on four hydrocarbon samples intended for use as reference fuels in knock rating. Seventy-nine fuels and cants, fifty-seven miscellaneous samples, and fifteen oil filter cartridges were tested for compliance with Government specifications. Automobile engine economizers, fuel and oil additives, and other automotive devices were tested or inspected for the Federal Trade Commission by the Post Office Department. Other automotive products tested for Government agencies included an armored car, a muffler, and seven motor speed governors. Twenty-two nonroutine tests on aircraft electrical fork equipment were conducted for the Bureau of Aeronautics, Department of the Navy.

Mic and Radiation Physics

The cobalt-60 calibration program has expanded markedly in the past year. During 1952, 300,000 millicuries were calibrated, and applications were received for calibrations of an additional 2,000,000 Me that could be accepted. A total of 1,221 radioactive standards were issued this year, including the I^{131} and P^{32}, Ra D+E, C^{14}, Co^{60}, radon, radium gamma-ray dards, rock samples, and alpha-ray standards. The Bureau measured 1,808 radium, mesothorium, and cobalt preparations; tested ores and sludges and 24 water samples for radium content; made 868 determinations of air samples, 28 miscellaneous gamma-ray determinations, and 6 leakage tests. Neutron measurements were carried out for Naval Research Laboratory, the Atomic Energy Commission Instru-

ments Branch, the Naval Radiological Defense Laboratory in San Francisco, the Radium Chemical Company of New York City, and the University of California. Demands for calibrated sources of thermal radiation issued at previous levels with 29 such standards issued.

Thirty-three mercury-198 lamps (a new and atomic standard of length) were distributed. Eight went to universities and government institutions in foreign countries and 25 were sent to places in this country; 4 to Government institutions, 14 to universities, and 7 to private industries. This is the first fiscal year this program has been in operation.

Calibrations and performance studies of more than 40 r-meters and other meters (including ionization chamber, G-M Counter, photographic, etc.) were carried out for Government agencies, medical institutions and the general public. Numerous tests have been carried out for Veterans' Administration and other Government agencies on protective materials and devices use in X-ray installations. Among the items tested were lead-impregnated building blocks used in protective barriers, lead glass for protective doves, leaded aprons and gloves, and similar accessories.

Chemistry

Samples received for acceptance and regulatory testing numbered approximately 2,600. They covered a wide range of materials: organic protective
coatings and their components; soaps, detergents, and waxes; type-ribbons and carbon papers; metals and alloys; and reagent chemical service of highly accurate analysis for carbon, hydrogen, and oxygen organic compounds was maintained and called upon from time to time by other Government agencies. The Bureau calibrated 585 Magnes painting devices used to measure the thickness of electroplated coatings. A total of 27,000 NBS standard samples of certified composition were issued.

Mechanics

Physical testing of materials, structures, mechanical apparatus, and instruments for various purposes and calibrations of instruments continued at a high level. In connection with the preparation of specifications for books for the blind, 40 phonographs were tested. Various acoustic materials were tested for manufacturers and Government agencies. Calibrations of 388 elastic calibration devices (proving rings, Amsler boxes, air weighing cells, etc.) were completed. Tension, compression, bending, and hardness tests were made to determine mechanical performance and compliance with specifications on a variety of specimens which included reinforcing steel, aluminum and copper conductors, wire and fiber rope, expansion joint filler, and hand tools. Tests for compliance with specifications on an investigative basis were made on 8 mechanical appliances, 14 resonators, 4 groups of electrical hygrometers, and 4 groups of mechanical hygrometers. Evaluation tests were made on electric razors and watches for the Federal Trade Commission, on a newly designed postage meter for the Office Department, and on dewatering indicators and electrical pressure-up devices for the Bureau of Aeronautics, Department of the Navy.

Over 700 water-current meters of various types, several pitot tubes, a number of special watershed indicators, and a plankton sampler were tested. One hundred sixty master beer meters, used as primary standards by the Bureau of Internal Revenue to check meters used in breweries to determine revenue taxes, were calibrated. Thirty-eight wind speed-measuring instruments were tested. Special purpose tests on instruments to be used asondary standards were made on 574 instruments, including 474 timepieces, and a number of mercury barometers used as working standards by the Force and the Atomic Energy Commission.

The Bureau calibrated 8,540 weights for several State governments, laboratories, various other Federal agencies, and for the general public. Volumetric calibrations were completed on 25,000 pipettes, more than 2 flasks, 2,500 hydrometers, 132 capacity standards, and 50 fluid meters. Sixty-five density determinations were made. Nonroutine testing and calibration of gas-temperature-sensing instruments applicable in jet engines was conducted for the Air Force on the following types: bare, shielded, total-temperature thermocouples; sonic-flow pyrometers; and an infrared monochromatic radiation pyrometer.
ganic and Fibrous Materials

The methods of test for automobile and truck tires developed during the last two years in the NBS tire testing program have been incorporated in Federal Specification ZZ-T-381f, Tires, Pneumatic, Vehicle and Equipment. Alginate impression materials, denture base resins, amalgamators, rubber, and rubber compounds were tested for the Naval Corps of the Air Force, Army, Navy, and the Veterans' Administration Dental Service. Three hundred samples of light-sensitive blue paper manufactured in the NBS paper mill, along with standard faded strips, were supplied to textile laboratories for calibrating fading lamps. The demand for standard samples of rubber compounding ingredients has continued to increase. A total of 6 of the original 7 has been exhausted and replacements obtained. A ninth, an oil furnace black, has been established. In cooperation with the American Society for Testing Materials, steps have been taken toward setting up a "standard" natural rubber. This standard rubber with properties determined by the National Bureau of Standards will be issued to rubber laboratories desiring to check their apparatus or procedures.

Metallurgy

Seventy items were examined for quality of material and compliance with specifications, for various Government agencies; 92 fusible boiler plugs were tested for the U. S. Coast Guard. About 750 castings of various alloys and cast iron and special compositions were prepared in the experimental foundry, and 628 items were heat treated at the request of other Government agencies. Miscellaneous services included rolling, forging, swaging, and die drawing of metals, determination of gases in metals, and metallographic and X-ray diffraction examinations.

Mineral Products

The construction programs of the Federal agencies required an increasing volume of tests on portland cement and related concreting materials. During the past year approximately 15.8 million barrels of cement represented by 26,000 samples were tested as compared to 10 million in the previous year. In addition to cement testing, 435 tests were made for Federal agencies on building stones and associated mortars and compounds. Testing work on safety glass for compliance with the American Standards Association Code for Glazing in Motor Vehicles was continued for the various States. A wide variety of acceptance tests was conducted on refractory materials such as fire-clay brick, air-setting mortars, insulating refractory bricks, flake graphite, and mullite brick. Six hundred standard samples were prepared and furnished to other laboratories for use in testing calking materials. The demand for the Cement Standard Fineness Sample has been increasing steadily.
Weights and Measures

The Bureau tested and calibrated master railway track scales, railway track cars, commercially operated railway track scales, and other large capacity scales. Special tests were concluded on cordage-measuring devices, small capacity scales, and ice-cream measure-containers. Definite methods of testing were devised and refined. Calibration of large standards of mass was continued. These calibrations included 50-pound weights of cast iron and aluminum weights over 50 pounds that were submitted to the Bureau by Government agencies and industry.
18. Cooperative and Advisory Activities

Advisory services are provided on many topics and problems for agencies of the Federal Government and State and municipal governments. Such services were rendered to the Army, Navy, Air Force, State Department, actual Security Agency, Department of Agriculture, Department of Interior, Department of the Treasury, Post Office Department, Atomic Energy Commission, Federal Communications Commission, Civil Aeronautics Administration, Federal Trade Commission, Naval Observatory, Veterans' Administration, Civil Defense Administration, Defense Minerals Administration, Weather Bureau, National Research Council, Central Intelligence Agency, Armed Forces Security Agency, Coast and Geodetic Survey, Naval Advisory Committee for Aeronautics, District of Columbia, Housing and Home Finance Agency, Maritime Commission, Office of Rubber Reserve, Panama Canal, General Services Administration, Public Health Service, etc.

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 Research and Development Board of the Department of Defense, 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.

Federal Specifications

An important phase of the Bureau's work consists in cooperation with the General Services Administration and standardizing agencies in the development and improvement of specifications. The GSA compiles and adopts specifications for the purchase of supplies by the Federal Government. These specifications result in purchase economies by establishing criteria which guarantee quality and provide an opportunity for all business to compete for Federal trade through the bid system. These functions are discharged through 70 technical committees. A total of 120 positions on these committees, including 25 chairmanships, are filled by specialists of the Bureau's staff. Considerable experimental investigation is carried on at the bureau in the development of test methods, which are often indispensable before a specification can be framed or applied. Other laboratory studies become necessary in connection with the continual revision of the specifications to keep them abreast of industrial practices and the changing needs of the Government. More than 2,200 Federal specifications are now in effect.

Mechanical and Electrical Equipment

The Bureau was consulted on a variety of technical problems related to motor vehicles. The numerous problems handled were relative to Govern-
ment purchases of temperature-measuring equipment, automotive equi-
ment, fuels, and lubricants. A new specification for automotive antifire
was prepared for the Post Office Department. Information was furnis-
in reply to inquiries about automobiles and their accessories, including fu-
lubricants, and engine coolants. Consultation with the branches of
Army, Navy and Air Force and their contractors on design, testing, 
maintenance of airborne electrical and pneumatic equipment (switches, 
cuit breakers, air compressors, solenoid-operated control valves, and o
components of pneumatic and electrical systems) continued to be import
Specifications were drafted for the Navy Bureau of Aeronautics for sto
bottles, pressure reducers, check valves, and pressure relief valves.

Expert advice was given the Bureau of Aeronautics on the acoustic tr
ment of noisy jet-engine testing stands and on the preparation of specif
tions for acoustical materials (to be used for the sound insulation of craft). Related consultative services included advice on the design of
Audiology Test Clinic for the Veterans' Administration, on the design of 
room for research in hearing at the Walter Reed General Hospital, a
on the design of a room for sonar listening tests at the Naval Resea
Laboratory.

The Office of the Chief of Engineers, Department of the Army, consul
t the Bureau regarding the reliability of tests made on friction losses in 
flow of water through corrugated steel pipes, and the Bureau of Pub
Roads was given advice in connection with a culvert problem. Represen
tives of the David Taylor Model Basin conferred in regard to the des
of a wave tank at the Basin. Assistance was rendered to the Army Corps
Engineers in density current problems.

Rubber

In connection with the stock piling of rubber, the General Services A
ministration has frequently been given advice in regard to the purcha
and storage of natural rubber. Samples of rubber and rubber latex are se
to the National Bureau of Standards by the General Services Administra
for analysis and evaluation. Tests and evaluations have been made on n
types of natural rubber which do not have a place in the present syste
of classification of natural rubbers. The Department of Agriculture oft
requests the National Bureau of Standards to test and evaluate wild rubbe
The results are used for ascertaining the quality of rubber obtained fro
various species of rubber trees.

Fungus Proofing of Leather

The Second World War emphasized the need for a dressing for shoes whi
would maintain them in a serviceable condition and prevent their attac
by mildew in the tropics. A satisfactory treatment was developed for th
Quartermaster General, which contained paranitrophenol as the activ
fungicide. Experience has shown that at least 0.2 percent (more than 0
percent is toxic) of paranitrophenol must be added to the leather to prevent mildew growth.

The quantity of paranitrophenol in leather is easily controlled but in order to enforce the requirements in specifications, a method for determining the exact amount present is necessary. Difficulty was encountered in extracting the paranitrophenol from chrome-tanned leather used for inner soles, and the Quartermaster General requested the Bureau to cooperate with several laboratories to develop a reliable procedure for extracting all of the fungicide from the leather. It was apparent that the paranitrophenol was being held in some manner by the leather, and it was found that the addition of an amount of water equal in weight to the leather freed the paranitrophenol so that it could be completely extracted by chloroform.

Mineral Products

The Bureau furnished a variety of consulting services to other agencies in connection with the technology of mineral products. Measurements were made on volume changes in a concrete floor laid over a lightweight concrete fill which had given considerable trouble to the Veterans' Administration in a Chicago hospital. Tests were conducted on a disintegrated concrete submitted by the National Advisory Committee for Aeronautics at Cleveland. An investigation for the Department of Interior was made of the suitability of scorias in the Pribiloff Islands for the fabrication of concrete building blocks in areas where wood is not available. Further tests were made for the Navy Department on the suitability of certain Hawaiian aggregates from an alkali-aggregate reactivity standpoint. Tests of a similar nature were made on samples of North Dakota sands. Advisory assistance was given the Technical Committee on Abrasives and Polishing Materials of the Federal Supply Service in the development of specifications for abrasive-coated paper and cloth.

Building Technology

The Bureau assisted a variety of Government agencies during the year, including State, county, and municipal agencies, in the solution of technical problems relating to building construction and materials. The volume of correspondence from the public seeking advice and information on specific problems was very high: about 9,000 letters of inquiry were received and answered, some 5,000 of which were from the general public, including homeowners and builders, supply dealers, engineering firms, architects, and educational institutions. At the request of the General Services Administration, a detailed analysis was made of the causes of cracking of masonry for a number of Government agencies. In the field of fire protection, advice was supplied to the National Archives and the Public Buildings Service on the protection of historic documents, to the Army Corps of Engineers on the fire resistance of building materials and constructions, and to the Architect of the White House on reconstruction problems and the insulation of air-conditioning ducts. Consultative services were provided to a number of Federal
agencies on various phases of heating, refrigeration and air conditioning as on roofing, flooring and related problems; technical advice was given to the Army and the Navy on contracts for the repair and replacement of roofing and floor coverings.

**Mathematics**

The principal part of the activity of the mathematical services of the Bureau consists of services given to other Government laboratories and the contractors. Increased use is made of the NBS Institute for Numeric Analysis for such services. The Bureau has undertaken the solution of specific problems in mathematical statistics for the Biological and Radiologic Laboratories of the Army Chemical Corps, National Advisory Committee for Aeronautics, Ship Steel Committee of the National Research Council, Navy Bureau of Ships, and the Naval Ordnance Test Station (Inyokern, California).

**Radio Propagation**

The Bureau regularly furnished the Department of Defense with the basic information used in preparing, for internal service use, recommended radio frequencies for various communication purposes. A variety of specific circuit problems were studied, and advice was given to the Air Force, Navy Research Laboratory, Armed Forces Security Agency, and Department of Interior. Assistance was given to the Air Force on calculations of a long-distance point-to-point communication system in the frequency range of 50 to 200 kc, and on problems related to radio navigational systems. Suggestions were given to a member of the Missouri State Geological Survey regarding techniques of radio geological sounding. Miscellaneous services were given to the Defense Minerals Administration on classification of mica and to the Signal Corps Laboratory (Fort Monmouth, N. J.) on noise meter standards and calibration and on adjusting crystal-controlled oscillators. Advice was given to the Navy Bureau of Ships on rf noise measurements and time measurements, the Coast and Geodetic Survey on reception of standard frequencies and time signals in Liberia, Federal Communications Commission and Bureau of Prisons on diathermy equipment, Naval Observatory on quartz-crystal clocks, Naval Research Laboratory on impedance measurements, and Engineering Research and Development Laboratory (Fort Belvoir, Va.) on magnetic design.

**National Cooperation**

The National Bureau of Standards cooperates extensively with technical and trade groups, on a national basis, where the interests of the Government are involved. Such cooperation is not only of value to the Government but provides a means of disseminating the results of the Bureau's work to industry.
Weights and Measures

As custodian of the national standards of measurements the Bureau provides calibration services to the Federal Government, state and municipal governments, universities, industry, and private laboratories. The transition of the basic 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 in this country and to all purchasers of commodities. To aid in this work, the Bureau has an Office of Weights and Measures which assists in improving the standards of efficiency and coverage and increasing the degree of uniformity of State weights and measures supervision throughout the United States. A program of assistance to state and local departments of weights and measures as well as to business and industry has been pursued.

A large part of the activity consists in consultative services rendered through correspondence, consultations by representatives of Federal agencies, business and manufacturing concerns, and weights and measures officials, and through field activities. The range of inquiries is broad, embracing the drafting of new legislation, interpretation of laws, specifications, tolerances and regulations, design of testing equipment, methods of test of commercial equipment, and problems of weights and measures administration.

A major medium of cooperation with weights and measures officials, equipment manufacturers, and associated interests is the National Conference on Weights and Measures. The 37th meeting of this organization was held in Washington in May 1952, with an official registration of 408, including 179 weights and measures officials from 35 states and the District of Columbia, 121 representatives of manufacturers of weighing and measuring devices, 66 representatives of associations, business, industry, and railroads, and 33 representatives from Federal agencies. It is the responsibility of the Office of Weights and Measures to plan and conduct the sessions of the National Conference on Weights and Measures. The Chief of the Office is the Secretary of the Conference and the Director of the Bureau is its president. The most important standing committee of the Conference 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 which are presented to the Conference for adoption, thence to the several States for promulgation.

Actions of the 37th National Conference included the adoption of further specifications and tolerances for commercial weighing and measuring devices. Recommendations were made on soap bars and cakes; ice cream and ices on sticks; peat moss in package form; Permalite, or any material or substance of the nature or character thereof; tomatoes in package form; prepackaged meats at retail; fractional terms of ounces; quantity declara-
Location of transmitter and receiver sites used in radio propagation studies (p. 62). Two transmitters are on Cheyenne Mountain, Colorado, at elevation of 9,000 and 7,000 feet. Permanent receiver installations are located near Ke drick, Karval, and Haswell in Colorado, and Garden City and Medicine Lodge, Kansas. Mobile units operate near Anthony, Kansas, and Fayetteville, Arkansas.

Scientific and Technical Groups

By actively participating in the projects of professional societies and standardsizing bodies, the Bureau plays an important part 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 participate in over 100 national groups such as the Acoustical Society of America, American Society for Testing Materials, American Standards Association, American Society of Textile Chemists and Colorists, American Concrete Institute, American Geophysical Union, 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, National Fire Protection Association, Optical Society of America, Society of Automotive Engineers, Society of Plastic Industry, American Petroleum Institute, American Ordnance Association, American Chemical Society, and National Association of Corrosion Engineers.

The Bureau's participation in the work of these and related organizations is largely through the activities of technical committees. Sixty members of the staff maintain personal membership in the American Society for Testing Materials. Thirteen of these hold the chairmanships of main committees dealing with such diverse subjects as magnetic properties, magnesium chloride cements, gypsum, asbestos products, porcelain enamel, electrical insulation, emission and absorption spectroscopy, textiles, wax polishes, plas-
adhesives, and analysis of metals. Forty-three other staff members are men of working committees while a still larger number lend assistance serving on technical committees and task groups so that in all about 425 committees are held by Bureau personnel.

Participation in the activities of the American Standards Association is wise through the work of technical committees. Bureau staff members chairmen of ten main committees dealing with such subjects as the Naval Electrical Safety Code, Safety Codes for X-rays, Building Codes for masonry, and standardization in the fields of Textiles and Photography. In addition, Bureau personnel are chairmen of twenty-three working committees and occupy 220 other committees.

Bureau publications and technical reports are drawn upon extensively in preparation of many standards such as the ASTM Method of Compressing Testing of Metallic Materials in Sheet Form or the Specification for Bars for Concrete Reinforcement. Also, various items of equipment developed at the Bureau form the basis of test methods, as for example, the Abrasion Tester in specifications for textiles. The continuing programs of the Bureau in fire protection, building technology, electrical measurements, and plumbing research are used as the basis for the periodic revision of American Standards and other codes in these respective fields.

Science

The basic facts of color vision have been discovered by researches in the diverse fields of physics, chemistry, physiology and psychology, but full utilization of these facts has been impeded because they have been scattered throughout a very extensive literature and expressed in different terminologies. The Optical Society of America has provided a meeting place for these diverse interests, and committees of this Society have been working nonstop continuously since 1919 to establish a unified consistent set of terms in the measurement of color and to collect and tabulate the quantitative data. The basic ideas, terms, and data are completely presented for the first time in a book, *The Science of Color*, prepared by the Colorimetry Committee of the Optical Society of America (New York, Crowell, 1952). As a part of its cooperation with technical societies, the Bureau has contributed importantly to this book. Much of the basic data was developed in the laboratories of the Bureau; members of the staff have served on the SA Colorimetry Committee throughout the years and have contributed to the writing and editing of *The Science of Color*. This book supplies the basic information required by America’s technical experts to enable them to take full and intelligent use of color standards in American industry.

Research Associate Program

The research associate plan is an arrangement whereby technical, industrial, and commercial organizations can support work at the Bureau 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 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 of the industry concerned, projects may be undertaken in cooperation with single companies or individuals when the results may be expected to have 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 organizations and individuals have supported cooperative research at the Bureau. Many of the projects have been extremely specific and there 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 1930. Fourteen groups now supporting 35 research associates at NBS. Cooperative projects underway include pyrometry, solid adsorbents, sugar refining, electrodeposit plumbing systems, gas orifice meters, dental materials, cement test equipment, crystallography, Portland cement, porcelain enamel testing, asphalt repairing products, and reinforced concrete. During the year fifteen papers on the subject of various fields were published as a direct result of the research associate program work.

**International Cooperation**

The National Bureau of Standards is active in such groups as the International Union of Chemistry, International Telecommunications Union, International Committee on Weights and Measures, International Scientific Radio Union, International Commission on Illumination, and International Commission on Uniform Methods of Sugar Analysis. 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 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 policy of the Government, are coordinated on the diplomatic level by the State Department.

**International Intercomparison of Standards**

The second international intercomparison of photometric standards which has been in progress for the past several years, was complete. A final report was received from the International Bureau of Weights and Measures (BIPM) in Paris. Adjustment of the units of the various countries is not contemplated at this time. However, if adjusted on the basis of the NBS values, the maximum change in any U. S. value would be 0.3 percent; other countries would have maximum adjustments ranging from 0.1 to 0.86 percent.
group of NBS saturated cadmium standard cells was taken to Paris comparison with those maintained at the International Bureau of weights and Measures and those sent in by other national laboratories. A study of the results of the 1950 intercomparison showed that the electrical standards of the various cooperating nations have been maintained satisfactorily since the 1939 intercomparison. The study also showed that the change to new absolute units as carried out in 1948 has been accomplished satisfactorily.

**New Threads**

Further progress toward common standards for screw threads for Canada, United Kingdom, and the United States was made during the year by efforts of the Interdepartmental Screw Thread Committee, A. S. A. National Committee B1 on the Standardization and Unification of Screw threads, and the Bureau. A conference with Canadian and British delegates was held in New York in June 1952. At this conference the British accepted the American Standards for General Purpose Acme Threads and agreed to consider further the stub acme and the centralizing fit acme threads. With regard to buttress threads, inasmuch as American industry has not used buttress threads with a basic depth of thread as small as the depth used in Great Britain, it was decided to add the British standard as an appendix to the American standard; the British agreed to reciprocate by including the American standard with 0.6 pitch thread depth in the next printing of their standard.

**International Meetings**

The International Congress of Chemistry and the American Chemical Society held their 75th anniversary meeting in New York in September 1951. The Sixteenth Conference of the International Union of Pure and Applied Chemistry was held in New York and Washington during the same month. Many members of the staff of the NBS participated in the meetings. The International Union honored the Bureau by taking special notice of its 50th anniversary, which occurred in 1951. Members of the NBS staff attended several international conferences in the United States and in other countries, official delegates of this country.

**International Relations**

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 (Point IV), the United States International Educational Exchange 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 not only strengthen the relations of this country with other nations, but also permit the National Bureau of Standards to keep more closely in touch with scientific developments in other countries and benefit from them.
The Bureau also renders services to foreign countries in the form of technical calibrations, and exchange of standards, and also exchanges publications on a world-wide basis. An example of an advisory service rendered to a foreign country by the Bureau 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 would 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.

During the past year over 1,000 scientists and technicians, including some special groups, visited the Bureau from abroad. They ranged from directors of research establishments similar to the National Bureau of Standards to postgraduate students. Twenty-seven guest workers spent 1 to 12 months at the Bureau observing or receiving training in a field of special interest to them. Countries represented included the Union of South Africa, Colombia, Italy, Egypt, Pakistan, Spain, Uruguay, Formosa, Portugal and Japan. Some of the guest workers directly represented their governments while others represented private industry or institutions of learning.

Publications

The results of the Bureau’s work are to a considerable extent presented in the form of papers and reports. During the last year these totaled some 1,500, exclusive of those reports which have to do with calibrating services and testing. Over 1,000 reports, classified and unclassified, were prepared; most of these were issued to other government agencies, particularly the Department of Defense, on projects supported by transferred funds.

Approximately 500 papers and documents were issued for formal publication. Of these, some 300 consisted of scientific and technical papers; 11 papers were published in the National Bureau of Standards Journal of Research; the remainder were published in the familiar scientific and technical journals of various professional, engineering, and trade organizations. In addition, 118 summary reports were published in the Bureau’s Technical News Bulletin. The third monthly periodical of the Bureau, Basic Radio Propagation Predictions, presented each month, for a one-month period, three months in advance, radio-propagation data needed in determining the best frequencies to use in long-range radio communications.

Forty-three papers were published in the Bureau’s nonperiodical series of publications: 6 in the Applied Mathematics series, 5 in the Handbook series, 16 in the Circular series, 6 in the Building Materials and Structure Reports series, and 5 in the Miscellaneous Publications series.

A. V. Astin,
Director, National Bureau of Standards.
SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY
- Resistance Measurements
- Inductance and Capacitance
- Electrical Instruments
- Magnetic Measurements
- Applied Electricity
- Electrochemistry

OPTICS AND METROLOGY
- Photometry and Colorimetry
- Optical Instruments
- Photographic Technology
- Length
- Gage

HEAT AND POWER
- Temperature Measurements
- Thermodynamics
- Cryogenics
- Engines
- and Lubrication
- Engine Fuels
- Cryogenic Engineering

ATOMIC AND RADIATION PHYSICS
- Spectroscopy
- Radiometry
- Mass Spectrometry
- Solid State Physics
- Electron Physics
- Atomic Physics
- Neutron Measurements
- Infrared Spectroscopy
- Nuclear Physics
- Radioactivity
- X-Rays
- Betatron
- Nucleonic Instrumentation
- Radiological Equipment
- Atomic Energy Commission Instruments Branch

CHEMISTRY
- Organic Coatings
- Surface Chemistry
- Organic Chemistry
- Analytical Chemistry
- Inorganic Chemistry
- Electrodeposition
- Gas Chemistry
- Physical Chemistry
- Thermochemistry
- Spectrochemistry
- Pure Substances

MECHANICS
- Sound
- Mechanical Instruments
- Aerodynamics
- Engineering Mechanics
- Hydraulics
- Mass Capacity Density and Fluid Meters

ORGANIC AND FIBROUS MATERIALS
- Rubber
- Textiles
- Paper
- Leather
- Testing and Specifications
- Polymer Structure
- Organic Plastics
- Dental Research
METALLURGY


MINERAL PRODUCTS


BUILDING TECHNOLOGY


APPLIED MATHEMATICS


ELECTRONICS


RADIO PROPAGATION


ORDNANCE DEVELOPMENT

ELECTROMECHANICAL ORDNANCE

ORDNANCE ELECTRONICS

These three divisions are engaged in a broad program of research and development in advanced ordnance. Activities include basic and applied research, engineering, pilot production, field testing, and evaluation of a wide variety of ordnance matériel. Special skills and facilities of other NBS divisions also contribute to this program. The activity is sponsored by the Department of Defense.
MISSILE DEVELOPMENT

Missile research and development: engineering, dynamics, intelligence, instrumentation, evaluation. Combustion in jet engines. These activities are sponsored by the Department of Defense.

OFFICE OF BASIC INSTRUMENTATION

OFFICE OF WEIGHTS AND MEASURES