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National Bureau of Standards

U. S. Department of Commerce

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Sinclair Weeks, *Secretary*

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

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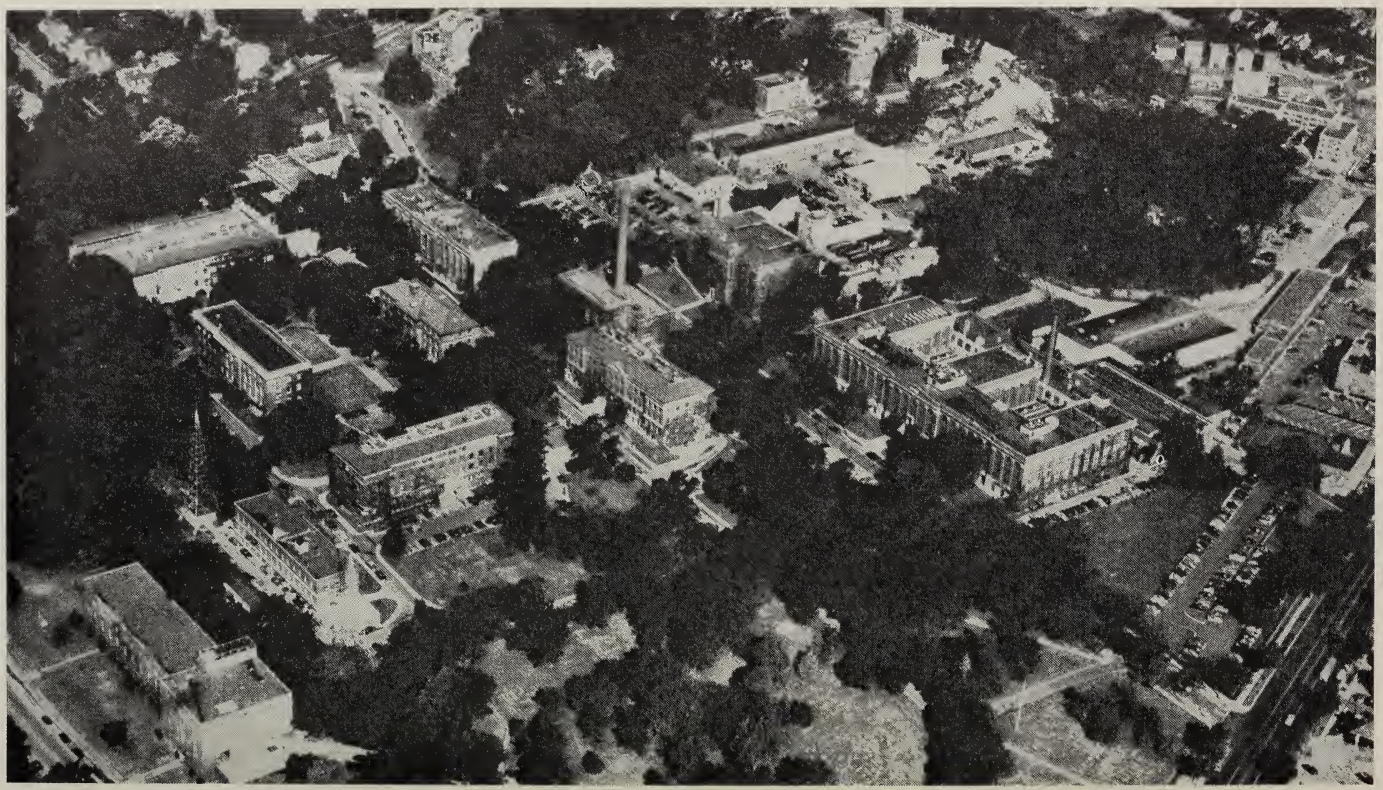

The National Bureau of Standards, Washington, D. C.

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1. General Review

1.1. Introduction

During the past year, the National Bureau of Standards has continued its concerted effort to strengthen its programs by increasing the basic research undertaken, and by developing proper technical balance in all Bureau activities. With the help of Bureau technical advisory committees, the scientific programs of the Bureau have been carefully reviewed and steps have been taken to follow recommendations to meet the growing critical needs in various fields of science and industrial technology.

The Bureau recognizes as its principal mission the conduct of research related to the development of standards of physical measurement, to the development and improvement of methods of measurement, to studies of the basic properties of materials, and to investigations leading to a more accurate determination of basic physical constants. By undertaking work related to this mission, the Bureau can best serve the scientific and technological advancement of the Nation. The Bureau recognizes that its work can be of great benefit to the national economy by providing technical organizations and laboratories with basic data related to standards and measurement. These data can then be applied to the development of new or improved products, new and better devices, and improved production and technological service to the public.

The role of standards research and development in this context can then be more adequately understood. Its importance and influence can thus be made more widely effective. Standards and effective measurement techniques provide a basis for confidence in production and commerce. But even more they provide the basis of continuous technical and industrial achievement. Standards underlie the Nation's modern technological and industrial health; they are the basis for mass-production methods that give a high standard of living.

In this introduction it seems appropriate to summarize the nature of the Bureau's work. By virtue of its responsibility for the custody, maintenance, and establishment of the Nation's primary standards of physical measurement, the National Bureau of Standards serves Government, science, and industry. The Bureau is the source for physical standards used in our modern economy. For industry and science, the Bureau performs critical calibrations of working standards and distributes standard samples for use in production and research. For Government, the Bureau develops methods for acceptance testing of materials in procurement and helps devise codes and specifications. In addition, the scientific staff of the Bureau provides technical advice to various scientific and Government groups and undertakes a large variety of studies to meet the special needs of other Government agencies. To perform all the above services effectively, the Bureau must retain a highly competent staff and must conduct active and imaginative basic research in all of the fields of the physical sciences, especially as such research relates to the Bureau's basic mission.

1.2. Technical Activities

Standards and Measurements. To meet the requirements of science and industry for standards and methods of physical measurement, the Bureau carried on research and development in widely diverse fields of the physical sciences. Thus, to improve the accuracy of standard resistance thermometer calibrations, new apparatus was developed for obtaining the boiling point of oxygen. In this apparatus temperature is automatically controlled to within a 10-thousandth of a degree and pressure measurement errors are reduced to a negligible level. To meet the needs of nuclear research, the Bureau redetermined the emission rate of the Nation's primary standard photoneutron source. For this purpose, an absolute calibration method was developed that is more precise and more easily performed than most existing techniques. Under the sponsorship of the Air Force, a new pressure standard covering the range below two inches of mercury was completed in preliminary form. Improved measurements of low pressures in this range (corresponding to altitudes above 80,000 feet) are needed for instrumentation of high-performance military aircraft. New polonium-210 alpha-particle standards having great mechanical durability were developed, and beta- and gamma-ray solution standards of hydrogen-3, potassium-42, zinc-65, and tantalum-182 were made available for distribution. At the request of the United States Geological Survey and under the sponsorship of the Atomic Energy Commission, the Bureau undertook a program of preparing and distributing standards of isotopic abundance. These standards are for use by laboratories throughout the world in determining the age of minerals and in deducing the temperature and other physical conditions of the earth in various geological periods. A set of approximately 60 impedance standards was completed to facilitate calibration of high-frequency impedance measuring instruments. Also, a new technique for making precision measurements of impedance at microwave frequencies was developed.

During the year standard resistors and standard cells used to maintain the ohm and the volt were submitted to the International Bureau of Weights and Measures at Sèvres, France, for comparison with the international standards. The United States standards were found to differ from the international standards by less than one part per million.

Properties of Matter and Materials. Studies of matter and materials ranged from basic research on frozen molecular fragments to development of high-temperature coatings for jet turbine blades. In the low-temperature studies a technique was developed for capturing and storing large numbers of highly reactive molecular fragments at temperatures near absolute zero. By this method unstable atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped into solid form. Because these atoms are frozen in the excited state, they can be conveniently studied by optical spectroscopy. In the Bureau's experiments

solids were produced containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy molecule. These solids have very unusual properties and when warmed they combine very actively, releasing large quantities of heat energy.

This method of storing free radicals appears to have broad possibilities for fundamental research. In such fields as solid state physics and basic chemistry, the trapped atoms could be used as powerful probes into the solids containing them. From a study of their properties, information could be obtained about the arrangement of the atoms and molecules in the solid and about the forces acting on them. Similarly the mechanism of diffusion of atoms and of reactions between atoms and molecules could be studied.

Other low-temperature research showed the feasibility of a potentially low-cost method for obtaining deuterium (heavy hydrogen) by low-temperature distillation of liquid hydrogen. With the advent of electrical energy from nuclear power, a considerably increased demand for heavy water can be expected, and its cost will be a significant factor. The heavy hydrogen obtained by the distillation process might then be used in making heavy water. Plans are now being made for construction of a pilot plant to evaluate the process on a larger scale.

In research on semiconducting intermetallic compounds, information was obtained having an important bearing on the further improvement of electronic devices such as transistors and photodetectors. The binary compounds of indium and antimony and of magnesium and tin were synthesized in the form of extremely pure single crystals and their electrical, optical, mechanical, and thermal properties were measured. In this way increased knowledge was obtained of the behavior of semiconducting materials.

Because of its structural strength at high temperatures, molybdenum would be useful for the turbine blades of jet engines were it not for its ease of oxidation, which becomes serious above 800° C. In work performed for the Navy Bureau of Aeronautics, a process was developed for electrodepositing nickel-chrome protective coatings on molybdenum. These coatings have afforded molybdenum protection in excess of 1,000 hours at 1,000° C.

Basic knowledge of the reactions involved in the thermal decomposition of cellulose is needed to develop new nonflammable textile materials and methods of treating present textiles to render them more flame-resistant. In an investigation sponsored by the Army Quartermaster Corps, it was found that by modifying the cellulose structure, cellulosic materials could be made more flame-resistant. The modification of the chemical structure evidently caused the molecules to break up differently, so that their decomposition products contained more of the nonflammable materials, such as water and carbon dioxide, and less of the highly flammable tarry materials.

Another development in textile research was an instrument for measuring the stresses and strains produced in yarns, fabrics, and films when they are subjected to transverse impact at speeds up to 150 miles per hour. The ability of textile yarns to withstand high-speed impact stresses, or shock loading, is becoming increasingly important to modern industry and national defense. Extremely high rates of strain are experienced by airplane tire cords during landing, by seat belts and safety lines when accidents occur and by the fabric, shroud lines, and webbing during the opening of a parachute. In high-speed industrial sewing the thread is subjected to high-frequency cyclic accelerations which may equal several million centimeters per second per second, and similar conditions may be attained in high-speed processing of fibers. To provide design data for these various applications, the Bureau has been making an extensive study of the behavior of textile yarns under very high-speed impact. Supported in part by the United States Army Quartermaster Research and Development Command, the study is providing data that are useful in establishing specification requirements for the webbing of parachutes.

Plastics research sponsored by the Army Ordnance Corps led to a practical procedure for mass-producing plastic springs from glass fiber-reinforced resin. Until now plastic springs have been little used because suitable techniques for making springs of the types needed have been lacking. However, springs formed by this process have desirable mechanical properties for a wide range of applications. They also have a number of advantages for special purposes. For example, they are nonmagnetic and have low electrical and thermal conductivity. They can be molded directly to dimensions without developing any considerable internal stress. Their high corrosion resistance should make them of value for applications in chemical plants and installations subject to acid fumes or to salt air. Other applications may benefit from the strength-to-weight ratios of plastics, which are often higher than those obtained with spring-making metals. Also, the broad range of transparent and colored materials that can be used makes striking decorative effects possible.

Data Processing Systems. This program, embracing both digital and analog electronic computers, includes research, development, systems design and analysis, and technical advisory services. During the past year an increasing number of requests were received from Government agencies for advice on the use of high-speed digital techniques in new areas such as massive paperwork operations, control systems, and simulation, as well as in the solution of specific technical problems.

As in previous years, the Bureau's high-speed digital computer, SEAC, was used to solve a variety of problems in science, engineering, and management. Work continued on the electrostatic memory for SEAC, and additional input-output circuitry was installed for greater efficiency and convenience of operation.

In computer research, emphasis was placed on the logical systems design of high-speed digital computers. Studies in this area are directed toward more effective means for organizing electronic components into systems for carrying out computing and data processing operations. Development of more advanced logical systems is expected to make possible considerable increases in over-all speed and computing power without imposing corresponding increases in the performance requirements of the electronic components. Thus far, improved designs have resulted in addition and multiplication units capable of operating 150 times faster than those in SEAC constructed from essentially the same components.

To prevent radioactive material from falling on inhabited areas after a nuclear explosion, extensive calculations must be made when tests are planned to determine the fallout pattern. With high-speed electronic digital computers, such laborious hand computation can be eliminated and the calculation time reduced to 15 minutes. However, the digital computers are usually large, permanent, expensive installations. To provide even faster predictions with portable, relatively inexpensive equipment, the Bureau developed a special-purpose analog computer for the Weather Bureau and the Atomic Energy Commission. This computer gives instantly, within an area of 250 miles of "ground zero," the radioactive fallout pattern resulting from a nuclear detonation. The pattern is presented visually on the face of a cathode-ray tube, over which a map on a transparent backing can be laid. Two models of the fallout computer were sent to Eniwetok, Marshall Islands, and were used in predicting the distribution of radioactivity following the explosion of nuclear weapons in May 1956. In the event of nuclear attack on this country, the computer should be very useful to civil defense.

Special Electronic Devices. Two machines were developed to help solve the information storage problems now being encountered by Government agencies. One of these is an automatic microimage file; the other is a microfilm-to-punched-card converter.

The microimage file provides rapid access to any one of 10,000 information containing frames recorded in miniature on a 10-inch-square sheet of microfilm. It is particularly applicable where large volumes of data must be assembled in a predetermined sequence from a master random file. The machine combines electronic circuitry with precision servomechanisms. It operates on a continuous basis, automatically searching the microfilm and printing out one frame every 2 seconds. Information may be in the form of pictures, drawings, fingerprints, sets of numbers, letters or other symbols, or even single stages of electronic circuit diagrams.

The microfilm-to-punched-card converter was devised to aid the Weather Bureau in meeting the problem of storing weather records. At the present time punched cards containing weather data almost fill the space available for such records, and their volume is, of course, continually growing. The converter selectively scans microfilmed records of

punched cards and restores the information to the punched-card form. Thus, the present collection of punched cards can now be destroyed and individual cards replaced later as needed. The space required for the microfilm records will be only about one-hundredth of that needed under the present system.

Radio Propagation. Of broad significance to industry and the armed services was a program of research and development on the forward scatter of radio waves. This recently discovered mode of radio propagation promises to extend greatly the limits of long-distance communication. Through application of scatter propagation, new frequency channels can be opened up to long-range use, new path lengths can be utilized, and reliable service can be provided far beyond the line-of-sight limit in the extreme high-frequency ranges. Considerable savings may be expected through elimination of many relay stations.

Radio propagation by forward scatter is believed to result from small inhomogeneities due to turbulence in the atmosphere. These inhomogeneities scatter radio waves in all directions, but predominantly forward. With properly designed equipment, the scattered signal can be received over long distances along the earth's surface even though the direct wave has gone off into outer space.

Although this phenomenon has been known to science for several years, its successful application to radio communication has required extensive research by a number of cooperating laboratories. Thus, for more than 5 years, forward scatter has been the subject of experimental and theoretical investigation at the Bureau. Sponsored by the Department of Defense, this work has not only provided insight into the nature and causes of the scattering process but has also laid much of the groundwork for effective application of forward scatter in practical communication circuits.

The NBS program has included both ionospheric and tropospheric forward scatter. Ionospheric scattering takes place in the lower part of the ionosphere—a region of electrified particles 40 to 200 miles above the surface of the earth. Tropospheric scattering occurs in the part of the atmosphere that lies below the ionosphere.

Recently the Air Force requested the Bureau to undertake consulting, design, and supervisory responsibility for construction of a trans-Atlantic communication system using ionospheric scattering in the VHF (very-high-frequency) region. Previous experimental circuits were extended to provide a complete operational system from Maine to England by way of Greenland and Iceland. The detailed engineering design of the system was worked out with the aid of Page Communications Engineers, Inc., and the installation was contracted to that firm.

To provide information on the extreme range of ionospheric scatter communication, an experiment was carried out over an extended period between Newfoundland and the Azores. This experiment demonstrated

Four of the Bureau's sixteen technical divisions make up the Boulder Laboratories at Boulder, Colo. Three radio divisions are housed in the radio building, top. A new wing now under construction will house the Electronic Calibration Center. On the same site is the Cryogenics Engineering Laboratory whose main building is shown in lower picture.

that regular communication by ionospheric scattering is feasible at a range of 1,400 miles, provided special siting conditions exist and are properly utilized.

International Geophysical Year. At the close of the year preparations were well under way for NBS participation in the International Geophysical Year (IGY) of 1957–58. During the IGY, scientists of more than 40 nations will make simultaneous worldwide observations and measurements of physical phenomena related to the earth, its interior, its crust, its oceans, its atmosphere, and its immediate cosmic environment. The results of this international enterprise will provide a greater understanding of earth physics, and will have direct application to everyday human life in such fields as navigation, communication, instrumentation, and standards of measurement.

The United States National Committee for the IGY, organized by the National Academy of Sciences—National Research Council, is planning and directing United States participation in the program. The National Bureau of Standards will be principally concerned with the gathering of data on various atmospheric phenomena affecting radio propagation. These include sunspots, radio noise, aurora and airglow, and disturbances in the ionosphere. On the basis of observed solar and geomagnetic activity, the Bureau will select Special World Intervals, during which most of the observing parties throughout the world will undertake accelerated observing schedules. The Bureau will also assist in the earth satellite program of the IGY.

Although the taking of data for the IGY does not officially begin until July 1, 1957, considerable technical activity has been required in connection with those portions of the program assigned to the Bureau. Thus, for study of the night airglow which results from excited molecules and atoms in the upper atmosphere, a recording telescopic photometer was developed with greater spectral resolution and more rapid sky coverage than previously available. Six photometers of the improved design are being constructed for IGY observing stations, two to be operated by the Bureau and the remainder by other organizations.

The Bureau will be primarily responsible for vertical sounding of the various layers of the ionosphere. To this end, steps were taken to supply 14 new ionospheric sounding stations with vertical-incidence ionosphere recorders of improved design. Six of the stations will be in the Antarctic, five of them operated by NBS, and four in South America manned by Bureau-trained personnel. Because of the long logistic lead time required, equipment has already been sent to the Antarctic for installation of ionospheric sounding stations at the South Pole and at the Marie Byrd Land station. Siting studies were also under way for the observation of ionospheric forward scatter in equatorial regions.

Calibration, Testing, and Standard Samples. The Bureau's calibration activities are an outgrowth of its custody of the national standards of physical measurement. Periodically the master standards used in in-

dustry or by other laboratories must be checked against these national standards. Such calibration services are vital to industrial and scientific progress, insuring the accuracy of working standards throughout the Nation. Testing, on the other hand, is almost entirely confined to requests from Federal agencies, usually in connection with quantity purchase of materials like cement for Government use.

New calibration equipment completed during the year included an anechoic chamber, or "dead room," for calibration of microphones and sound level meters, two precision balances of 1,000- and 2,500-pound capacities for standardizing test weights, and a mechanical comparator for gage-block calibration. At the close of the year, construction had begun on a new Electronic Calibration Center that is being set up at the Bureau's Boulder (Colo.) Laboratories to meet the urgent needs of the armed services for accurately calibrated electronic equipment.

Approximately 36,000 standard samples of chemicals, metals, and alloys were issued to industrial and research laboratories. Standard samples are materials that are certified for chemical composition or for some physical or chemical property, such as heat of combustion, melting point, or index of refraction. They provide precise bases of comparison so that, for example, the manufacturer of a chemical can control its purity by comparing his product with the standard sample. Standard samples make possible uniform measurements of heat and temperature, define the colors of paints, and calibrate the instruments that control the composition of synthetic rubbers and motor fuels. During the past year new developments in industry brought increased activity to the standard samples program. Twenty-seven additional standard samples were issued, making the total number over 575.

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

Cooperation with other Federal agencies ranges from the supplying of technical information upon request to long-range projects undertaken through various scientific and technical committees. An important area of interagency cooperation is in the development and establishment of Federal Specifications. These specifications are issued by the General Services Administration. They result in purchase economies by establishing criteria that govern quality and by providing opportunity for all

businesses to compete for Federal trade through the bid system. The Bureau now has responsibility for preparation and maintenance of 180 Federal Specifications covering a wide range of materials and products; it also receives for review each year approximately 500 proposed specifications prepared for the GSA by other agencies.

Another phase of technical cooperation, somewhat broader in scope, involved the Bureau's participation in the work of national and international societies, associations, and standardizing bodies. During the past year, Bureau staff members held committee memberships in more than 110 groups such as the American Society for Testing Materials, American Standards Association, American Society of Mechanical Engineers, American Chemical Society, and the International Committee on Weights and Measures. By participating in these organizations, the Bureau is able to play an active part in bringing new advances of science into the technology of American industry, in developing test methods and criteria, in standardizing materials and products for greater economy and improved quality, and in establishing uniform scientific standards throughout the world.

An example is the Bureau's work on the National Committee on Radiation Protection. Sponsored by NBS and governed by representatives of 15 participating organizations, the NCRP studies problems involved in industrial and medical use of radiations and develops appropriate safety recommendations. Studies recently undertaken by the Committee dealt with incineration of radioactive wastes, industrial and medical uses of intense high-energy electrons, and permissible irradiation levels for emergency conditions.

1.3. Administrative Activities

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

During 1956, the total funds obligated for both areas of activity, including construction and facilities, were $21,997,846. Of this total, about $8,306,246 came from direct Congressional appropriation for the basic program, and the remaining $13,691,600 represented programs conducted for other Government agencies.

During this past year, several events have occurred that will have an important bearing upon the character and future of the National Bureau of Standards. Outstanding among these are two administrative occurrences: (1) approval by the Congress of the acquisition of a new site for the Bureau; and (2) implied approval by the Congress of the Bureau's policy to strengthen its basic programs by undertaking more of its work under direct Congressional support.

Activities relating to the first point may be summarized as follows. Congress has appropriated $930,000 for the purchase of a new site and

for initial planning. A 518-acre site in Montgomery County, Maryland, about 20 miles from downtown Washington, D. C., was acquired in July 1956 and steps are now under way for developing plans and architectural drawings to be completed by the end of the next fiscal year. Construction of the new facilities is contingent upon Congressional approval of the plans and is not expected to begin before 1959. Completion of relocation of the Bureau is not expected prior to 1961.

Equally important is the second point. The Bureau has felt a strong need to reconstitute its research and development programs so that major support came from directly appropriated funds and so that greater emphasis might be placed upon research related to standards of physical measurement and to methods of measurement. Since 1949, work for other Government agencies has dominated the Bureau's programs. This has meant that a larger portion of the Bureau's technical staff was diverted from basic Bureau research to work more directly relating to the missions of other agencies. It has also meant that the Bureau was dependent in large measure upon other agency support, thus seriously hampering the Bureau's ability to create a stable research environment and to pursue long-range research goals consistent with its assigned mission. About two years ago, the need for technical balance in the Bureau's basic programs was enunciated, especially in these two aspects: (1) increasing the level of basic research; and (2) concentrating on the Bureau's assigned mission. This position has been supported by the Bureau's technical advisory committees who have made recommendations to increase the level of fundamental studies at the Bureau and to strengthen basic activities in several scientific areas. Along with this general policy for achieving technical balance, the Bureau has been seeking to reduce the number of projects undertaken for other agencies. It is accomplishing this by carefully screening other agency proposals and accepting only those projects that have a general scientific value, or are closely allied to the Bureau's basic mission, or which the Bureau can alone undertake because of its unique facilities or competence.

Another Congressional action during the past year has had a bearing on one of the Bureau's special activities. The Bureau has now been authorized to retain fees for services performed for industry. This will enable the Bureau to meet the continuing demand from industry for tests, calibration, and standard samples, and to support these activities on a direct cost basis.

During the past year, 12 technical committees were serving the Bureau's scientific program (appendix, page 137). Composed of prominent scientists and industrial representatives, these committees, which supplement the Bureau's Statutory Visiting Committee (appendix, page 137), are a valuable source of consultation and stimulation and serve to bring to the Bureau the views and needs of the Nation's scientists and technologists.

During the past year the Bureau held its second Open House or Guest Week. More than 1,200 scientists and officials of Government, industry, and education attended. The Guest Week theme was devoted to the science of measurement. Major laboratories were opened to the visitors, in addition to special exhibits and a lecture by the Director.

At the end of the reporting period, total employment at the Bureau was 3,052. Most of the staff was stationed at the Bureau's laboratories in Washington, D. C. About 700 were located at the NBS Boulder Laboratories and at field stations in the United States and abroad.

1.4. Publications

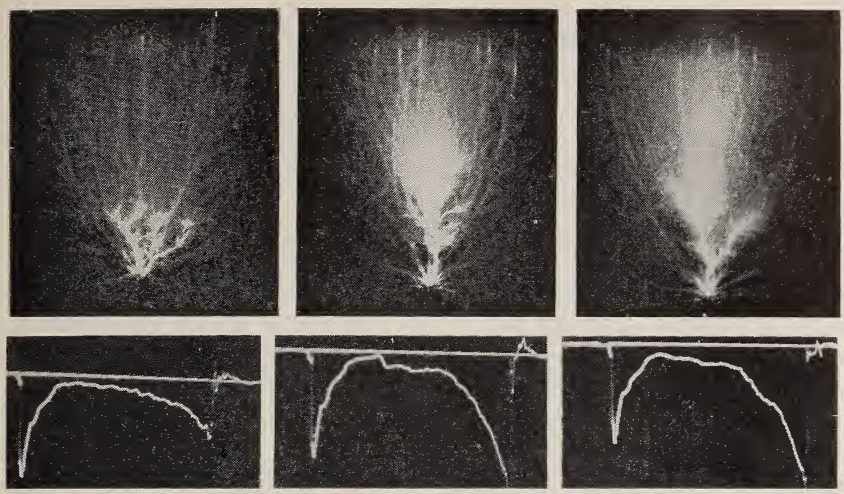
The results of the Bureau's technical program are in general embodied in its reports and publications. Even when the work is developmental in nature—for example, the development of a specific device—a report will represent the culmination of the activity, and it is this report that will often prove of most value to Government, science, and industry. The reports and publications of the Bureau are therefore suggestive of the scope of its activities. During the year these totaled over 1,300, exclusive of calibration and test reports and of general administrative documents. Some 725 classified and unclassified reports were issued to other Government agencies, particularly the Department of Defense, while 591 papers and documents were published formally. Of the formal publications, some 488 consisted of scientific and technical papers, 88 of which were published in the *Journal of Research of the National Bureau of Standards* (a monthly periodical) and the remainder in the journals of various professional, engineering, and trade organizations. In addition, approximately 75 summary reports were published in the Bureau's monthly *Technical News Bulletin*. The third monthly periodical of the Bureau, *Basic Radio Propagation Predictions*, presented each month, for a 1-month period 3 months in advance, radio propagation data needed in determining the best frequencies to use in long-range radio communications.

Twenty-eight papers were published in the Bureau's nonperiodical series of publications: 2 in the Applied Mathematics Series, 3 in the Handbook series, 16 in the Circular series, 3 in the Building Materials and Structures Report series, and 4 in the Miscellaneous Publication series.

A list of publications for the fiscal year is given in the appendix, section 5.6 (page 141).

2. Research and Development Program

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



Photographs of electrical discharge show the breakdown process in air suddenly stopped at various stages prior to complete breakdown. Such pictures, together with oscillograph records (below) of current and voltage taken at the same time, make it possible to study the details of breakdown phenomena that occur in one-millionth of a second or less (p. 17).

2.1. Electricity and Electronics

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

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

Fundamental Electrical Units. The program for absolute measurements of resistance and current is a continuing one, as it is the only means available for checking upon the stability of the electrical units that are maintained by the standards of resistance and electromotive force. During the past year the value of the ampere as measured in terms of the resistance and electromotive force standards was determined in terms of the basic mechanical units by means of the Pellat current balance. This brings to completion a project started several years ago to provide an independent check on the determinations made in 1940 with the Rayleigh

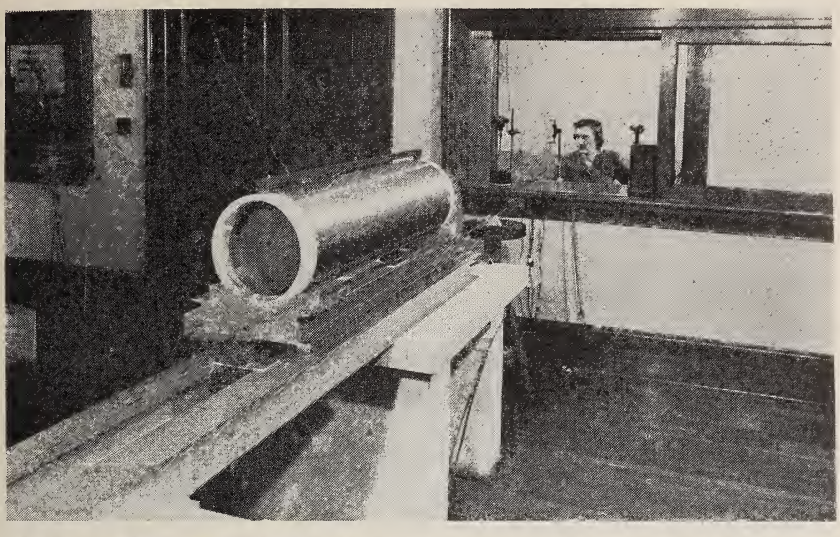
current balance. The results obtained with the two current balances differed by less than 10 parts in a million.

The comparison between the results obtained with the Pellat and Rayleigh balances necessarily involves the assumption that the units of resistance and electromotive force, as maintained by the NBS standard cells and resistors, have remained constant between 1940 and 1956. To avoid this assumption it was decided to repeat the measurements with the Rayleigh balance so that results from the two balances would be obtained only a few months apart. This program has been carried almost to completion. One of the benefits accruing from repeating the Rayleigh balance measurements will be a check upon the stability of the unit of electromotive force as maintained by standard cells. If this check proves satisfactory it will be repeated at regular intervals, just as the absolute measurement of resistance is being repeated. Then for the first time the stability of the units will be dependent primarily upon the stability of standards of length, mass, and time, rather than upon an assumed stability of groups of standard resistors and standard cells.

The experimental procedures used to establish the units of electromotive force and resistance require precisely constructed inductors. The inductances of these coils are calculated using formulas that consider the conductors to be mathematical filaments having no cross-sectional area. However, the copper wires used for the actual windings have a finite area, and the nonuniformity of the current distribution over the cross section leads to uncertainties in the calculations. This current distribution is influenced by several factors, one of which is the strain in the wire. Therefore, the effect of strain on the properties of copper wires has been the subject of considerable research at NBS. The results so far have served to reduce the uncertainties in the basic absolute electrical measurements.

During the past year the Bureau has again cooperated with the International Bureau of Weights and Measures at Sèvres, France, by submitting standard resistors and standard cells for measurement and comparison with similar standards from other countries. Observations were made at Sèvres in August 1955, and in the United States both shortly before and after that date. The conclusions were that the units of resistance and electromotive force maintained at NBS and at the International Bureau differ by less than 1 part per million. This close agreement helps to confirm the confidence in the stability of the primary electrical standards.

Electrochemistry. Under the sponsorship of the Atomic Energy Commission and the Army Bureau of Ordnance, a punched-cell wax electrolyte battery was developed. This battery is 0.3 inch in length, 0.25 inch in diameter, weighs 0.05 ounce, and has an emf of 37.5 volts. It has a short-circuit current of 3×10^{-8} ampere and exhibits an insignificant drop in electromotive force and current capacity even after 1 year of storage. A similar battery has also been built with the same voltage and length,



Using the Pellat current balance, the absolute value of the ampere has been determined in terms of the basic mechanical units (p. 13). The equipment is operated from another room to avoid air disturbance and dimensional changes produced by heat from the body.

but it is 0.5 instead of 0.25 inch in diameter. This larger size, weighing 0.2 ounce, gives a short-circuit current of 3×10^{-7} ampere. These new batteries are unique in that the normal electrolyte is dissolved in solid polyethylene glycol instead of water.

Electromotive-Force Series for Solid and Molten Chlorides. A new emf series gives theoretical electromotive forces for 96 different solid and molten chloride electrolytes used in galvanic cells. The series was arrived at both from theoretical considerations and from many calculations performed on the Bureau's electronic computer, SEAC. The work was carried out for the Office of Ordnance Research. When listed in order of magnitude, the computed emf's provide a relative scale of chemical activity that should prove helpful to scientists and engineers working out new processes in high-temperature chemistry. It supplements the usual and well-known electrochemical series in aqueous and nonaqueous systems.

EMF-Temperature Hysteresis Studies. The studies of emf-temperature hysteresis of unsaturated standard cells were completed, except for a few check runs. Some data were also obtained on a reevaluation of the international temperature coefficient of saturated standard cells.

Gassing of Dry Cells. The work for the Navy Bureau of Ships on the rates of gassing of commercial dry cells at temperatures from 21° to 55° C was completed. Results show that commercial dry cells gas at a rate of 0.2 ml/day at the lower temperature and at 6 ml/day at the higher temperature. These findings are important to manufacturers who wish to seal cells in plastic or other material.

Improvements in Measuring Techniques. Further improvements have been made in the use of an a-c bridge for the measurement of core losses at high induction. Measurements of core loss can now be made as accurately by a bridge method as by the wattmeter method. This new bridge method has also contributed to a better understanding of the measurement of nonlinear impedances and the treatment of harmonic currents that arise as a result of the nonlinearity of the circuit.

Further improvement of the a-c Kelvin bridge has extended its operating range up to a frequency of 6,000 cps. Both its usefulness and its reliability have been increased, especially at lower frequencies, thus permitting more accurate determinations of the phase-defect angle for a-c shunts used as standards in current-transformer testing.

Automatic Microimage File. Development work was successfully completed on a microimage data storage and retrieval device, which provides rapid access to any one of 10,000 microfilmed images located on a 10-inch-square sheet of film. The instrument operates on a continuous basis; it automatically searches the microfilm and prints out one frame every 2 seconds. It is particularly applicable where large volumes of data must be assembled in a predetermined sequence from a master random file. Information may be in the form of pictures, drawings, fingerprints, sets of numbers, letters, or other symbols. Quantity and kind of data are limited only by the size of the individual frame ($\frac{1}{10}$-in. square) and the photographic resolution of the film emulsion.

Microfilm-to-Punched-Card Converter. A development for the United States Weather Bureau reaching the stage of satisfactory laboratory operation is a microfilm-to-punched-card converter. This device selectively scans microfilmed records of punched cards and restores the information to punched-card form. Present files of punched cards containing weather data, accumulated over a 20-year period, have become a storage problem. By microfilming and then destroying the present stock of punched cards, a saving of space of about one hundredfold can be effected.

Magnetic-Core Transducer. The Atomic Energy Commission and the Department of Defense sponsored experimental and service work with transistor circuits. Measurement and waveform inspection in the milliampere and microampere range are frequently required under conditions where it is not convenient to open the circuit and insert the measuring or viewing device. Also such insertions unavoidably affect the current flowing in the circuit. For such measurements the Bureau developed a special transducer consisting of a toroidal magnetic core, split into two parts that can be clamped around a wire conducting the current to be measured. A winding is located on one or both parts of the core, and may be connected through a suitable amplifying and filtering circuit to a measuring instrument or oscilloscope.

Mechanized Production of Electronics. The NBS–BuAer program for automatic production of modularized electronic equipment, formerly code-named "Project Tinkertoy," was brought to a prescheduled conclu-

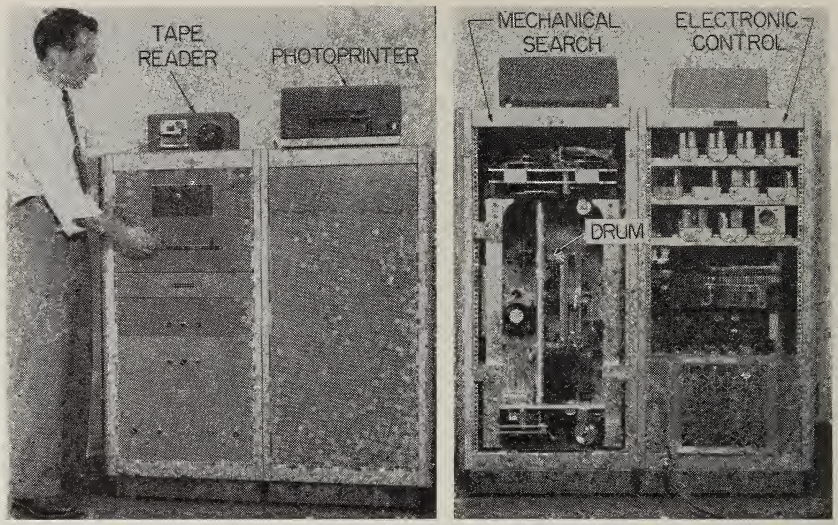
sion in July 1956. Sponsored by the Navy Bureau of Aeronautics as a military-preparedness measure, the initial phase of the program covered the development of the modular design and mechanized production concepts and culminated in a pilot-plant facility. Since these concepts were first announced in 1953, the art has been further developed and full technical information has been released to private industry. A number of manufacturers of electronic components and equipment have shown extensive interest and have undertaken developments similar to the Bureau's. This broadened industrial activity and the further improvements now under way in industry make it appropriate for the Bureau to end its pilot-plant activities.

Electronic Miniaturization Techniques. As one phase of a continuing program on electronic miniaturization for the Navy Bureau of Aeronautics, a very compact, easily repaired, and highly reliable oscilloscope was developed. This 32-tube instrument can be maintained by subassembly replacement. With this design, portions of the circuit can be replaced by transistorized assemblies, thereby permitting a sound engineering comparison between vacuum-tube circuits and their transistorized counterparts.

Miniaturized Receiver. In another miniaturization-techniques program, sponsored by the Rome Air Development Center, the Bureau designed a receiver containing approximately 150 microwave components and 1,600 vacuum tubes. In spite of the complexity of the equipment, its plug-in assembly structure provides for rapid location and easy replacement of faulty assemblies.

Preferred Circuits. The manual of preferred electronic circuits has been formally published for wide distribution to promote the standardization of electronic circuits. It is the result of a program undertaken for the Navy Bureau of Aeronautics. Its main purpose is to encourage voluntary reduction of unnecessary circuit variations in military equipment. If standardization of electronic circuits is achieved, even in part, substantial economies will be realized. For the manufacturer, standardization will result in lower production costs, quicker shifting from development to production, lower parts inventories, simplification of mechanized production, and conservation of engineering manpower. For the military services, standardization will result in lower procurement costs, simpler maintenance training, shorter lead time on delivery of equipment, fewer spare parts at field installations, and greater operational reliability.

Research on Electric Spark Discharge. As part of a study of surge voltages, the recording speed of an unmodified cold-cathode cathode-ray oscilloscope was compared with one provided with traveling-wave deflecting plates. For this evaluation, a pulser was devised to give extremely fast and steeply rising or steeply falling surges. Negligible distortion was found with the cathode-ray oscilloscope equipped with the traveling-wave deflector when suitably terminated. This cathode-ray oscilloscope



Front and rear views of microimage data storage and retrieval device that provides rapid access to any one of 10,000 information-containing frames recorded in miniature on a 10-inch square sheet of microfilm (p. 16).

equipment of reliable high-speed recording performance was used to study steep-front surge breakdown when photographing sphere-plane breakdowns for chopped surges.

2.2. Optics and Metrology

The Bureau's work in optics and metrology is principally concerned with problems of measurement, instrumentation, and standardization. Fields of activity include photometry, colorimetry, interferometry, optical instruments, refractometry, photographic technology, thermal expansion, and the calibration and maintenance of length standards. Work in progress includes improvement of the fundamental standard of luminance (a total radiator at the temperature of freezing platinum), development of a satisfactory procedure for defining the meter in terms of the wavelength of the radiation of a selected spectral line, and redetermination of color-mixture functions for calibrating the color standards used in industry.

Intercomparison of Length Standards. The yard, foot, and inch used in this country by industry, as well as the meter used in much scientific work, are derived directly from the International Prototype Meter through the United States national prototype meter, which is in the custody of the Bureau. To insure the accuracy of the length calibrations that the Bureau performs for Government and industry, the national prototype meter and the various working standards of length must be rechecked periodically because most scales ruled on metal gradually change their length. Thus, the national prototype meter is scheduled to go to the

International Bureau of Weights and Measures at Sèvres, France, in the coming year, to be checked against the international prototype. In preparation for this intercomparison, United States Meter bar prototypes No. 27 (the national standard), No. 21, No. 12, and No. 4 were intercompared. These four bars are all of platinum-iridium alloy. The working standards, used for routine calibrations, are made of alloys of baser metals and in general show a greater change with time than do the platinum-iridium bars. During the past year, 13 of the Bureau's decimeter working standards were recalibrated. These decimeter standards were originally ruled on stainless steel by the use of light waves 25 years ago. The steels used differ somewhat in composition and in heat treatment. Recalibration thus not only provides current corrections to the scales, but also shows the stability of different alloys and different heat treatments.

New Standards. Standards of haze were issued for use in checking hazemeters. The standards consist of titanium dioxide particles dispersed in cellulose acetate laminated between glass sheets.

Chromatic reflectance standards were issued for seven colors of commercial importance: safety red, international orange, safety orange, school-bus chrome, safety yellow, safety green, and safety blue. These standards are used to calibrate tristimulus colorimeters and also serve as physical representations of the color designations. They are made of porcelain enamel on steel and are 4¼ inches square with a ¼-inch fold at each edge.

Precision Liquid Light Filters for Photographic Sensitometry. The Bureau has developed five additional color filters which are used to simulate common sources of light when determining film speeds in the laboratory. Of the liquid type, the filters have been designed for use with a tungsten incandescent lamp operated at a color temperature of 2,850° K. These filters supplement the three liquid filters for testing black and white film which were designed by the Bureau many years ago and which have been adopted by the International Congress of Photography.

Size of Color Differences. In setting color tolerances of manufactured articles it is important to know not only the size, or perceptibility, of color differences but also how this perceptibility is affected by viewing conditions, such as angular size of the colors, angular separation between them, and amount and kind of illumination used to inspect them. The Bureau has cooperated since 1948 with the Committee on Uniform Color Scales of the Optical Society of America in the collection of about 1,000 color standards, sampling all of the roughly 10 million colors detectably different. The sampling is intended to be uniform in the sense that each color will be equally different from each of its 12 nearest neighbors when judged under the conditions of commercial inspection. This collection of color standards is expected to serve as a reliable and convenient guide in setting color tolerances of all sorts.

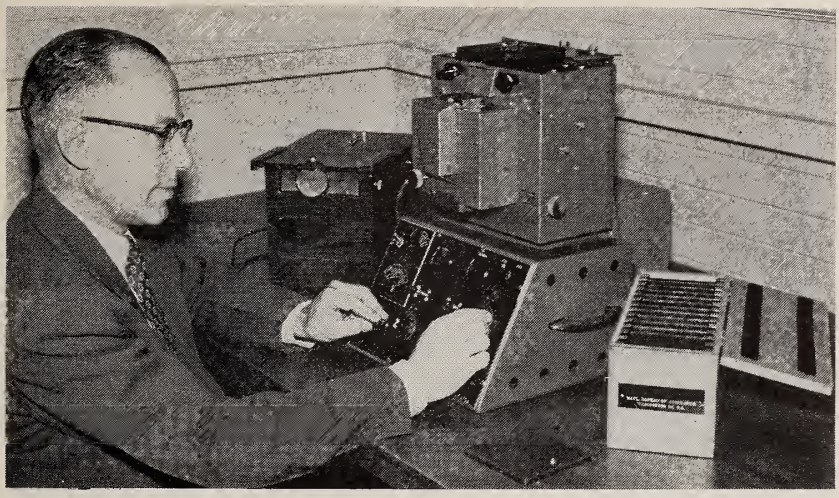
Dictionary of Color Names. The Bureau completed a comprehensive dictionary of color names with the cooperation of the Inter-Society Color Council (The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names, price $2.00). The end result of 4 years of research and study, the ISCC-NBS dictionary not only includes color names from the various fields of application but also relates all the names listed to a common, fundamental system of designation. It lists 7,500 individual color names and defines them in simple, accurate terms that can be easily understood by persons working in different fields. The wide interest and demand for this type of information is illustrated by the fact that in 4 months the sales stock (3,000) has been nearly exhausted. A second printing is in preparation.

Interlaboratory Photometric Intercomparisons. To promote the uniformity of light measurements throughout the United States, interlaboratory intercomparisons on six different sizes or types of lamps were inaugurated. The Bureau, one commercial laboratory, and six industrial laboratories participated. A smaller group of laboratories is cooperating in colorimetric intercomparisons of fluorescent lamps.

Refractometry. Large transparent synthetic crystals, suitable for lens construction, have been increasingly used for studies in the spectral regions of the ultraviolet (rocket spectroscopy) and infrared (molecular spectroscopy). However, before such crystals can be generally useful in lens systems, their indices of refraction and dispersion as well as the thermal coefficients of the indices must be determined. Measurements of this type were carried out for several materials during the last year. The indices of cesium iodide for ultraviolet, visible, and infrared wavelengths were determined along with the dispersion and thermal coefficients. Data were also taken, out to 39 microns in the infrared, on an improved type of mixed crystal of thallium bromide and thallium iodide.

The change in refractive index was used as an indicating property to determine the time rate of recovery of a glass after subjection to hydrostatic pressure (of the order of 10^4 atmospheres). Data of this sort, used to study relaxation phenomena that are basic in studies of the fundamental nature of solids, may also be correlated with studies of rate processes in chemical reactions.

Photogrammetry. Photogrammetry, the science of making maps from airplane photographs, is important to both industry and the armed services. Its applications include small-scale mapping of continental areas, large-scale mapping of small sites to aid in the placing of factories, highway mapping to determine routes of minimum cost, mapping for tax purposes, and many other uses. To insure accuracy in the finished maps, camera-lens errors must be precisely determined and compensated for. During the past year, two studies were completed dealing with calibration errors and errors arising from incorrect alinement of the camera, which was found to produce asymmetric distortion and errors in the location of the principal point.



Instrumental measurement of color difference in the NBS colorimetry laboratory (p. 19). A current study indicates that color-difference meters are likely to be more reliable in determining color differences than are human observers. Accurate matching of colors is becoming increasingly important to modern industry.

Image Evaluation. Photographers often have difficulty in determining the suitability of a given lens for making photographs of a certain quality. The Bureau has published a circular and a set of test charts which permit measurement of the limit of resolution by the average amateur photographer. These charts have also been found useful by many professional photographers. Now in its third printing, 9,400 copies of the circular and 5,000 copies of the set of charts alone have been sold since 1953.

Waviness of Mica. Determination of the waviness of mica purchased by the Government has been done visually. In order to speed such determinations, the Bureau developed an objective method for evaluating the waviness of mica for the Emergency Procurement Service.

Aerial Reconnaissance Photography. Aerial black-and-white photographs have been widely successful in military applications such as locating enemy installations and assessing bomb damage. Special photographic materials for each type of target to be detected were developed as part of a project sponsored by Wright Air Development Center to sharpen aerial reconnaissance. A method was developed for detecting the amount of rust-damage to fields of wheat and rye. This method is based on reflectance differences between diseased and healthy plants measured by spectrophotometry. The technique shows clearly areas of wheat fields infected with rust, although ordinary photographs show nothing.

Aviation Lighting. To obtain a better measure of the distance from which a pilot can see the runway, an experimental slant-visibility meter was constructed and installed at the Arcata (California) Landing Aids Field Laboratory. The design of this instrument is based upon the present Weather Bureau ceilometer, originally developed at NBS. The

detecting unit is installed in the approach zone of the instrument runway, and the remote indicating and recording instruments are installed in the weather office.

2.3. Heat and Power

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

From the standards of temperature, the work in heat and power broadens to include the determination of quantities of heat by calorimetry at temperatures extending over a large part of the scale. Concurrent theoretical programs relate thermal properties to molecular structure and permit the calculation and compilation of tables of thermal properties over an even wider temperature range. Particular emphasis is placed on investigations of electrical, magnetic, and thermal properties of matter at extremely low temperatures. Other phases of the work are concerned with the flow characteristics of lubricants and other fluids; high-temperature lubrication; diesel oils, aircraft fuels, and motor gasolines; and combustion mechanisms in engines.

Temperature Standards. Temperatures on the thermodynamic scale must be more accurately known if the accuracy of thermodynamic computations is to be improved. Temperature can be determined more precisely, however, on the practical scale, known as the International Temperature Scale, than on the thermodynamic scale. Values of thermodynamic temperatures can then be derived from values on the International Temperature Scale if the small differences between these two scales are known. Engineers, for example, find these differences significant in the formulation of steam tables. To meet the needs of scientists and engineers, the Bureau is carrying out an extended program of precision gas thermometry to determine the differences between these two scales in the range of temperature from the steam point to 800° C.

From the boiling point of oxygen (—182.97° C) to the freezing point of antimony (630.5° C), the standard resistance thermometer is the instrument adopted for interpolation between the fixed points on the International Temperature Scale. However, at temperatures above the antimony point, less is known about the behavior of resistance thermometers and the factors affecting good thermometer design. Thus, the present instrument for interpolations in the range from 630.5° to 1,063° C is the standard platinum versus platinum-rhodium thermocouple with its inherent limited accuracy. Studies of resistance thermom-

Precision equipment for making exacting determinations of the optical characteristics of aerial camera lenses (p. 20). These factors are very important in photogrammetry, the science of making maps from airplane photographs.

etry at these higher temperatures are therefore being made in anticipation of the eventual adoption of the resistance thermometer as the accepted interpolation instrument up to the gold point at 1,063° C. This will permit the measurement of temperature with significantly greater accuracy in the higher range.

The normal boiling point of oxygen at −182.97° C is one of the primary fixed points on the International Temperature Scale. It is also one of four fixed points that are used in the calibration of standard resistance thermometers. Formerly, fluctuations in the cryostat temperature and errors in the pressure measurements limited the accuracy with which the boiling point of oxygen could be realized. During 1955 a new oxygen-point apparatus was developed in which the temperature is automatically controlled to within ±0.0001 degree and the errors in pressure measurement rendered negligible. This apparatus will enable the Bureau to improve the accuracy of its standard resistance-thermometer calibrations.

Above the gold point the extrapolation of the International Temperature Scale is effected by means of the standard optical pyrometer. Although the optical pyrometer has been a very useful instrument through the years, its potential accuracy is limited by several factors, one of the most serious being that observations are made with the human eye. For this reason a new pyrometer is under development in which visual observations are replaced by photoelectric detection of brightness matches.

The possibility of establishing a thermometric standard at low temperatures through the precise determination of the velocity of sound in helium gas is being investigated. Apparatus has been designed for work in the range from 1° to 20° K, with particular effort being devoted to the

problems of maintaining temperature uniformity and stability over the acoustic chamber, and the precision measurement of standing wave patterns for wavelengths of a few millimeters.

Low-Temperature Research. The salt, ammonium hexafluorochromite, was investigated for use in a magnetic thermometer and found to possess a large specific-heat anomaly in the neighborhood of 0.2° K. It and others of a fluoride series with similar structure are inherently more stable and reproducible than the more familiar hydrated paramagnetic salts. The Bureau plans to survey other fluorides with a view to using them both in thermometers and as heat sinks for work below 1° K. An exhaustive investigation into the properties of chromium methylammonium alum was brought nearer to completion with gamma-ray-heating specific-heat measurements from 0.01° to 1° K.

Earlier experiments on nuclear orientation had produced the accidental discovery of enormous nonresonant heating effects in a paramagnetic salt subjected to a radiofrequency magnetic field when cooled below 1° K. This has been confirmed to be a magnetic rather than dielectric effect, and investigations have been made on both a "helium-range" antiferromagnetic (manganous chloride tetrahydrate) and on chromic methylammonium alum with its Néel (or Curie) point of 0.02° K. In the region of the Néel point the relaxation time rises rapidly, and existing theories are completely inadequate to account for this. The low-temperature radiofrequency heating is of interest in providing more information on short-range order and in pointing up the directions in which theories of magnetic interaction and relaxation times must be developed. It is possible, also, that the phenomenon can be developed for calorimetry and absolute temperature determination below 1° K. The intensity and uniformity of the heating effect are excellent, but its extreme temperature dependence is a less desirable feature.

Investigations of superconductivity were continued under the sponsorship of the Air Research and Development Command. This property, common to many pure metals and alloys, involves the abrupt disappearance of electrical resistance at low temperatures. During the past year the program was devoted to an investigation of the superconducting behavior of microscopic tin filaments called "whiskers." These filaments, about 40 millionths of an inch in diameter, have provided new information concerning magnetic-field penetration in superconductors. Plans are under way to investigate the so-called "intermediate state" in lead. The intermediate state consists of alternating domains of superconducting and normal material. By measuring the domain periodicity it is possible to obtain information concerning the surface energy at a domain wall. A magnetic probe and auxiliary apparatus are under construction.

In work supported mainly by the Office of Naval Research and the Air Research and Development Command, a technique was developed for capturing and storing large numbers of highly reactive molecular fragments at temperatures near absolute zero. By this method, unstable

atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped in solid form. Because these atoms are frozen in the excited state, they can be conveniently studied by optical spectroscopy.

Within the last 5 years, several methods have been developed in other laboratories for stabilizing free radicals at low temperatures. However, the present technique has the advantage that the free radicals are stored in highly excited states as a result of the electric discharge, making it possible to study and analyze them by spectroscopic techniques. Also, because the radicals are collected at much lower temperatures than in previous methods, they can be stored longer in the uncombined form.

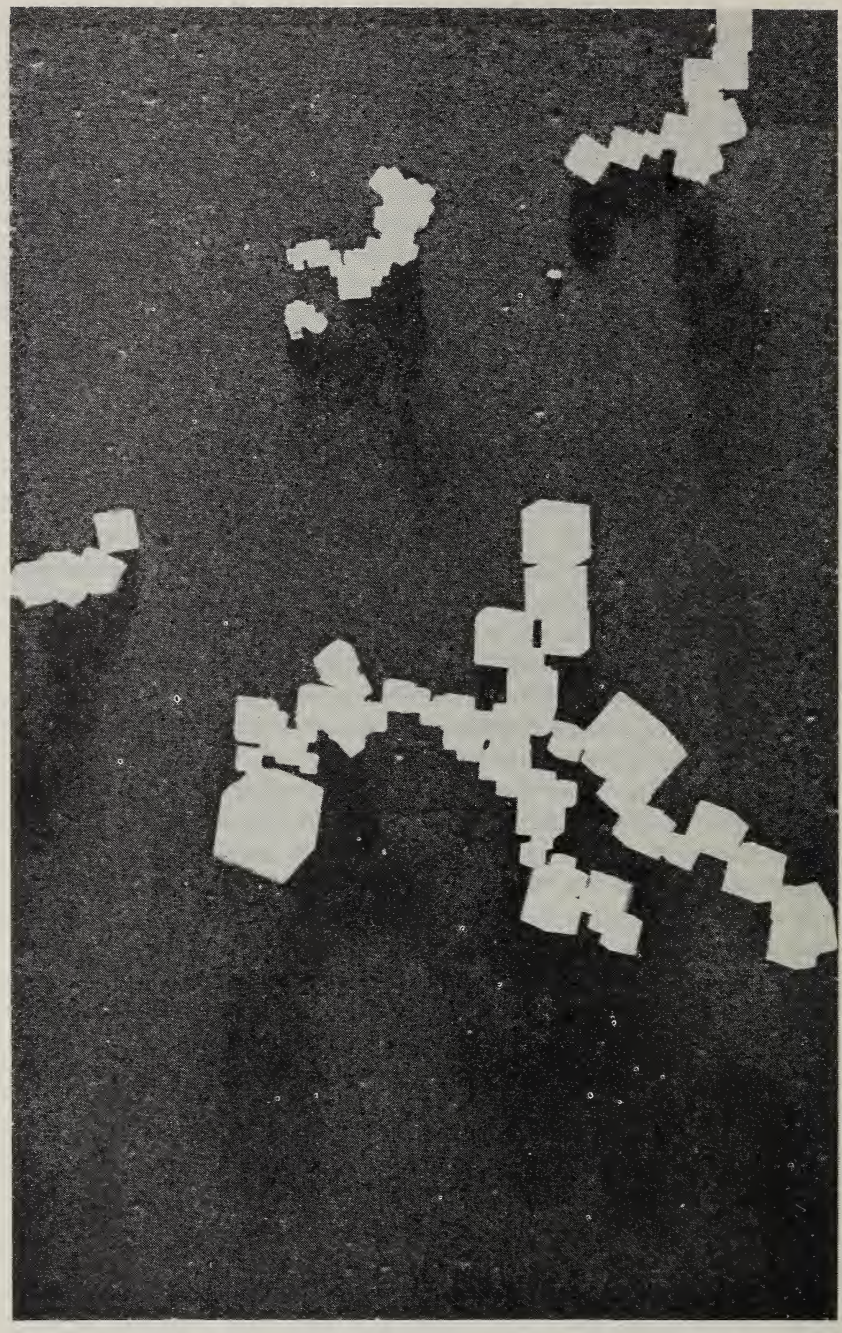
Thus far the method has produced solids containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy (OH) molecule. These solids have very unusual properties, emitting bright glows, blue "flames," and colored flashes of light. When warmed 20 or 30 degrees, they combine very actively, releasing large quantities of stored energy, principally as heat.

Possible fields of application for the technique include solid-state physics and basic chemistry. Here the trapped atoms could be used as powerful probes into the solids containing them. From a study of their properties, information could be obtained about the arrangement of the atoms and molecules in the solid and about the forces acting on them. Similarly, the mechanism of diffusion of atoms and of reactions between atoms and molecules could be studied.

Thermodynamics. The thermodynamics program is concerned with maintenance of heat standards, extension of basic thermodynamic theory, application of theory to specific problems, and improvement of experimental methods used to determine the properties of materials.

A new heat-capacity calorimeter was designed and built to permit accurate, detailed measurements on difficult materials that have a variety of forms or occur as glasses in the range from 25° to 500° C. Temperature control in the region surrounding the calorimeter is accomplished automatically by electronic equipment which reads, records, and regulates the temperature, and also computes required corrections. This calorimeter has been employed to measure the heat capacity of aluminum oxide, a standard material selected by the Calorimetry Conference. It is currently being used to determine the thermodynamic properties of sulfur which are of interest in the chemical and petroleum industries.

A new derivation was worked out for the Boltzmann equation, the basic equation of the kinetic theory of gases. This equation described the progression to equilibrium of an initial nonequilibrium state of a gas. It is derived classically on the assumption that the mechanism involves binary collisions between molecules. It has been found possible to express certain terms in the equation, which describe the effects of collisions, as a series in powers of the density. The first term corresponds to the classical Boltzmann equation, whereas the higher-order terms give



Electron micrograph of magnesium oxide smoke, showing particles as small as 0.025 micron (one millionth of an inch). Precise knowledge of the purity, size, and arrangement of these white cubic crystals is basic to their use as a reference standard in calibrating standards of color (p. 19).

the effects of triple and higher-order collisions among molecules and additional effects due to the finite size of the molecules. Classical theory neglected these effects. The term arising from triple collisions has been worked out explicitly, and this may be applied to the problem of calculating the first pressure-dependent correction to the viscosity and thermal conductivity of a dilute gas. The theory applies at pressures up to a few hundred atmospheres.

The thermodynamic properties of a gas may be calculated over a wide range of temperatures if sufficient information is available on the structure of the molecules that make up the gas. It is necessary to know both the geometric structure—the distances and angles between the constituent atoms—and the forces that hold the atoms together. The first type of information may be obtained from the microwave spectrum of the substance, whereas the second is derived from the infrared and Raman spectra. During the year a high-sensitivity microwave spectrograph was constructed. This apparatus covers the part of the electromagnetic spectrum that is used in radar applications.

In connection with a continuing research program on the properties of fluorine compounds, the new microwave spectrograph was used to study the structure of several molecules of current interest. An investigation of the microwave spectrum of sulfuryl fluoride has settled a dispute over the details of its structure. A joint microwave and infrared study was made of perchlorylfluoride, a recently discovered substance of considerable technological interest. The structure of this molecule was established and values of its thermodynamic properties were calculated. A study of the microwave spectrum of methylamine yielded interesting information about certain special internal motions that occur in this molecule.

A project on the vibrational spectrum of halogenated ethylenes was completed. This work was concerned with the modes of vibration of the atoms within a molecule. Simple theories about the forces in a molecule were developed and applied to certain typical molecules whose vibrations had been determined from experimental studies of their infrared and Raman spectra. With the aid of high-speed electronic computing machines, these theories were shown to give an accurate representation of the observed spectra. The theories were then used to predict the vibrations of a large number of related molecules. In this way vibrational frequencies were calculated for about 20 molecules that have not yet been studied experimentally. As a result, it is now possible to predict the thermal properties of these substances without the need for time-consuming experimental measurements. This method shows great promise for extension to other classes of substances.

Lubrication. In aircraft accessory equipment, such as gyros, motors, and inverters, it is highly desirable that the ball bearings be prelubricated so as to require no further lubrication. At ordinary temperatures, ball bearings prepacked with suitable greases may be operated satisfactorily for several thousand hours. Equipment in modern aircraft, however, is

subjected to temperatures ranging from −65° to +300° F, and in some cases much higher. In many such applications greases are not satisfactory because at low temperatures soaps or other thickeners cause high friction and at high temperatures chemical instability causes rapid deterioration.

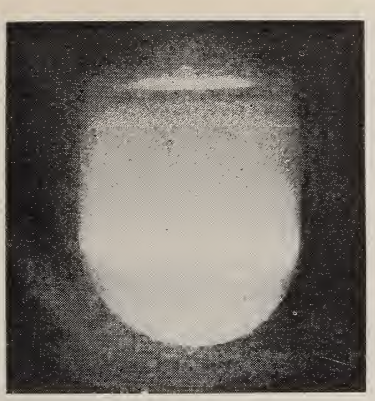
In previous work, supported in part by the Navy Bureau of Aeronautics, it was shown that felt-like materials can be used to hold a supply of suitable oil and to bleed it slowly to the races of the ball bearings. Wool felt rings on each side of the ball bearings were used at first, but they became badly charred at 325° F. More recently, synthetic felts that can withstand much higher temperatures than wool felt have become available. In further work, polyester felt rings were incorporated in ball bearings. At 325° F ambient temperature and 10,000 rpm, endurance tests were made with these rings saturated with di(2-ethylhexyl) sebacate containing appropriate additives, and with five greases for comparative purposes. Length of operation with the oil-soaked rings was far superior to that of the greased bearings. Comparative tests of oil-soaked felt rings and greases, made at temperatures down to −75° F and at speeds up to 10,000 rpm, showed greater ease of starting and lower friction at low temperatures with the oil-soaked felt than with the greased bearings. The work is being continued with extension to higher temperatures and speeds, including tests in gyros and other high-speed motors.

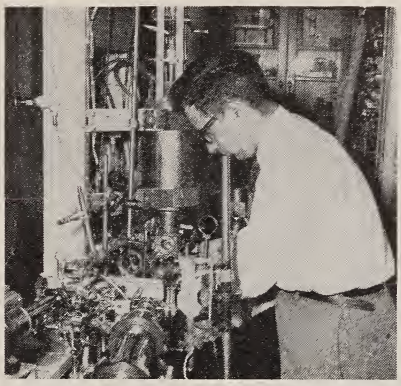
Engine Fuels. In isolated military posts, it occasionally becomes necessary to operate diesel engines on substitute fuels when a supply of specification fuel is unavailable. To aid in the intelligent selection of substitutes, a large number of fuels of diverse types were studied for the Army Ordnance Corps, particularly in regard to the cetane number and the effectiveness of ignition-quality improvers. From this study, it was possible to make general recommendations for selection of fuels to avoid hard starting and formation of deposits.

In another investigation, the relationship between cetane number and octane number was established for several fuels of various types. This study allows estimation of the cetane number of a diesel fuel by measurement of the octane number of the fuel in a 50-percent-isooctane blend. Thus, the Quartermaster Corps can now estimate the cetane number in the mobile petroleum-testing laboratories.

The relation between the net heats of combustion of aviation gasolines and other more easily measured properties of such fuels was investigated. Previous studies had shown that in certain cases net heat of combustion of a well-defined class of hydrocarbon fuels can be expressed as a linear function of aniline point, API gravity, or their product, but that in general a different relation must be used for each class of fuels.

Measurements were made of aniline points, API gravities, hydrogen and carbon contents, the contents of the four hydrocarbon types (paraffins, naphthenes, olefins, and aromatics), and net heats of combustion for 33 grade 115/145 aviation gasolines and 7 grade 100/130 gasolines, selected from a total of over 200 samples submitted by various producers. When





Glow from atomic nitrogen frozen into a solid a few degrees above absolute zero. The unusual properties of frozen free radicals—they emit bright glows, blue "flames," and colored flashes of light—are being studied spectroscopically using the apparatus shown at right (p. 24).

the results were correlated with heat-of-combustion data, the estimated standard deviation of a single observed value of net heat of combustion ranged from ± 23 to ± 49 Btu per pound, depending on the parameter studied. The observed results were also correlated with the measured composition of the hydrocarbon mixture and expressed as an equation in three parameters: percentages by weight of olefins, aromatics, and naphthenes. The standard deviation of a single experimental value of net heat of combustion from the resulting equation is ± 15 Btu per pound, which represents a considerable improvement over previously used equations.

Pneumatic Systems. The greatly increased flight speed of aircraft has stimulated interest in the use of pneumatic control and actuating systems as possible substitutes for more conventional hydraulic systems. Various difficulties are encountered with hydraulic fluids at the high temperatures encountered in high-speed flight. To aid the use of pneumatic systems, the NBS Pneumatics Laboratory has been engaged in standardization and research on pneumatic components under the sponsorship of the Navy.

The standards-development work involves preparation of specifications and of envelope drawings and evaluation tests of component prototypes. The research program includes a variety of problems such as determination of thermodynamic properties of air, study of pressure and temperature history during transient flow in pneumatic systems, response of pneumatic components to transient flow, and the explosion hazard associated with pneumatic systems. The explosion-hazard investigation is concerned with temperature-producing phenomena such as a single rapid compression pulse or repeated rapid compression pulses of low amplitude. Phenomena of this sort have been observed in pneumatic systems even at low pressure. Apparatus has been constructed that produces temperatures high enough to cause ignition of various organic materials, such as hydraulic oils.

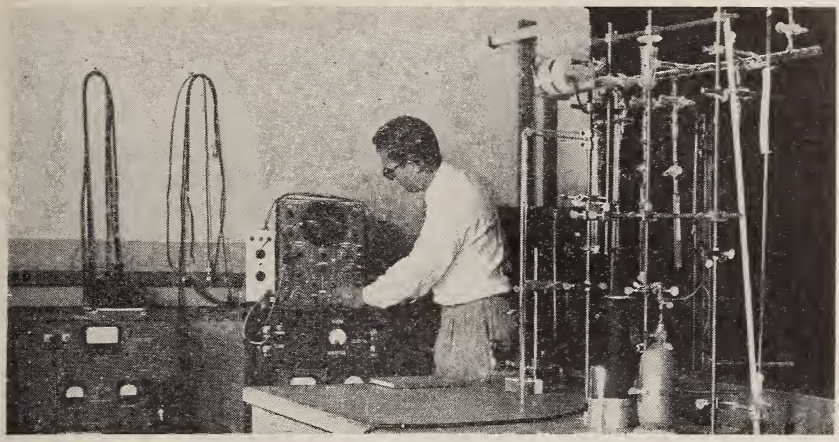
2.4. Atomic and Radiation Physics

The reliance of modern industrial technology and military defense upon advances in atomic and nuclear physics is creating a constant demand for additional and improved standards, for new methods of measurement, and for more extensive and precise data. The Bureau's program in atomic and radiation physics is designed to meet the most urgent of these needs through basic and applied research on particles such as atoms, nuclei, neutrons, and electrons; properties of radiation, particularly gamma and X-rays and ultraviolet and infrared light; and the interactions between radiation and particles. The results of such studies, both at the Bureau and elsewhere, are evaluated and compiled for publication in handbooks and circulars, which make the data readily available in the most useful forms for engineers, scientists, the medical profession, and others. The understanding of basic processes revealed by these studies is essential to the Bureau in devising suitable standards of measurement and in providing essential calibration services for new instruments and materials.

Spectroscopic Research. In 1946, the Bureau began to compile information on atomic energy levels as derived from analyses of optical spectra of atoms and ions. Such information includes precise energy values, magnetic splitting factors, quantum numbers, electron configurations, and excitation and ionization potentials. These data are basic to quantitative spectrochemical analysis in industry; astroyphysicists require them for determining the chemical compositions, temperatures, and gaseous pressures in stars; and the same data and methods can be applied to the study of nuclear weapons.

This information is being published as NBS Circular 467, "Atomic Energy Levels." Volumes I and II, containing data for 358 spectra of elements 1 through 41, have been issued. Volume III, now nearing completion, deals with all known spectra of elements 42 through 57, and 72 through 89. It will contain a vast amount of new information about heavy elements (molybdenum, technetium, ruthenium, iodine, hafnium, tantalum, tungsten, rhenium, and actinium), characterized by very complex spectra that have been intensively investigated for many years. Two of these elements, technetium and actinium, are artificial and unstable; the first was obtained from uranium fission, and the second by transmuting radium in a uranium pile. Milligram samples of these elements sufficed for accurate and extensive descriptions of the spectra emitted by neutral atoms or by singly or doubly ionized atoms, and analysis of the successive spectra yielded interesting information concerning atomic energies and electronic structure of the two elements.

Standards of Isotopic Abundance. The mass-spectrometer research carried on in many laboratories throughout the world on the natural abundance of isotopes is invaluable for determining the age of minerals and for important clues to the temperature and other physical conditions of the



A microwave spectrometer is providing new information on the structure of fluorine compounds of considerable technological interest (p. 27).

earth when the various minerals were formed. Unnecessary uncertainty exists, however, in available isotope-abundance data because of the lack of common standards to which all measurements can be referred. For this reason, the Bureau, at the request of the United States Geological Survey and with the sponsorship of the Atomic Energy Commission, undertook a program of preparing and distributing reference samples for use in such research. This will make it possible, for the first time, for all laboratories doing research on a particular element to work with the same material.

Samples are being made available on an international basis and will consist of elements and compounds in forms suitable for mass-spectrometer analysis. As a part of the program, the Bureau is determining the suitability of new chemical compounds for isotope measurements and is developing convenient preparation technique. The Bureau also will serve as an international clearing house for data on the natural abundance ratios for these samples. Accumulated data on each element will be distributed with every sample sent out.

Semiconducting Materials. In research on intermetallic compounds, emphasis was placed on the binaries of indium and antimony and of magnesium and tin. Both compounds have been synthesized in the form of extremely pure single crystals, and their electrical, optical, mechanical, and thermal properties have been measured. The increased knowledge thus obtained on the behavior of semiconducting surfaces is of great importance for judging the feasibility or improving the operation of devices such as transistors and photodetectors.

Both InSb and Mg_2Sn show potential possibilities as photodetectors for the far infrared spectral region, the first as far as wavelengths of 7.5 microns, the second up to 4 microns. Measurements on InSb have yielded the elastic constants of this material over a wide temperature range. Important information has also been obtained concerning the

anelastic properties of this compound. An investigation of the electrical conductivity of Mg_2Sn at very low temperatures has shown that it is possible to completely separate surface and bulk conduction. Also, the thermoelectric power of InSb has been investigated as a function of temperature. This phenomenon in semiconductors has recently drawn considerable attention, not only because of the theoretical implications, but also for its possible use in power sources and refrigerating units.

Another semiconductor of great interest is grey tin, because of its small energy gap. An extensive study of the crystal growth and transformation of this element was completed. Single crystals as long as 2 mm were produced and their electrical properties were investigated. This work was supported by the Air Research and Development Command and the Office of Naval Research.

Field-Emission X-ray Microscope. The development of an X-ray microscope making use of field emission has been completed in a project sponsored by the Air Research and Development Command. Having a resolving power of a few microns, the prototype is a simplified instrument which demonstrates the basic principles and design. The advantages of this instrument over previous devices are greater compactness and simplicity. The resolution is capable of considerable improvement by further engineering refinements. The X-ray microscope bridges a gap that exists between the conventional microscope and the electron microscope, having a resolution between the two, but with the advantages of increased penetration for the determination of inner structures of biological specimens.

Electron-Optical Studies of Low-Pressure Gases. With the development of high-altitude, high-speed missiles, a critical need has risen for knowledge of the flow of extremely rarefied air and of the heating and cooling effects of a high-velocity gas stream striking a metal surface. Unfortunately, conventional methods of flow visualization fail at an air density corresponding to that of the atmosphere at a height of about 30 miles. In work supported by the Office of Naval Research, a new electron-optical method has been developed to photograph the flow pattern at densities corresponding to altitudes greater than 100 miles. The preliminary experiments were done with a stream of cadmium vapor moving at approximately the speed of sound. The method, which is applicable to other gases or velocities, is being extended to permit measurement of the temperature and velocity of the gas before and after reflection from a surface. From such data, the aerodynamicist can predict the air resistance and heating of the surface at any speed or altitude.

Microwave Absorption. Significant progress has been made in the development of special techniques for measuring very small microwave absorption coefficients, such as those of importance for microwave propagation in the atmosphere. For this purpose, a unique design and method of excitation of very large cavity resonators has been thoroughly studied and tested. The method consists mainly in the successful separation of a single pure mode from an extremely densely populated cavity spectrum,

and thus considerably extends the practical range of cavity resonance techniques. In the microwave circuitry of such techniques, an arrangement is required for measuring extremely minute wave-guide attenuations, much smaller than those measurable by commercially available attenuators. To surmount this difficulty, a special microwave circuit has been devised which in effect multiplies the scale reading of an attenuator by several orders of magnitude. The latter circuit should have wide application in measurements of very small absorptions, such as, for example, in the study of the absorption behavior of ferrites. This work is supported by the Air Research and Development Command.

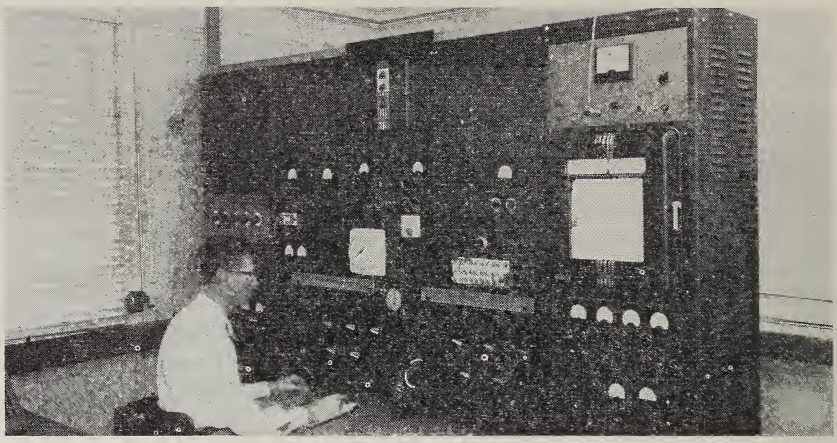
Radioactivity. The main function of the NBS radioactivity program is to produce radioactivity standards and to develop new means for calibrating and maintaining such standards. In this latter field, considerable attention has been given to the development and use of satisfactory liquid scintillators. The effects of secondary solutes, oxygen removal, and lower temperature have been investigated, and it is now possible, under special conditions, to make a liquid scintillator more efficient than anthracene.

New alpha-particle standards of great mechanical durability, consisting of polonium-210 deposited on palladium on silver disks, have been developed. These have little or no alpha straggling and no beta component. Beta- and gamma-ray solution standards of hydrogen-3, potassium-42, zinc-65, and tantalum-182 were added to the list of those produced or released for distribution. International comparisons have been carried out between the Bureau's short-lived solution standards and those of the United Kingdom and Canada. The United States primary radium standards have also been compared with those of Canada and the Federal Republic of Western Germany.

In the nuclear spectroscopy laboratory, the inner bremsstrahlung spectra of vanadium-49 and cesium-131 have been satisfactorily compared with theoretical calculations. A more complete determination of the disintegration scheme of silver-105 has been made and anomalies in the decay of scandium-43 resolved. The energy levels in the decay schemes of nickel-57, iron-53, and yttrium-86 have also been investigated. A determination of the decay rates of millicurie amounts of cobalt-60, submitted by Atomic Energy of Canada, Ltd., has been made.

X-ray Standards. To achieve uniformity of X-ray measurements not only within this country but throughout the world, it is necessary to make precise measurements of the constants involved in the conversion of measurements to the amount of energy absorbed in the human body, and insure that all of the laboratories in the world agree on their primary measurements.

Toward this end the Bureau has been investigating some of the quantities involved. A measurement was made of the amount of energy required for sulphur-35 beta rays to produce an ion pair in air. A value of 33.71 ± 0.24 electron volts was obtained.



Control panel of a new heat-capacity calorimeter for making accurate measurements on materials difficult to study in the range from 25° to 500° C (p. 25). Electronic equipment automatically measures, records, and controls the temperature of the region around the calorimeter.

In addition, a Swedish free-air chamber was calibrated against the Bureau's primary standard. After all corrections were made, the Swedish chamber was found to agree to within 0.5 percent with the NBS chamber and to within about 0.5 percent with an earlier calibration performed at Frankfurt, Germany. In this calibration, as well as in earlier ones, it was found that the items most likely to be in error were the diaphragm area and the electrical capacity used to determine the ionization charge. To facilitate checking of these items without having to transport the large free-air ionization chambers, the Bureau agreed, at the suggestion of the International Commission on Radiological Units, to construct a set of diaphragms and a set of standard capacitors. These are to be loaned to standardizing laboratories in other countries for intercomparison with their own similar equipments. In addition, the Bureau agreed to construct a small secondary standard, which is to be calibrated at NBS and then made available to the same laboratories. It is hoped that the availability of these three items will reduce the extensive amount of intercomparison required between the standardizing laboratories of the world.

High-Energy Accelerator Research. High-energy X-rays are being applied to food sterilization, industrial radiography, and medical therapy. To further understanding of these X-rays and their interaction with matter, the Bureau has completed research on two basic problems that have challenged experimenters since high-energy X-ray sources became available. The first is the measurement of energy and angular distributions of the X-rays produced in very thin targets by monoenergetic electrons. In this phase of the work the results for certain conditions show large departures from the approximate theories. The interpretation of many precise experiments needed for practical applications of the high-energy X-rays should be aided by these results.

The second investigation was carried out for the Air Research and Development Command. In this study, gamma rays from carbon and oxygen nuclei that had been excited by high-energy X-rays were detected and measured. For example, carbon when irradiated by high-energy X-rays emits monoenergetic gamma rays of 15 Mev. The number of these gamma rays and their angular distribution have been determined with specially developed Bureau equipment as part of a program to provide experimental data for nuclear structure theorists.

Reciprocity Law for X-rays. Photographic film has been used extensively for measuring radiation in atomic weapon tests. It was thought that at the high radiation intensities that occur, the energy loss due to luminescence within the photographic material might be large enough to cause competition between the process of luminescence and that of latent-image formation by high-energy radiation. However, the latent image formed by the visible light stemming from such luminescence would show reciprocity-law failure.

In a project sponsored by the Army Signal Corps, the validity of the reciprocity law for X-radiation of very high intensity (up to 66,000 roentgens per minute) was investigated both in the negative and in the positive (reversal) branches of the characteristic curves for some of the dosimeter film types. Conventional X-ray development, as well as surface and internal development. was employed, because it is known that certain film emulsions tend to show reversal when processed in a surface developer, whereas generally no such effect is encountered in other types of developer. Actually, reversal was found to occur only upon surface development of both of the film types studied. Within the experimental error, no failure of the reciprocity law was found in the negative branches of the characteristic curves of the films. The study of the positive branch of the characteristic curve of one of the films revealed both reciprocity-law failure and intermittency effects. These effects consisted not only in a shift of the characteristic curves, but in a change in the maximum density obtainable before the onset of reversal.

In the dose-rate range investigated, higher dose rates produced smaller film sensitivities and higher maximum densities. The latter effect explains why some of the film of this type, exposed during the 1955 weapon tests and developed in surface developer, had shown densities considerably above those found on simultaneously developed laboratory calibration films.

Medical X-ray Rooms. The calculation of the barrier requirements in X-ray rooms, as specified in protection handbooks, has been based on maximal assumptions for the various factors. This has provided adequate protection, but the question has been raised as to whether or not this is realistic. To find an answer, measurements were carried out in 22 medical diagnostic radiographic and fluoroscopic X-ray rooms by means of about 75 small ionization chambers distributed over the walls of the rooms. These chambers were read daily for several weeks in each room

and the amount and quality of radiation reaching the walls determined. At the same time, the workload was automatically recorded by means of an electronic integrating device developed specifically for the purpose. The results of the study, which was sponsored by the Atomic Energy Commission, have shown that the actual X-ray exposure of the walls is about one-tenth that assumed. These results would therefore permit a substantial saving in the lead or other protective materials used in the construction of this type of installation.

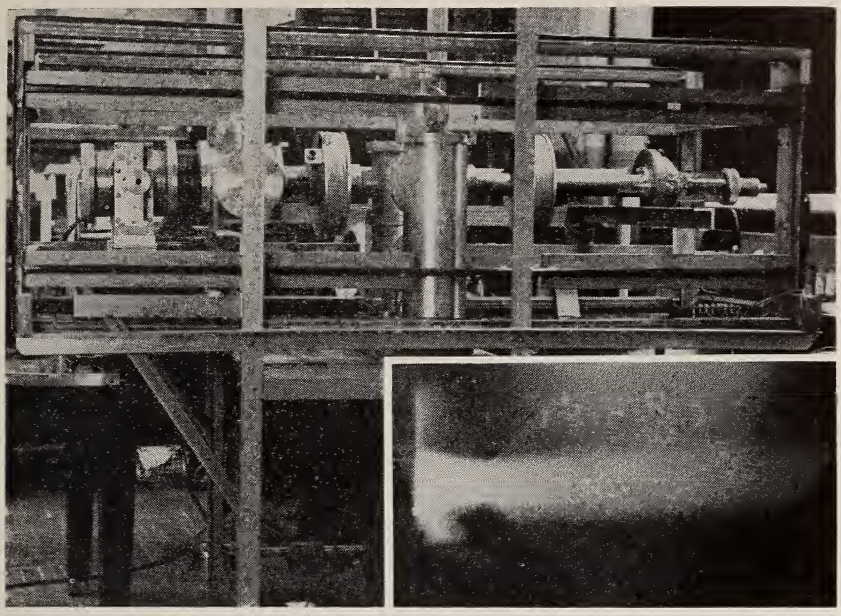
National Photoneutron Standard. A new determination was made of the emission rate of the Nation's primary standard photoneutron source. For this purpose, an absolute calibration method was developed which is more precise and more easily performed than most existing techniques. As a result of this work, the emission rate, or "Q", previously established for the standard has been confirmed and the accuracy of the measurement increased.

The primary photoneutron standard is a radium-gamma-beryllium source that produces neutrons by the interaction of gamma rays with beryllium. The source consists of 1 curie of radium bromide in a platinum-iridium capsule that is placed in the center of a beryllium sphere 4 centimeters in diameter. Because the capsule absorbs the alpha particles from radium and its decay products, only gamma rays can enter the beryllium sphere. A secondary photoneutron standard, similarly constructed and calibrated relative to the primary, is available to other laboratories for comparison measurements.

The development of nuclear reactors has made possible a widespread increase in neutron irradiation research. As a result, a need has developed for reliable standards to calibrate accurately neutron thermal fluxes and to measure neutron yields. The Bureau is engaged in a program to provide such standards and to establish improved methods of neutron measurement. The present recalibration was initiated partially as a result of the wide discrepancies revealed by international comparisons of neutron standards.

Low-Energy Electron Scatter. Considerable progress was made during the year in the Bureau's studies of electrons scattered by passage through thin films of matter. The results are applicable to the study of radiation effects of interest in biophysics and medical research, and have a direct bearing on the performance of electron microscopes. The program also contributes to better understanding of the solid state physics that underlies the operation of semiconductors and transistors, and the process of secondary electron emission which is essential to the operation of many types of vacuum tubes.

Using electron beams in the range 0 to 150 kev, the experiments have concentrated on the scattering losses below 100 ev due to single inelastic collisions. Data were obtained on the distributions in velocity and direction of electrons scattered by a large number of substances. Important improvements were made in experimental technique and in the



Apparatus used in electron-optical study of gas flow at extremely low pressures (p. 32). *Insert:* Obtained with this apparatus, shows dark field image of cadmium atomic beam at pressure of 0.003 mm of Hg. Bright spot above beam is incidental background.

design of apparatus, especially the instruments used for determining the velocity distribution of scattered electrons. These experimental studies are supported by the Atomic Energy Commission and the Office of Naval Research. At the same time, the Bureau itself is sponsoring a number of theoretical studies of the scattering process.

2.5. Chemistry

A wide range of fundamental and applied research is carried on in physical, analytical, organic, and inorganic chemistry. This work embraces investigations of analytical methods, separation and purification of substances, electrodeposition of metals, electrophoresis and light scattering by colloidal particles, growth of crystals, polarographic studies, labeling of carbohydrates with radioactive carbon, and developing electric devices for gas analysis, spectrometry, and thermochemical measurements. Most of the Bureau's standard samples, critical in industrial quality control and in research throughout the Nation, originate in the chemistry laboratories.

Rare-Earth Elements. Significant progress was made in separating the rare-earth elements from one another by ion-exchange techniques, based on the differential retention of metal ions on the surfaces of certain resins. Nearly all of the rare earths were refined to a high degree of purity, praseodymium and neodymium to 99.99 percent. The highly purified

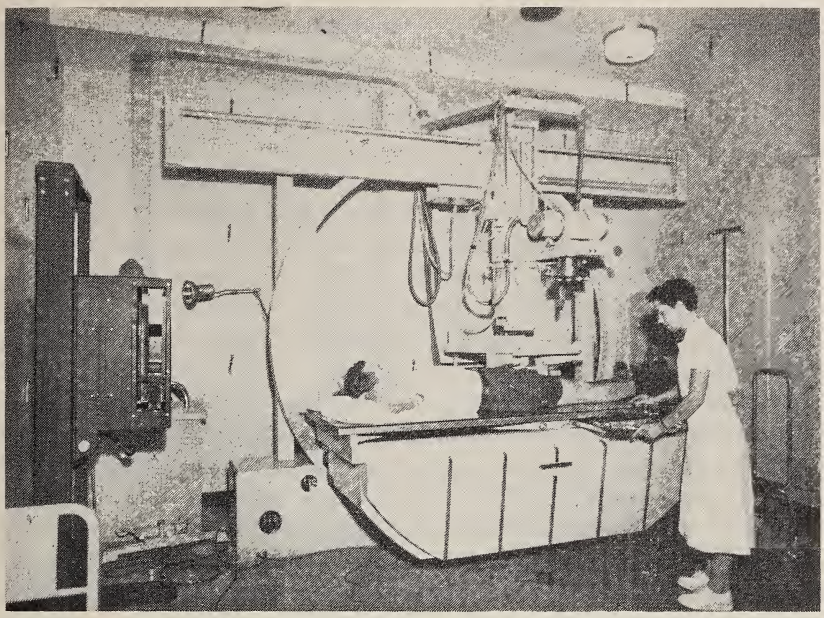
elements are for use in fundamental research on spectral properties, hyperfine structure, isotope shift, and X-ray diffraction. In the course of this work, an automatic cutoff valve and a collector were developed for use with ion-exchange techniques. The collector, a bed of resin, removes the rare earths quickly from dilute effluent solutions and recovers the metals in concentrated form.

Dielectric Constant of Water. The dielectric constant of water is an important physical quantity entering numerically into basic equations. However, discrepancies amounting to 1 percent or more exist in the best data previously reported for this constant. During 1955 the Bureau redetermined the dielectric constant of water by improved methods to an accuracy of 0.1 percent or better over the range 0° to 100° C. The dielectric constant of heavy water was also determined over the range 4° to 100° C.

Acids and Bases in Nonaqueous Solvents. In a program sponsored in part by the Department of the Air Force, further insight into acid-base behavior was gained by systematically investigating nonaqueous solvents. Such solvents are constantly increasing in uses and multiplying in number. Knowledge of their acid behavior is important in the petroleum, food, and drug industries; in understanding physiological processes; in the manufacture of chemical compounds; in chemical analyses; in electrodeposition; and in many other areas of science and industry.

A puzzling aspect of acid behavior has been a lack of constancy in the order of relative strengths when certain nonaqueous solvents are substituted for water. Systematic investigations are revealing the relationship between the structures of individual acids and their behavior in different kinds of solvent. In this work, use is made of a special indicator dye developed at the Bureau and now commercially available.

Thermochemistry. Determination of the heats of formation of chemical substances is the primary method for obtaining precise values for the binding energies in molecules and the variation of energy content with molecular structure, such as occurs in isomeric substances or in a homologous series of organic compounds. Thermochemical data are also required by engineers for determining heat balances in chemical-process plants and calculating reaction equilibrium constants needed for process design and development. During the past year, measurements on *cis*- and *trans*-isomers yielded information on the steric effects in substituted hydrocarbons. Measurements on several acyl peroxides provided data on the energy of formation of the various acyl radicals and the strength of the O–O bond. Survey reports summarizing the available thermodynamic properties of the alkali metals, halogen compounds, and boron compounds were also prepared and published. Investigations of the heats of formation of various boron hydrides and other boron compounds are in progress.



One of 22 medical X-ray rooms surveyed by NBS to compare actual radiation present with recommended safe levels. Pocket-size ionization chambers suspended from walls and ceiling measure intensity of radiation reaching those points. Duration and quality of radiation were also recorded (p. 35).

Analytical and Physical Chemistry. Improved analytical methods were developed for controlling the composition of ceramic dielectrics used in proximity fuses. Such dielectrics contain barium titanate, lead titanate-zirconate, and other complex combinations or compounds. Developed for the Diamond Ordnance Fuze Laboratory, the procedure involves the separation of barium from strontium, titanium from zirconium, and a number of other elements from one another.

In many cases, the determination of lead and cadmium in spelter and zinc-base alloys is most conveniently and accurately performed by polarographic methods. A procedure was developed for the polarographic determination of cadmium and lead in zinc-base alloys which involves separation of these metals from the zinc by electrolysis at controlled potential using a mercury cathode. By this procedure as little as a few ten-thousandths of a percent of cadmium and lead can be determined.

Measurements of dielectric loss were made with resonant cavity techniques on methane, ethane, propane, *n*-butane, isobutane, isopentane, and neopentane up to pressures that approached the saturation pressure. Significant loss attributable to the presence of small permanent dipole moments was found in propane, isobutane, and isopentane. The results yield important information concerning the molecular structure of these compounds, especially with regard to polarities and bond angles.

A comprehensive investigation was continued on methods for analyzing the new complex heat-resisting alloys used in the aircraft industries. At

the request of the Atomic Energy Commission, methods were developed for analysis of sodium and potassium borohydrides and platinum-uranium alloys.

Special Investigations and Developments. A simple, compact oven that stabilizes the temperature of quartz crystals for precise oscillator frequency control was developed for the Army Signal Corps. The oven utilizes the heat of fusion of an extremely pure organic compound—*p*-dibromobenzene—to hold the oven temperature within 0.01 degree of 87.31° C. The special-purpose oven eliminates the need for much of the complex equipment ordinarily used to stabilize crystal temperature in oscillator circuits. The oven can also be used wherever a simple, compact thermostat for close temperature control is required.

Ether peroxides have been prepared rapidly in appreciable amounts by irradiation of ether with ultraviolet light in the presence of oxygen. These peroxides appear to be identical to those formed in ether during storage and can thus be used to study their explosive and other properties.

Ion-selective membranes have promising possibilities for increasing the efficiency of various electrolytic processes for desalting sea water. Results from initial work for the Department of the Interior indicate the possibility of obtaining membranes with a very high positive charge. If these membranes can be modified to have sufficient mechanical strength, they will provide a valuable material for biological and other studies as well as for Interior's saline-water program.

Molybdenum possesses considerable structural strength at elevated temperatures at which steel loses most of its strength. Molybdenum would thus be useful for the turbine blades of jet engines were it not for its ease of oxidation, which becomes serious above 800° C. Numerous methods of protecting molybdenum have been explored, but the types of protective coatings are limited because they must not only be oxidation-resistant and nonporous but also ductile. One of the chief problems is to make such coatings completely pore-free. Even the most minute imperfections can cause the molybdenum beneath a coating to form a volatile oxide and completely disappear within a few hours. During the year a process was developed for the Navy Bureau of Aeronautics for electrodeposition of protective coatings consisting of a layer of chromium 1 mil thick followed by a nickel coating about 7 mils thick. These coatings have afforded molybdenum protection in excess of 1,000 hours at 1,000° C and 300 hours at 1,100° C. It is now feasible to make service tests of molybdenum turbine blades having these protective coatings.

2.6. Mechanics

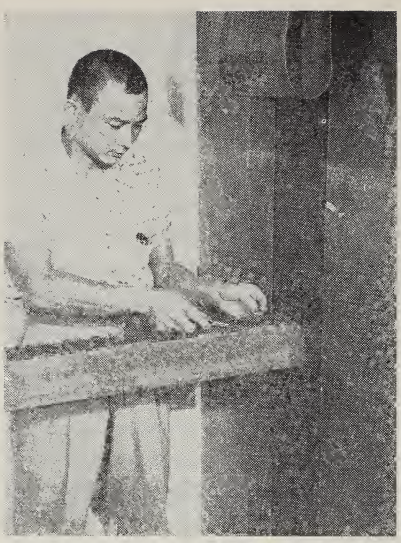
Basic to the Bureau's program in mechanics is the development, improvement, and maintenance of standards and the development and evaluation of techniques for the measurement of a large variety of mechanical quantities. These include volume capacity, weights and other forces, static pressures, the flow of liquids and gases, vibration amplitudes, and

the speed, attenuation, and intensity level of sound. To provide fixed points for comparison and otherwise to supplement these basic activities, precise determinations are made of physical constants and properties of materials, such as density, viscosity, and sound-transmission characteristics. In addition, fundamental research is performed in the mechanics of solids and in fluid dynamics.

A large part of the Bureau's work in mechanics during the past year has been in direct response to technological trends toward higher speed, power, and thermal efficiency. The increased vibration that often attends higher speed and power, for example, has led to the evaluation and calibration of vibration pickups and the study of special pickups that may be suitable as secondary standards in other laboratories or in the field. Similarly, the sudden pressure changes occurring in the combustion chambers of modern engines have required a study of the behavior of pressure pickups under the new conditions. The possible damage to hearing from the intense noise of jet aircraft has led to the study of hearing loss and its compensation by hearing aids, and to the more accurate measurement of sound levels generally and the calibration of sound-level meters over a wider range of frequencies and intensities. Much attention has also been given to the calibration of strain gages and to the development of thin evaporated films whose resistance would change in proportion to strain at temperatures up to the highest expected in jet engines and other machines operating at high temperatures.

The advance toward higher speeds in aircraft and missiles lends increased importance to the Bureau's long-term studies of turbulence, which controls the frictional drag on objects moving through the air. It has also increased the demand for calibration of the electronic dynamometers used to measure engine thrust in thrust stands. The control of fuel flow for aircraft engines and the efficient combustion of the fuel-air mixtures in the engine is under constant study for the Department of Defense to develop standards and specifications in this field. The effect of high temperature on the production of creep in structural material and in joints is another serious practical problem that has been studied.

Vibration Pickups. In determining the effect of shock and vibration on certain types of equipment, it was necessary to measure the vibration of fairly flexible sheets of plastic or metal. Commercially available vibration pickups were found unsuitable for this purpose because they were too large, heavy, and expensive. Simple vibration pickups were therefore developed in an investigation sponsored by the Diamond Ordnance Fuze Laboratories. The NBS pickups are much smaller and lighter than commercial models, although their sensitivity and frequency range are comparable. They consist of a barium titanate disk and a brass mass cemented together with a conducting epoxy resin and attached to the vibrating surface with a thermoplastic resin. The pickups are $\frac{3}{16}$ inch in diameter, weigh 0.6 gram, and have an output of about 1.5 millivolts per gram and a capacitance of about 100 picofarads. The first resonance oc-



Methods of evaluating neutron sources. *Left:* An indium foil is inserted into pile containing neutron source; foil is later removed and its beta-ray activity measured. *Right:* A dip counter measures the activity of a manganese sulfate bath that has been irradiated by the national photoneutron standard. This permits calibration of the standard to within 2 percent (p. 36).

curs above 90 kc and the transverse response is about one-tenth the axial response. Electrical shielding is provided by a coating of silver paint over a coating of insulating paint.

Pressure Measurement. Interest continues to increase, both for industrial processes and for military application, in precise measurements of pressure, particularly at very high and very low pressures. During the year further attention has been given to improved measurement and calibration of very high pressures, both static and transient. In the field of static pressures, steps were taken toward the ultimate construction of a 200,000-psi dead-weight piston gage. Following the issuance of NBS Circular 558, "Bibliography and Index on Dynamic Pressure Measurement," the current state of the subject was examined once again; and, under the sponsorship of Ballistic Research Laboratories, Aberdeen Proving Ground, preliminary investigations were carried out on high-pressure dynamic calibration methods.

At the other end of the scale, improved measurements of low pressures (corresponding to altitudes above 80,000 feet) are needed for instrumentation of high-performance military aircraft. Under the sponsorship of the Air Force, a new pressure standard covering the pressure range up to 2 inches of mercury was completed in preliminary form. This instrument incorporates modern techniques for precise sensing of the height of mercury columns and promises to provide a standard having the necessary high accuracy.

Forces Produced by Waves. Because of the importance of wave action on engineering structures and on the design of ships, a continuing program of wave research has been under way at NBS supported principally by the Office of Naval Research. An investigation of forces exerted on cylinders and plates exposed to sinusoidal currents, such as are produced by continuous waves, was recently completed. A similar investigation of the forces on cylinders in the path of a solitary wave is now under way.

Origin of Turbulence. Another step forward has recently been made in solving the puzzling question of the origin of turbulent motions occurring near the surface of bodies moving through air or water. These motions remove the fluid (air or water) that would otherwise be carried along with the body, and thus simultaneously remove energy from the body with a resultant increase in surface friction. They also increase the rate of heat transfer and therefore increase the amount of heating that occurs at supersonic speeds. The question, when and how turbulence begins, was partially answered about a year ago when it was discovered, in the course of an investigation sponsored by the National Advisory Committee for Aeronautics, that turbulence originates on a surface at isolated points and develops as growing spots. A continuation of this investigation has now revealed that the points occur where a wave motion in the laminar flow becomes unstable. The instability has been studied by producing waves artificially and controlling the amplitude and frequency at will. An initially plane wave front has an inherent tendency to become irregular, developing points of high amplitude. At these points high-frequency oscillations set in, and these constitute the beginning of a turbulent spot. This finding has an important bearing on the theoretical as well as the practical aspects of the problem. Although numerous important questions remain to be answered, this constitutes a significant step toward the solution of the turbulence problem, which is important in the science of flight and vital to the attainment of sustained speeds many times that of sound.

Culvert Hydraulics. It has been estimated that approximately 10 percent of the cost of multilane-highway construction, amounting to several hundred million dollars per year under the present construction program, is required for culvert installations. The high costs of modern culverts make it imperative that the most efficient installation be used and that the water-carrying capacity be accurately known. About 2 years ago, the Bureau began a laboratory study of culvert performance for the Bureau of Public Roads. The aim of this investigation is to establish design criteria and to develop improved culverts of nonrectangular cross section.

The principal problem arises from the fact that conventional culverts do not flow full even when the entrance is completely submerged. They will, however, change over to full flow after some considerable depth of submergence, depending on inlet shape and other factors involving a complex inter-relationship between hydraulic and pneumatic processes.

It has been found for long culverts that the regime change from part-full to full flow is controlled for a particular inlet by such different physical processes as hydraulic jump, strength of vortex action over the inlet, air entrainment in the inlet and culvert barrel, and turbulence of the approach flow. Performance characteristics have been determined from model studies of a variety of conventional inlets under various conditions. The results have not only yielded presently needed information, but more important, have provided the necessary insight into the factors controlling efficient operation to form the technical framework for improving the design of culvert inlets.

Creep of Aircraft Structural Joints. Most of the major problems associated with the attainment of higher speeds for aircraft and missiles result from the effects of aerodynamic and jet-engine heating. One such effect is creep, the phenomenon of continuously increasing deformation under constant loading.

Although considerable effort has been expended toward determining the creep properties of materials, relatively little research has been conducted on the creep behavior of structures. To provide data in this field, an investigation was undertaken concerning the creep and creep-rupture testing of riveted, bolted, and spotwelded joints of aircraft materials under constant loads and temperatures. From the results of these tests, which are supported by the National Advisory Council for Aeronautics, methods were developed for predicting the deformation, the mode of rupture, and the time-to-rupture for structural joints in creep. These methods are based upon the creep properties of the materials of the joints in tension, bearing, and shear.

In another phase of this work, tests were begun for creep in joints subjected to cyclic changes in temperature and load. These tests provide a closer simulation of actual flight conditions, in which load and temperature are continually affected by speed, maneuvers, and altitude. The test results obtained to date suggest that a conservative estimate of the creep behavior of a structural joint under cyclic conditions of temperature and load can be obtained from the creep properties of the materials of the joint under equivalent cyclic conditions.

Vibration of Telephone Wires. As a horizontal wind passes over a wire, distinct vortices are formed in the wake. The vortices subject the wire to an alternating vertical force at a frequency that depends on the wind velocity and the diameter of the wire. This force can cause severe vibrations if the frequency of the force is near one of the transverse natural frequencies of the wire. The vibrations, sometimes heard as a "singing" of the line wires, have caused structural failures at the points where the wire is tied to insulators on the telephone pole. Because these failures increase the cost of maintenance of telephone lines, the Rural Electrification Administration requested the Bureau to conduct laboratory tests that subject telephone wires to this type of vibration. In the tests, which are run for 100,000,000 cycles at approximately 0.125 inch double

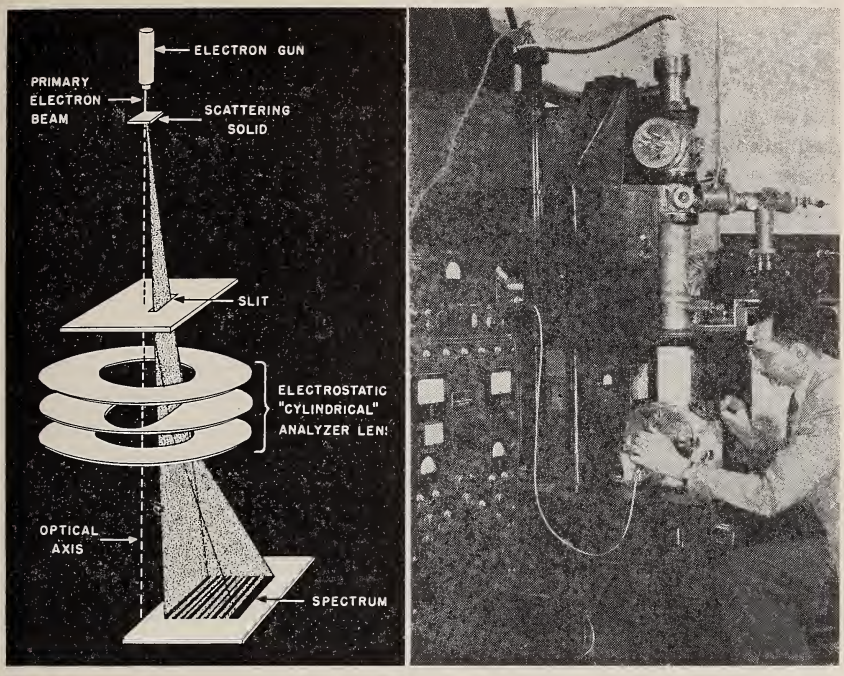


Diagram (left) shows one of the methods of determining the velocity distribution of electrons scattered by thin films. In the actual instrument (right), the velocity spectrum is automatically recorded (p. 36).

amplitude and 200 cps, the vibration is automatically maintained at exactly the desired natural frequency even when frequency changes occur as a result of changes in temperature and other factors. Tests were made on several different types of ties and on REA standard tie No. 163. The ties were used with steel and copper-coated steel wires to determine the wear that occurs between different parts of the tie. The test results have been of assistance to REA in the development of a suitable "pretie" type of tie. A pretie tie is superior to other types because its initial cost is less, it is tied before it is placed on the pole, and it need not be cut off when the line is resagged.

High-Temperature Strain Gages. In recent years the use of remote-reading strain gages for studying the properties of materials and behavior of structures at normal temperatures has become common procedure. The gages most frequently used consist of fine wire or foil resistance elements, which are attached to the surface of the structure by means of adhesives. Because the properties of both the resistance material and the adhesives change with temperature, the normal-temperature relationship between change in resistance and strain may no longer hold at elevated temperatures. Furthermore, the gage material may become unstable or fail completely when subjected to the high temperatures and rapid temperature changes that are encountered, for example, in aircraft

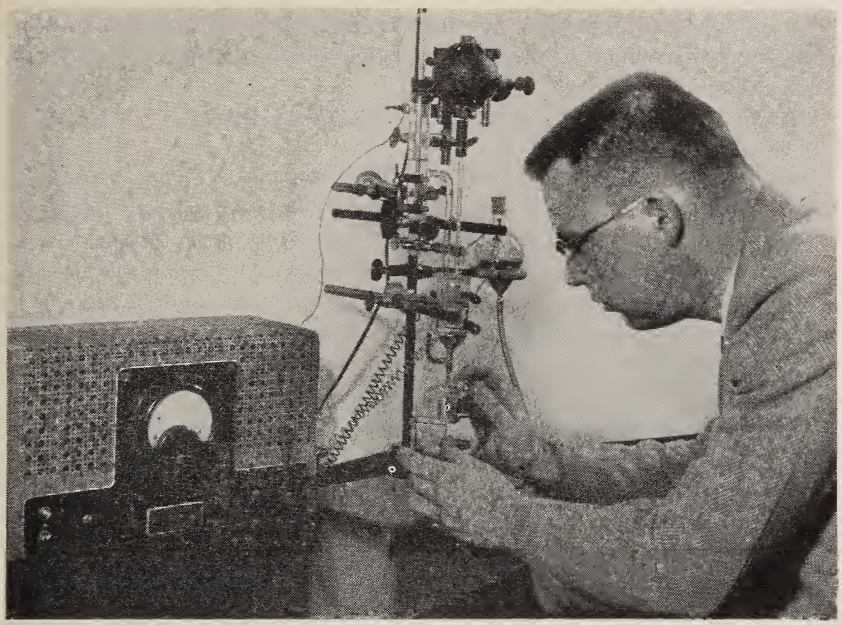
engines and reactor components. Considerable effort is now being expended to develop resistance strain gages, similar to the normal-temperature ones, for use at temperatures up to at least 1,600° F. Because the materials, manufacturing methods, and users' techniques are different from those developed for the more familiar room-temperature gages, the characteristics of these gages must be determined at the temperatures at which they will be used. A critical evaluation of these high-temperature strain gages is necessary in order that the gages currently available may be used with a full understanding of their limitations. Such an evaluation is also necessary if the further development of these gages is to proceed rapidly.

Under the sponsorship of the Navy Bureau of Aeronautics, the National Bureau of Standards is establishing facilities for the comprehensive evaluation of remote-reading strain gages at elevated temperatures. A partial evaluation of four types of gages has been completed for temperatures up to 600° F, and the results have been made available to developers and users of such gages.

Milk Meters for Trucks. A study was made for the Department of Agriculture of methods being used to measure the flow of milk from the farmers' tanks into pickup trucks. Several methods were analyzed and two commercial meters were tested in the laboratory. It was demonstrated that air in the milk lines presents the major obstacle to accurate metering and that components now available from manufacturers are adequate, provided that the systems of measuring are improved.

Jet-Engine Controls. Safe and successful operation of aircraft gas turbines and jet engines depends largely on operation of control devices that generally are actuated by instruments measuring the temperature of the hot gases of the systems. When the output of an engine is increased by increasing the fuel rate, controls act to limit the temperature rise to a value that will avoid damage to engine parts. Accuracy, speed of response to temperature changes, and durability under conditions of engine operation are necessary properties of temperature-measuring devices used in jet engines.

A survey has been made of commercially obtainable thermocouples used in jet engines to determine their performances under conditions of engine operation. For example, the effectiveness of various coatings applied to thermocouples in improving durability has been determined. Because the need for faster response of the measuring element is becoming more urgent, a number of methods for achieving this purpose have been examined. As a result of the higher temperatures attained in afterburners and ramjets, observational data have been obtained for a reference table on the high-temperature iridium versus iridium-40%–rhodium-60% thermocouple. Observations have been completed for temperatures up to 2,500° F; the complete table will cover the range up to about 3,700° F.



A polarographic method was developed that will determine as little as a few 10-thousandths of a percent of cadmium and lead in zinc-base alloys. The metals are separated from the zinc by electrolysis at controlled potential using a mercury cathode (p. 39).

As a consequence of the complexity of the thermocouple systems in aircraft, provisions for breaks in thermocouple circuits must be made. Special connectors are used at the breaks, and if the connectors are not properly designed and constructed, serious errors in temperature indications may result. Equipment and a method for evaluating performance of these connectors have been proposed and have been accepted by the sponsor, the Wright Air Development Center, and by industrial organizations in the field.

Jet-Engine Combustors. Under sponsorship of the Navy Bureau of Aeronautics, a gas-turbine combustion chamber was developed which employs a control on the quantity of primary air, internal vaporization of the fuel, and injection of the vapor and stabilization of the flame across the entrance plane of the primary zone. Maximum capacity of this chamber is about 50 percent greater than that of conventional chambers, but combustion efficiency is about the same. Because combustion efficiency appears to depend on the degree of mixing of the primary air and fuel, a new combustion chamber was designed and is being tested in an attempt to increase the efficiency as well as the capacity.

The effects of adding hydrogen to the zone of flame stabilization in a burner simulating conditions in a ramjet have been determined. Maximum altitude for stable combustion is increased, and the maximum velocity of stable combustion at a given altitude is increased about 100 per-

cent. Schlieren photography has been used to determine the path of the additive in an effort to understand its influence on the stabilization process.

2.7. Organic and Fibrous Materials

The Bureau conducts basic and applied research on a variety of natural and synthetic polymeric materials, including rubber, textiles, paper, leather, and plastics. These materials are composed of very long, chainlike molecules formed by the process of polymerization. Many of their useful properties depend upon the size, shape, distribution, and flexibility of their molecules. To advance fundamental knowledge of these industrially important materials and thus aid in their efficient utilization, the Bureau investigates the mechanisms involved in forming polymers, their constitution, molecular structure, and properties. The basic data thus obtained are of value not only in developing new commercial polymeric materials having specified properties, but also in devising techniques for evaluating those materials that are already in use.

During the year, for example, basic research studies provided information on such topics as thermal degradation of rubber and plastics as a function of molecular structure, specific heats of collagen and leather, compressibilities of long-chain normal hydrocarbons, stability of record papers, and stress-strain relationships in yarns subjected to shock loading. In other projects, test methods were developed for direct determination of dynamic bulk modulus, evaluating abrasion resistance of organic coatings, chromatographic analysis of collagen, snag testing of coated fabrics and plastic films, and measuring flexibility of shoe-upper leather. Significant contributions were also made to knowledge of the properties of dental materials in research conducted in cooperation with the American Dental Association and the Federal dental services (Army, Navy, Air Force, and Veterans Administration).

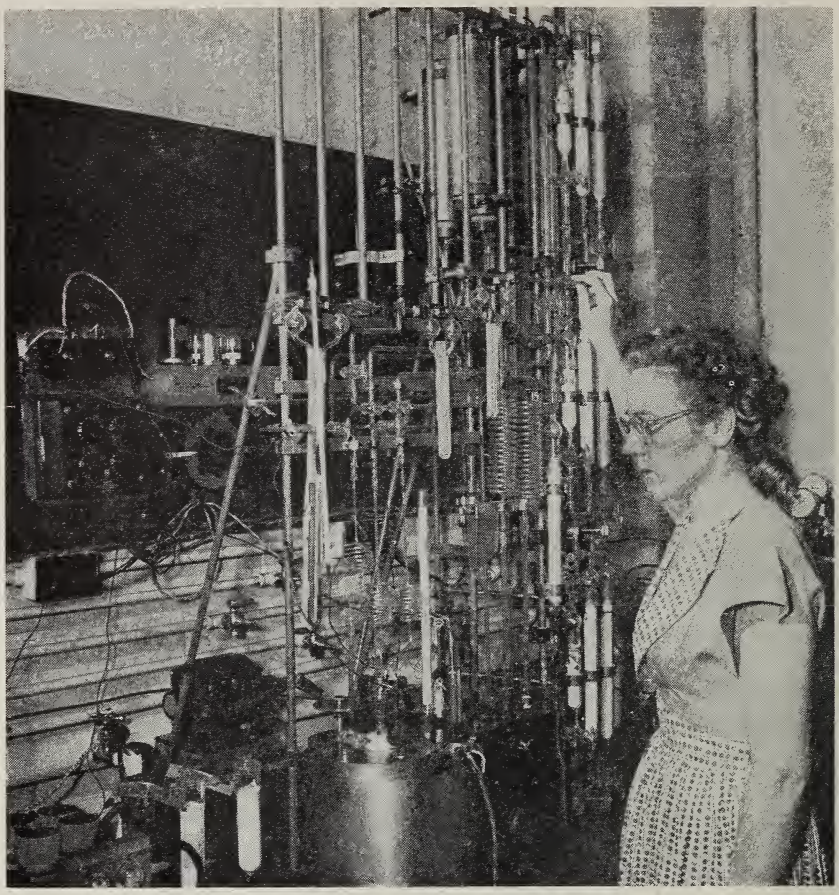
Dynamic Bulk Modulus of Polymers. A method for measuring dynamic bulk modulus was developed to investigate the properties of polymers in the transition region between the rubbery and glassy states. The sample plus a confining liquid is placed in a small cylindrical cavity made by clamping together two steel blocks. Two piezoelectric crystals act, respectively, as a generator of volume velocity and a detector of alternating pressure. Provided the wavelength of sound in the confining liquid is large compared to the dimensions of the cavity, the pressure at any instant will be the same throughout the cavity. The bulk modulus of the sample can then be calculated from the ratio of the voltages of the two crystals and the bulk modulus of the confining liquid. The apparatus can be used over a frequency range of 50 to 5,000 cycles per second and over a wide range of temperature. Static pressures of 1 to 1,000 atmospheres can be superposed on the alternating pressures. The apparatus is suitable for the determination of the dynamic bulk modulus of any solid or liquid substance.

Heat of Vulcanization of Rubber. It has long been known that a heat exchange takes place during vulcanization, in which rubber combines chemically with sulfur or some other agent. However, there has been considerable disagreement among rubber technologists and scientists regarding the amount of the heat exchange. In work sponsored by the National Science Foundation, a precision adiabatic-type calorimeter was designed and constructed to measure this heat of reaction. The calorimeter records quantities of heat liberated over a period of a day or more. Tests showed that the apparatus can hold a constant temperature or a constant small drift so that any normal temperature change can be known to within a few thousandths of a degree after several days' operation of the thermal shields.

In the soft-rubber reaction, which involves only the lower percentages of sulfur, the quantity of heat liberated was about constant per unit quantity of sulfur. However, the reaction with higher percentages (20 to 32%) of sulfur, which forms hard rubber, or ebonite, produced less heat per unit of sulfur. In fact, very little, if any, heat exchange was observed for the last few percentages of sulfur entering into the hard-rubber reaction. This correlates very well with rubber-sulfur density changes. The density increase accompanying rubber vulcanization is greatest for the soft-rubber reactions, but it also approaches zero for the high percentages of sulfur in the hard-rubber reaction.

Analysis of Rubber Mixtures. A rapid, convenient method was developed for determining the amount of natural rubber in vulcanizates containing both natural rubber and GR–S synthetic rubber (butadiene-styrene copolymer). The procedure involves thermal decomposition of the vulcanizates and infrared spectroscopic examination of the resulting products. The concentration of natural rubber is measured by comparing the relative intensity of absorption bands at wavelengths characteristic of the pyrolysis products of natural rubber (11.25 microns) and of GR–S rubber (11.02 microns). The method permits quantitative analysis where lack of solubility or the presence of interfering fillers has prevented analysis by other methods. The total time required is only about 15 minutes.

Temperature Control for Mixing Rubber Compounds. Better reproducibility in compounding rubber and decreased variability from one operator to another were obtained by the development of special rolls for laboratory rubber mills. These rolls provide rapid heat transfer between the rubber and the coolant flowing through the rolls, making possible automatic temperature control during the mixing of rubber compounds. The temperature of the rolls on conventional laboratory mills is maintained by manual adjustment of valves controlling the flow of water or steam through an axial cavity in the rolls. Because the heat transfer through such rolls is very slow, the operator must anticipate cooling or heating requirements and adjust the valves in advance.



The flame calorimeter is used to measure the heats of formation of hydrocarbons (p. 38). These data are of value in calculating other thermodynamic quantities, in the study of the fundamental properties of molecules, and in the development of industrial processes.

Development of the temperature-controlled rolls was sponsored by the Federal Facilities Corporation, Office of Synthetic Rubber, in connection with the Government synthetic rubber program. The design includes a well for a thermocouple temperature-sensing element near the working surface and a cavity for mounting collector rings and brushes. A commercial electropneumatic temperature recorder-controller automatically operates valves for controlling the temperature of the water flowing through the rolls. This system controls the temperature of the rolls containing the thermocouple within 2 degrees F of the desired temperature during the mixing process.

Static Charge Generation in Military Clothing. A soldier wearing rubber-soled shoes and a nylon-lined jacket over a wool shirt may become charged to a potential exceeding 5,000 volts when he removes the jacket, and may draw a sizable spark upon touching a metal ground. The resulting spark

may ignite gasoline fumes or dust or set off explosive detonators. These hazards and ways of minimizing them were investigated under sponsorship of the United States Army Quartermaster Research and Development Command. Under ambient conditions ranging from cold-dry to hot-damp, the Bureau measured charges developed by various combinations of military clothing assemblies, and the electrical conductivities of fabrics treated with various antistatic finishes. The results of these studies will be used by the Quartermaster Corps in the design of safer military clothing.

Shock Loading of Fibrous Materials. The ability of textile yarns to withstanding high-speed impact stresses, or shock loading, is becoming increasingly important to modern industry and to national defense. Extremely high rates of strain are experienced by airplane tire cords during landing, by seat belts and safety lines when accidents occur, and by the fabric, shroud lines, and webbing during the opening of a parachute. In high-speed industrial sewing the thread is subjected to impact velocities ranging from 1 to 10 meters per second as often as 5,000 times per minute. This results in high-frequency cyclic accelerations of the thread, which may equal several million centimeters per second per second. Similar conditions may be attained in high-speed processing of fibers, such as carding and combing or the weaving and knitting of yarns into fabrics.

To provide design data for these various applications, the Bureau has been making an extensive study of the behavior of textile yarns under very-high-speed impact. Supported in part by the United States Army Quartermaster Research and Development Command, the study seeks to determine the effects of high rates of strain on textile materials and to relate these results to the molecular structure of the fibers and the geometry of the yarns and fabrics. In connection with this work, an instrument was developed for measuring the stresses and strains developed in yarns, fabrics, and films when they are subjected to transverse impact at speeds up to 150 miles per hour. The procedure is to impact a clamped yarn segment at the midpoint and to photograph the successive configurations of the yarn by means of a camera which takes as many as 15,000 pictures in a second. The series of pictures provides sufficient data to compute the stress-strain curve. The limiting breaking velocity of a textile material, an important measure of energy absorption under impact loading, can also be determined with this equipment. This property, as well as stress-strain curves at very high rates of straining, was determined for high-strength textile materials. The data thus obtained are useful to establish adequate specification requirements for the webbing of parachutes. The data also have been used to determine the minimum requirements of safety lines for different conditions of use so that loss of life may be avoided.

Properties of Glass Fibers. Knowledge of the properties of glass fibers is important to the growing glass-fiber-paper industry, both in improving manufacturing techniques and in evaluating the product for new uses. In work sponsored by the Naval Research Laboratory, the chemical

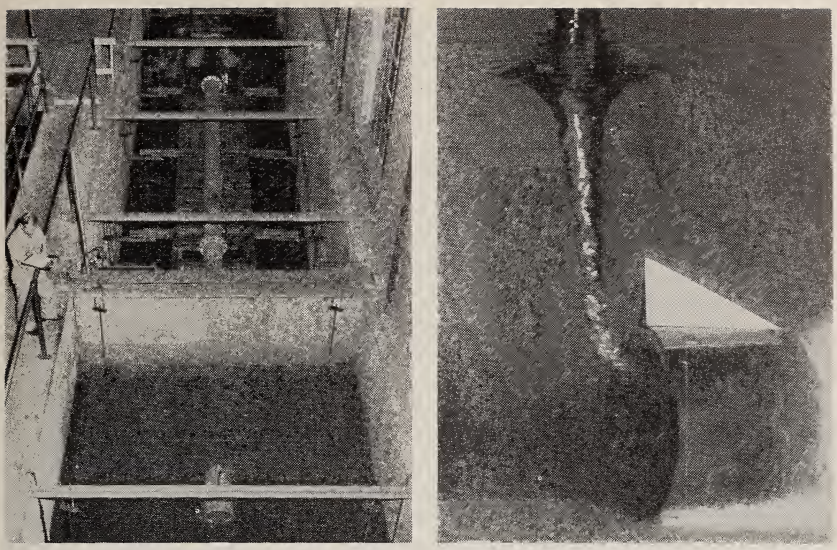
durability, heterogeneous equilibria, hygroscopicity, *p*H response, dispersal, and thermal expansion characteristics of glass fiber used in producing paper were studied and compared with corresponding properties of other types of glasses. The chemical durability of this glass was very poor at *p*H values below 2, improving above *p*H 2; there was no detectable attack between *p*H 4 and *p*H 8. Above *p*H 8 the durability again decreased. Dispersal characteristics of the fibers in aqueous solutions followed the "critical points" indicated by the chemical durability curve. The data are consistent with the previous work in the Bureau's experimental paper mill which indicated that *p*H 2.9 is a critical condition for the optimum production of paper from fibers of this glass.

Mildew on Leather. Prevention of mildew growth on military leather items has been an important problem since World War II. Most tanning agents and leather lubricants for military leathers are mildew susceptible. Thus a fungicide must be incorporated into the leather to make it mildew resistant in hot and humid areas. The fungicide now being used for this purpose is *p*-nitrophenol, but it does not meet all requirements. Better fungicides are being sought in a program supported by the Army Quartermaster Corps.

Leathers treated with different fungicides were exposed at various locations in the United States, in Panama, and in a tropical room at the Engineering Center of the United States Army at Fort Belvoir, Virginia. The results of this study show that 2-chloro-4-nitrophenol, 4-thiocyanophenol, and bis(4-nitrophenyl) carbonate are about as effective as *p*-nitrophenol in preventing mildew growth on leather. The study also shows that the tropical room exposure test correctly predicts the performance of leather fungicides under natural severe mildew-growing conditions. Establishment of good correlation between laboratory evaluation and field performance makes time-consuming field tests unnecessary in future evaluations of new fungicides, and thus facilitates the search for a replacement for *p*-nitrophenol.

Determination of Lignosulfonates in Tannin Compounds. Small amounts (5 to 10%) of lignosulfonates are used in tannin mixtures without impairing the tannage; however, larger amounts act as harmful adulterants. Thus, an analytical method for the control of lignosulfonates in mixtures of vegetable tannins has been needed. In cooperation with the American Leather Chemists Association, the Bureau developed such a method based on the precipitation of lignosulfonates by cinchonine. Tests made in six laboratories with four contrasting types of commercial lignosulfonate materials showed that the method is useful for determining the adulteration of tannin materials with lignosulfonates. The procedure is simple and rapid, requires no special equipment, and appears applicable to lignosulfonates generally.

Sounding balloons. Aerological sounding balloons are used by several Government agencies to carry radiosondes into the stratosphere and to obtain meteorological data. In the past the properties of the rubber in



Laboratory studies on an experimental model (left) of a highway drainage culvert provide information on which efficiency of operation depends. Main problem is the intake of air even when inlet to culvert is well below surface of water. At right is a closeup of a vortex of air being sucked into culvert inlet (p. 43).

the balloons have been measured by stretching the film in one direction at room temperature. However, the results did not correlate with performance because in flight the rubber stretches in two dimensions at a low temperature.

Under the sponsorship of the Bureau of Aeronautics, Department of the Navy, a new laboratory method was developed in which conditions simulate those in flight. That is, the rubber is stretched in two dimensions at a temperature approximating those encountered in flight. Good correlation has been obtained between the laboratory results and flight performance when other factors, such as resistance to ozone and neck strength, are satisfactory. The Bureau of Aeronautics has incorporated the method in its purchase specification for aerological balloons. The test should be very useful in plant control and in the development of new materials for balloons.

Statistical Treatment of Test Results. In the statistical theory of fitting straight lines to experimental results, it is common to derive uncertainty intervals for the slope and the intercept by using the classical theory of least squares. Recent work on analytical procedures for organic and fibrous materials has shown that the use of joint confidence regions, also based on least squares theory, is often more appropriate and that it leads to uncertainty intervals for any function, either linear or nonlinear, of the slope and the intercept. Unlike intervals derived in the usual manner, intervals based on the joint confidence region have the desirable property of being collectively valid, regardless of their number, with a joint probability that is never less than the adopted confidence coefficient. These

results have been found particularly useful in the study of the accuracy and precision of analytical methods.

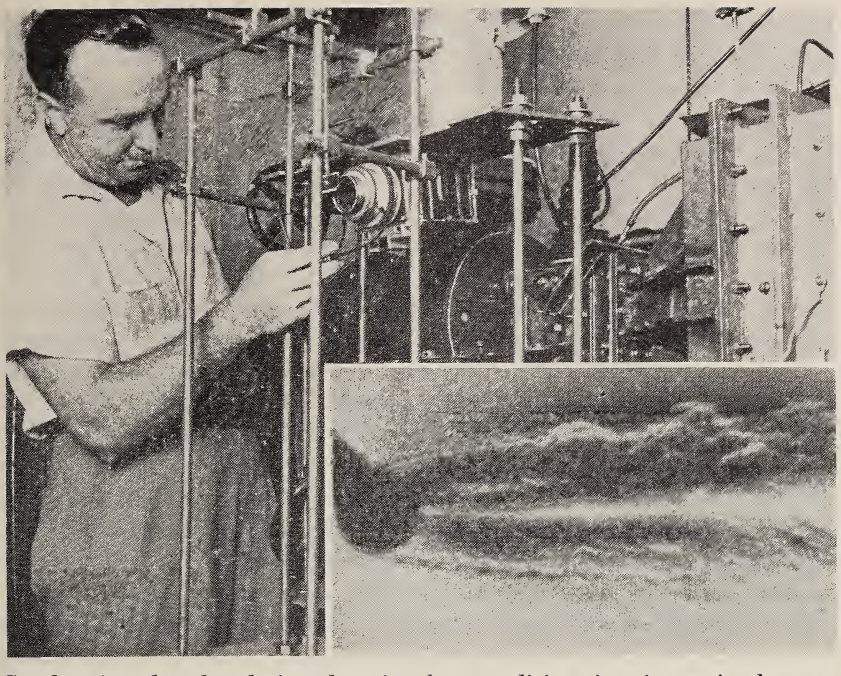
Thermal Decomposition of Cellulose. Basic knowledge of the reactions involved in the thermal decomposition of cellulose is needed in the development of new nonflammable textile materials and methods of treating present textile materials to render them more flame resistant. It is generally considered that the flaming of cellulosic materials takes place in two consecutive steps: first, degradation of the material under the influence of heat to form volatile and nonvolatile products, and second, ignition of the flammable constituents of the products, with further decomposition of the cellulose. A decrease in flammable decomposition products is therefore desired.

In an investigation sponsored by the Quartermaster Corps, it was found that by modifying the cellulose structure or by treating the cellulose with certain materials, not only the rates of decomposition but also the products of decomposition of cellulose can be altered. When cellulosic materials were impregnated with ordinary salt, borax, sodium carbonate, or boric acid, they were rendered more flame resistant in that their decomposition products contained more of the nonflammable materials, such as water and carbon dioxide, and less of the highly flammable tarry material. Oxidized cellulose was also found to be more flame resistant than the unmodified cellulose. The modification of the chemical structure evidently causes the molecules to break up differently.

Radiation Chemistry of High Polymers. When polymers are exposed to high-energy radiations, as in a nuclear reactor, important chemical changes take place. As a result, some materials are improved, becoming stiffer, stronger, and more difficult to melt. Other materials readily deteriorate. Basic research to provide explanations for such effects is needed for proper use of these materials (for example, as electrical insulation in atomic reactors), for preparing specifications, and for developing better materials.

Thus far, experiments have been conducted with gamma rays from two small cobalt-60 sources. A 2,520-curie source, at present being installed, will be used for more intensive work. In addition, through cooperative arrangements with other agencies, it has been possible to expose high polymeric materials to high-speed electrons, and to the combined neutron and gamma radiation of a nuclear reactor.

A variety of organic materials in fiber and film form, as well as in the raw chemical state, have been exposed to these high-energy radiations, and the effects on their physical properties and chemical structure noted. Carefully designed experiments have also been conducted to determine the mechanism by which chemical changes are produced. For example, recent work with deuterium-substituted organic polymers has revealed how gamma radiation attacks polystyrene and polymethyl methacrylate. Experiments have also been conducted to explain why some materials degrade while other materials improve in physical properties when exposed to gamma rays.



Combustion chamber designed to simulate conditions in a jet engine burner. This equipment was used to study the effects of additives on the stability of combustion (p. 47). The schlieren photograph (insert) shows the flame stabilized on a circular rod in a high-speed stream. Note the laminar nature of the flame near the rod. The stripes are zones of constant gradient of index of refraction.

Plastic Packaging Materials. Hot-dip plastic packaging materials for precision metal parts have several disadvantages. The hot-dip coating deteriorates during application, undesirable odors are produced, and workers are subjected to burn and fume hazards as a result of the high temperatures used during application of the coating. During the year, plastisol-based cold-dip coatings were developed for the Navy. The cold-dip coatings overcome these difficulties and also have superior low-temperature properties, lower application cost, and less bulk than hot-dip coatings. Data obtained in this investigation formed the basis of a specification the Navy prepared for plastisol coatings for magnesium anodes used to protect submarine hulls.

Plastic Eyeshields. A transparent eyeshield to protect military personnel in combat areas from shell, grenade, and land-mine fragments was developed for the Office of the Quartermaster General. This eye armor supplements the plastic body armor already in use and provides additional protection against fatal or disabling eye injury due to flying fragments. The shield combines the impact-resistant properties of selected transparent plastics with the flexibility of other plastics in a laminated structure. A relatively thick, rigid plastic is backed by a flexible plastic layer and a film of transparent plastic. The heavy front piece absorbs the

impact and prevents penetration of the eye shield by the fragments. The interlayer and backing film serve to catch and hold any secondary fragments resulting from the impact.

Plastic Springs. A practical procedure for mass-producing plastic springs was developed in work sponsored by the Army Ordnance Corps. Springs formed in this way from glass fiber-reinforced resin have desirable mechanical properties for a wide range of applications. Until now plastic springs have been little used because suitable techniques for making springs of the types needed have been lacking.

The reinforced plastic springs have a number of advantages for special purposes. For example, they are nonmagnetic and have low electrical and thermal conductivity. They can be molded directly to dimensions without the development of any considerable internal stress. Their high corrosion resistance should make them of value for applications in chemical plants and installations subject to acid fumes or to salt air. Other applications may benefit from the strength-to-weight ratios of plastics, which are often higher than those obtained with spring-making metals. Also, the broad range of transparent and colored materials that can be used makes striking decorative effects possible.

Electronic Measurement of Adhesion. Good adhesion is important in the service performance of protective coatings. Reliable test methods are therefore needed that will permit evaluation of coating adhesion in the laboratory. Expensive and time-consuming service tests may then be reserved for only the more promising materials.

In a project sponsored by the Navy Bureau of Aeronautics, equipment was developed that translates the variable stripping force obtained in the measurement of adhesion into electrical impulses. The device then sums these varying pulses to give a single average value that can be read directly from either a voltmeter or a standard recorder. This development has increased the speed and ease of operation of present testing equipment and the precision of measurements of adhesive strength.

Crazing of Plastics. Many plastics, including those used in aircraft canopies and windows, "craze" or develop fine cracks when subjected to tensile stresses for varying periods of time. Crazing impairs mechanical properties and, in the case of transparent plastics, affects optical properties as well. This limits the service life of these products.

During 1956, studies were conducted for the National Advisory Committee for Aeronautics to determine the mechanism of crazing in an effort to reduce or eliminate it in plastics. Recent optical investigations of crazed plastic surfaces, using light and electron microscopy, indicate that crazing is not merely a cracking process but is accompanied by surface flow. This flow results in a "pile-up" of material at the two edges of the craze crack. The flow is completely recoverable in some cases, resulting in an apparent "healing" of the crack. Actually the physical separation remains and propably reopens on reapplication of stress. In some transparent plastics, craze cracks are associated with physical impurities

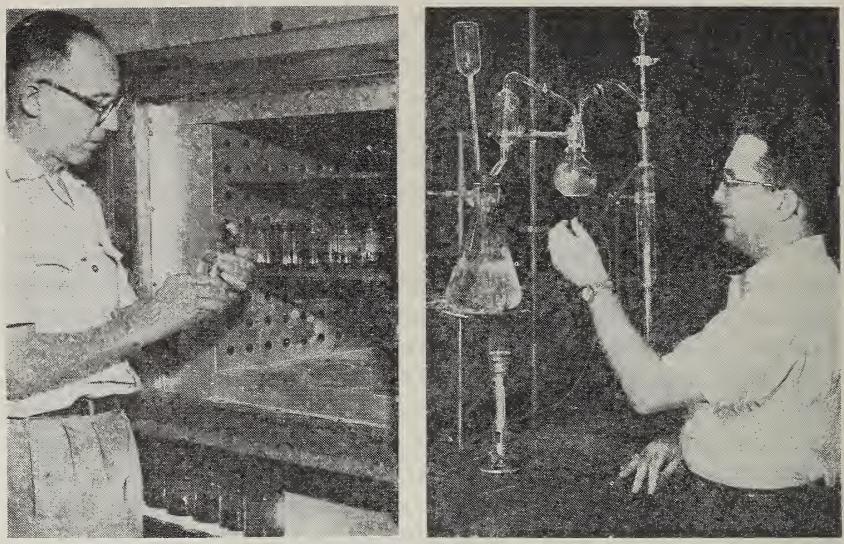
throughout the material. This explanation of the crazing mechanism should aid in the development of craze-resistant plastics, thus extending the service life of transparent plastics.

Dental Resins. Reactions involved in polymerizing the acrylic plastic used to make dentures, artificial teeth, filling materials, and cements were studied. Effects of various accelerators and inhibitors and of residual monomer content were determined.

A study of the accelerating efficiency of amines on the benzoyl peroxide-initiated polymerization of methyl methacrylate showed that the reaction proceeds fastest in the presence of tertiary aromatic amines. Decreasing hardening time improves the indentation and recovery values of the polymeric products. The efficiency of typical inhibitors used to stabilize methyl methacrylate against premature polymerization was investigated by measuring their radical scavenging properties. An improved procedure was developed to determine residual monomer content, which greatly affects the physical properties of the final dental product; the new method is based on infrared analysis of the sublimation products of the solution of the polymer in benzene. The basic knowledge gained from these studies, which are sponsored by the Federal Dental Services and the American Dental Association, will be used in the development of improved dental resins for curing at room temperature.

Dimensional Accuracy of Dentures. One of the most important factors in the evaluation of materials and methods used in making artificial dentures is the dimensional accuracy and stability of the denture. In the past, limited information on accuracy has been obtained by observation of the fit of dentures on plaster models and by measurements in a horizontal plane between reference marks placed on the denture. To provide more complete information, a pantographic instrument was developed in which a comparator method is used to measure the accuracy of dentures, impressions, and models of the oral cavity. The comparator is so constructed that as one pointer moves over the surface of a standard impression, or denture, a second pointer attached to a dial gage moves over the "duplicate" impression, or denture. The dial gage indicates any discrepancies between the surfaces of the objects being compared with an accuracy of 0.001 to 0.002 inch. Contact with the irregular surface is indicated electronically to prevent distortion of elastic materials.

Crystallography of Tooth Enamel and Dentin. The crystallography of the mineral portion of teeth and bone and allied phosphates is being studied as part of a research program sponsored by the American Dental Association at the Bureau. The major mineral constituents of bone and teeth are some form of apatite, $Ca_{10}(PO_4)_6(OH)_2$, mixed with a smaller amount of calcite, or calcium carbonate, $CaCO_3$. The verification of the presence of the calcite as a second phase and an explanation of the apparent nonstoichiometric nature of tooth and bone apatite have been the immediate objectives of the study.



Laboratory studies provide basic information in developing Federal Specifications for leather fungicides (p. 52). ***Left:*** **Oven at 30° C stimulates a tropical environment for leather specimens treated with test fungicides.** ***Right:*** **Using steam distillation to separate and identify leather fungicides.**

Removal of the carbonate by an acid treatment did not change the X-ray diffraction pattern of the apatite. Infrared absorption spectra identical to that of calcite were still found in both tooth enamel and dentin. These facts indicate that the calcium carbonate is present as a separate phase.

Certain biological and synthetic apatites as well as certain mineral phosphorites give X-ray diffraction patterns similar to hydroxyapatite. However, these "apatites" often differ from pure hydroxyapatite in chemical analysis and physical and chemical properties. Lead apatite and calcium apatite were synthesized as stoichiometric (containing combining weights of elements) and nonstoichiometric crystalline powders. X-ray diffraction and index-of-refraction data demonstrated the existence of crystalline, nonstoichiometric apatite with cations missing statistically from certain structural positions in the amount corresponding to the chemical analysis. The better understanding thus obtained of this type of structure and its chemical behavior may lead to an understanding of some of the factors involved in dental caries.

2.8. Metallurgy

The Bureau's work in metallurgy is concerned with the physical, chemical, mechanical, and thermal properties of metals and alloys, and with their behavior under both normal and unusual conditions. In general, the objective of the program is to increase both theoretical and practical knowledge of metals in order to provide improved materials

constantly demanded by science and industry. Special emphasis is placed on lighter materials and those that must meet special requirements with respect to strength at high or low temperatures.

Constitution Diagrams. In order to understand and predict the behavior and best use of alloys, it is necessary to have detailed constitution diagrams that show their melting points or ranges, structural changes occurring at various temperatures, intermetallic compounds, and solubility relationships.

The demand for alloys to be used at high temperatures, in such applications as turbine buckets and automobile valves, has been met by designing multicomponent alloys. These may contain as many as 10 chemical elements, each of which is important to the behavior of the alloy for engineering applications in the range 1,500° to 2,200° F. Reactions within an alloy during its preparation and use often result in the formation of hard intermediate phases which have a pronounced effect on strength properties. There is little information on the compositions of multicomponent alloys that define their phase constitution at specified temperatures. In order to supply information of this kind, the Bureau is making a phase-diagram study of alloys in the quaternary system, chromium-iron-molybdenum-nickel (Cr-Fe-Mo-Ni).

Examinations of Cr-Fe-Mo-Ni alloys that contained 70 percent of iron and additional alloys in the Fe-Mo, Cr-Fe-Mo, Fe-Mo-Ni, and Cr-Fe-Ni systems were completed. The phase constitution of the 70-percent-iron alloys at five temperatures were summarized in diagrams and the contemporary Fe-Mo phase diagram was modified to show the Fe_2Mo phase. In addition, the composition of a ternary phase, not previously reported, was determined, and a standard X-ray diffraction pattern of this phase was obtained.

Differences exist in the published constitution diagrams of the magnesium-zinc alloys. Because of the increased interest in light alloys used in the airplane and other industries, Wright Air Development Center has supported a program that succeeded in resolving most of these differences. The Air Force is also interested in the constitution diagrams of magnesium with the lanthanide series of elements because these alloys are known to have improved strength and stiffness at high temperatures, properties essential in modern high-speed aircraft. The solid solubilities of several of the lanthanide metals have been established.

Research sponsored by the Atomic Energy Commission on a series of alloys of uranium with the platinum metals (platinum, palladium, rhodium, ruthenium, osmium, and iridium) resulted in a tentative constitution diagram for the uranium-platinum system, and the major reactions of the other binary systems have been determined.

High-Strength Steels. The necessity of increasing the strength of structural parts in aircraft and thereby reducing the dead weight becomes more pressing as aircraft increase in size and speed. This is particularly important in military aircraft. Under the sponsorship of the Navy Bureau

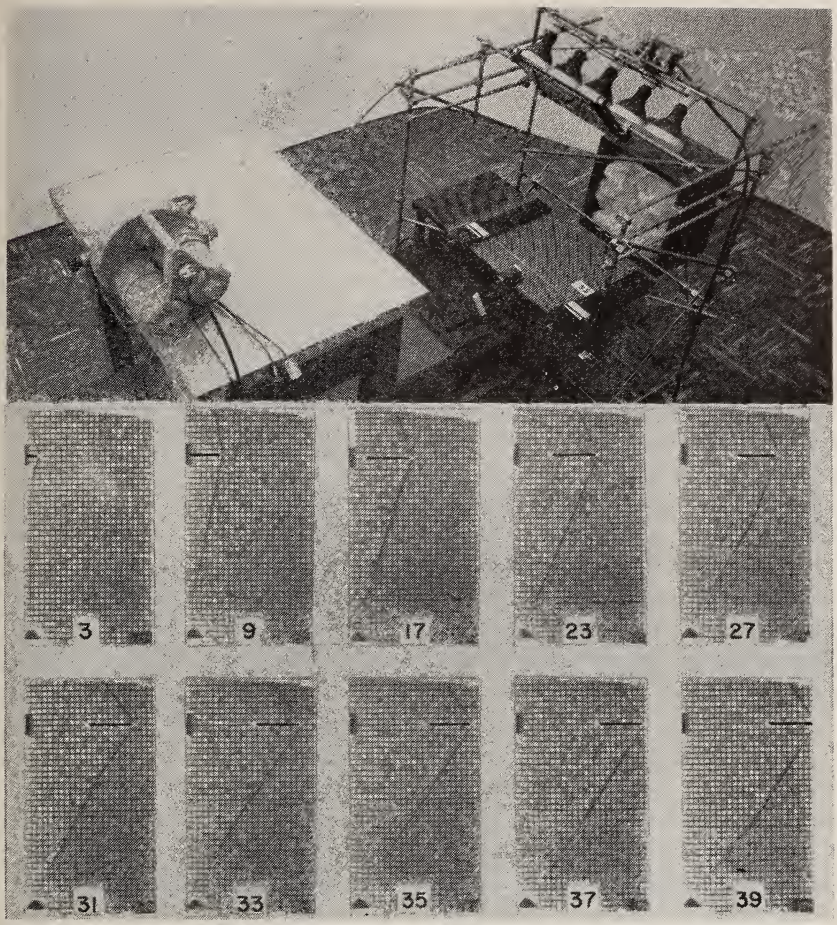
of Aeronautics, the Bureau has developed an ultra-high-strength steel that can be heat-treated to strengths of 300,000 lb/in.^{2} with sufficient ductility and impact resistance to be used in aircraft components.

Slack-Quenched Steels. Although slack-quenched steels, i. e., steels that are incompletely hardened, are frequently used in industry, the mechanical properties of such steels are difficult to evaluate because of the complexity of controlling the slack-quenched structures. Under the sponsorship of Watertown Arsenal, a method was developed for accurately controlling the degree of slack quenching of impact specimens, and the effect of such treatments was determined on the toughness of a series of alloy steels both with and without boron. Generally, the impact strengths of slack-quenched steels were inferior to those of the same steels fully hardened and tempered to the same hardness as the slack-quenched steels. These differences were reduced substantially by appropriate tempering treatments.

Temper Embrittlement. Steels tempered at high temperatures frequently exhibit temper embrittlement which is manifested by decreased impact toughness after slow cooling from the tempering temperature. Boron-treated steels, important because they can be used to conserve critical alloying elements in heat-treated steels, are susceptible to temper embrittlement. An investigation sponsored by Wright Air Development Center has shown that boron itself has a negligible effect upon this phenomenon but that titanium, an element present in many of the boron addition agents commercially used, tends to make the steels more susceptible to temper embrittlement.

Titanium. Several titanium alloys have higher strength-weight ratios than many other structural materials. However, they cannot be used to best advantage until their performance is determined at different temperatures under a number of stress conditions. Work sponsored by Wright Air Development Center showed that the tensile properties at $-196°$ and $+100°$ C of both unnotched and notched specimens of commercially pure titanium and a titanium alloy containing 4 percent of aluminum and 4 percent of manganese were, in general, impaired by prestraining in tension at $+25°$ C; the retained ductilities at $-196°$ and $+100°$ C were decreased by the prestraining.

Mechanism of Deformation. A fundamental knowledge of the mechanism of deformation is essential for the best utilization of available metals and alloys and the development of new materials for high-temperature service. Numerous theories have been proposed to predict the time-temperature relationships in single and polycrystalline metals under stress, but none is entirely satisfactory. The Bureau has continued a study of the flow and fracture characteristics of high-purity copper, nickel, and binary alloys of these elements. Creep tests were completed on annealed specimens of 70 percent nickel-30 percent copper and 30 percent nickel-70 percent copper alloys. The program for evaluating the short-time-



Experimental setup for photographing high-speed transverse impact in textile yarns (p. 51). A hammer impels a projectile at the yarn specimen clamped on a grid system. Film frames (below) show configurations of yarn specimen during a transverse-impact test.

high-temperature tensile properties of all the materials, annealed and cold drawn to 40 percent reduction in area, was also completed.

X-ray Studies of Stresses. The performance of metals in service is frequently related to factors not always evident in measurements of bulk properties, such as elastic after-effect, or in the observation of gross structure, such as grain size and phase constitution. One such factor is the condition of the small crystals that compose the metal. The lattice of these crystals is strained when under stress, but the stress cannot be distributed uniformly in the metal because the elastic and plastic properties of the crystals are anisotropic. X-ray diffraction studies may be interpreted to give detailed information regarding the strained condition of crystals, which is important in attempting to explain phenomena such as fatigue and stress-corrosion cracking, that are restricted in the early stages to an individual crystal or the boundary between crystals.

Previous investigation by X-ray diffraction has indicated that the strained condition of the crystals after a uniform plastic deformation could be interpreted as resulting from a body stress, but there was no evidence of how this stress was balanced. One theory is that the stress reflected by the strained condition of the crystals is balanced by opposite stresses in adjacent crystals of different orientation. Another is that the observed stress occurs only in the surface layers and the balancing stress is present in the interior. Recent experimental results obtained from measurement of strains in ferrite crystals do not satisfy either of the foregoing explanations and another has been suggested. The balancing stress is supplied by stresses in material in which the crystal lattice is so distorted that it does not scatter X-rays coherently. The work is being continued by measuring, in crystals of two-phase alloys, the strains that result from differences in contraction when the alloy is cooled from an elevated temperature.

Fatigue. A study of the effect of crystal orientation on fatigue crack initiation was completed under the sponsorship of the National Advisory Committee for Aeronautics. In the two aluminum alloys studied, slip bands that formed on the crystals in the pre-crack stage of the tests served as nuclei for fatigue cracks. These slip bands were parallel to traces of (111) planes in the crystals. It was found that of the four possible (111) planes, the crack originated on the one having the highest resolved shear stress, and that this stress was higher than the resolved shear stresses on (111) planes in crystals that were not cracked.

In connection with this project, a torsional fatigue machine small enough to be mounted on the stage of a metallurgical microscope was designed and constructed. With this machine, observations could be made of the progressive changes that occur on the surface of the metal during the initiation and development of a fatigue crack. Time-lapse movies made of these changes showed at one stage of the crack development a sudden extrusion of an unknown substance from the crack.

The fatigue properties of spring wire and springs were investigated under the sponsorship of Springfield Armory. A comparison of cold-drawn music wire and an oil-tempered wire of the same diameter showed that the fatigue properties of springs coiled from the oil-tempered wire are superior to those of springs coiled from high-quality music-spring wire. An investigation of the effect of shot peening on the fatigue properties of springs coiled from small-diameter wire showed significant improvement in both cold-drawn and oil-tempered wire springs.

A torsional testing machine with an automatic stress-strain recorder for testing small-diameter wire was designed and constructed in connection with the work on fatigue. The data are recorded by means of an electric spark passing through a heat-sensitive paper.

Corrosion. Corrosion is estimated to cost this country more than 5 billion dollars annually. To obtain a better understanding of the corrosion process, the Corrosion Research Council of the Engineering Foundation is sponsoring a study at the Bureau on the fundamental aspects of

A method was developed for making plastic springs from glass fiber-reinforced resin (p. 56). First step is to soak glass fibers in resin (above, left). Next the impregnated fibers are drawn into plastic tubing (above, right) and the tubing wound around a mandrel (below, left) to form a helix, which is placed in a curing oven. After curing, the plastic tubing is removed, leaving the finished spring.

corrosion. A study of the simple system, copper-water-oxygen, has shown that corrosion takes place at different rates on different faces of single crystals of the metal. Other studies indicate that rates and nature of corrosion of single crystals in different media are related to the structural features of the metal. Likewise, metals corrode differently when they are

subjected to stress. Stress corrosion in α-brass is intercrystalline; in β-brass it is transcrystalline.

Polarization curves obtained during the corrosion of plain carbon steels indicate that carbon content and heat treatment affect the rate of corrosion. Studies are under way to determine the effects of alloying elements on corrosion.

Studies of the corrosion of metals used in naval aircraft were made through exposure tests for the Navy Bureau of Aeronautics. Three phases of the project on magnesium alloys with various protective systems have been completed.

2.9. Mineral Products

The Bureau conducts both fundamental and applied research on a wide variety of inorganic materials. These materials are of interest to the nonmetallic mineral industries in the production of refractories, porcelains, pottery, glasses, enamels, cermets, and cements. The primary objective of this work is the accumulation of basic data on the properties, constants, and behavior of these materials as an aid in advancing the technological developments in the ceramic industries. Particular attention is given to those areas of research that are most applicable to all branches of the industry.

Basic research during the year included such studies as the atomic arrangement, lattice constants and related properties of three inorganic phosphates, mechanism of the bonding of ceramics to metal surfaces, relation between structure and ferroelectric properties of crystals, kinetics of the thermal decomposition of carbonates, phase-equilibria studies of a number of ceramic systems, immiscibility of liquids in glass-forming systems, and properties of materials at very high temperatures.

Particular emphasis was placed on obtaining data on chemical, physical, and mechanical properties of a number of refractory materials at temperatures of 1,500° C and above. Such data is required for adequate engineering design of ceramic components in high-speed missiles, atomic-power plants, and other applications where very high temperatures are encountered. In connection with this work, special laboratory equipment was designed and constructed for studying vapor transport and related properties of materials at temperatures up to 3,500° C. Investigations at temperatures up to 10,000° C under controlled atmospheres are also possible with the recent completion of a high-current arc.

High-Temperature X-ray Diffraction. Cermets, metal-ceramic combinations that withstand high temperatures, are being considered for use as turbine blades in jet aircraft. To select suitable binders and predict the performance of such materials at high temperatures, data on thermal expansion and polymorphism were obtained with the high-temperature X-ray diffraction method. This method requires only small amounts of powdered materials for measurements and eliminates the need for fabricating special specimens or growing large single crystals. A special furnace was developed to maintain the specimen at selected temperatures

while X-ray patterns were made. Work has been completed for the Wright Air Development Center on the determination of the crystal structure and lattice dimensions at 200-degree intervals between room temperature and 1,400° C. Approximately 20 compounds, including carbides, silicides, borides and oxides, were studied.

Engineering Properties of Ceramic Materials. The Atomic Energy Commission and Wright Air Development Center have jointly supported a program at the Bureau to provide the data leading to more efficient utilization of ceramic materials in high-temperature applications. As a part of this program, all the room-temperature elastic constants for approximately 35 materials (oxides, carbides, silicides, cermets, and intermetallics) were determined.

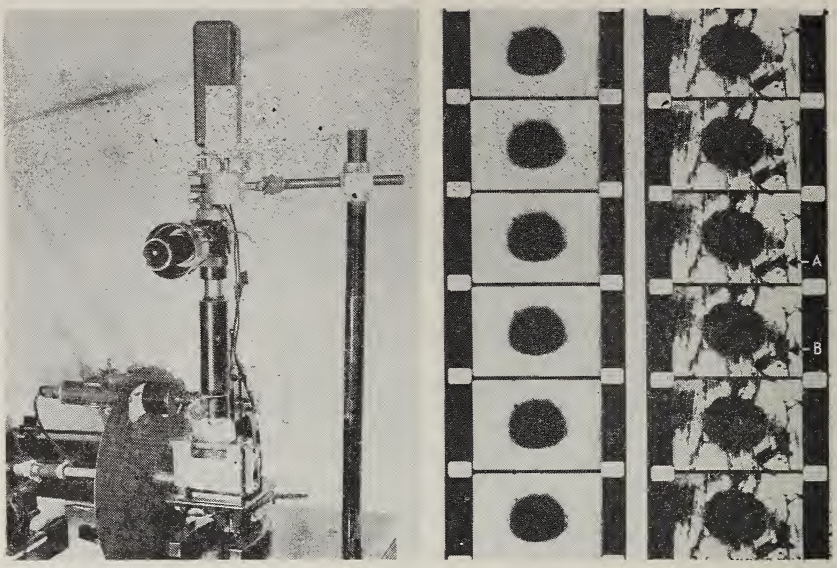
The study of the plastic deformation of polycrystalline ceramic oxides has been continued under the sponsorship of the Wright Air Development Center. Previous investigations showed that polycrystalline alumina and magnesia undergo creep in the range 1,000° to 1,200° C. The results also showed that alumina exhibits strong creep recovery whereas magnesia shows very little. To clarify this creep behavior, both alumina and magnesia were studied over a range of stress and temperature to develop an empirical law describing creep. Young's Modulus and the internal friction were also measured as a function of temperature up to 1,300° C for alumina and magnesia. These measurements suggest that creep at 1,000° C occurs by grain-boundary slip in polycrystalline alumina and by slip with the grains in polycrystalline magnesia.

The Bureau has developed an apparatus to extend the temperature range of measurements of Young's Modulus and internal friction. A new furnace employing stressed tungsten heater wires has been constructed that makes measurements possible as high as 2,000° C, where the upper limit was previously 1,500° C.

Phase-Equilibria Investigations. As part of its continuing study of high-temperature phase equilibria important in cement clinker chemistry, the Portland Cement Association Fellowship, in cooperation with NBS, completed a determination of equilibria in the system CaO-$CaO{\cdot}Al_2O_3$-$2CaO{\cdot}Fe_2O_3$. This work establishes the relation between the composition of the important iron-containing constituents of portland cement and the composition of the cement raw mix in this system. The results will be of particular value to the producers of the Nation's tremendous annual output of portland cement by making possible the more effective operation of cement kilns.

Studies of phase equilibria in certain aqueous systems, essential to an understanding of the hydration reactions of hydraulic cements, are also in progress. A recently completed study related to the system CaO-Al_2O_3-SiO_2-H_2O presents data on the variation of composition of the hydrogarnet phase in this system with temperature of formation.

The glass-forming regions of the Na_2O-TiO_2-SiO_2 and the BaO-TiO_2-SiO_2 systems have been determined and the liquidus temperatures of



Torsional fatigue machine and equipment for taking time-lapse motion pictures of aluminum undergoing fracture by fatigue (p. 62). ***Center:*** **Motion picture frames from early stages of the test show slip bands that have developed around 0.01-in. drilled hole.** ***Right:*** **Later frames show that slip bands have developed into cracks. A material of unknown composition was extruded at irregular intervals from one of the cracks (Note difference in amount of dark material at A and B).**

the glasses have been measured. This is a part of an investigation to study the correlation, if any, between the physical properties of glasses and the phase equilibria in such systems.

Immiscibility of Liquids in Glass-Forming Systems. A quantitative study of the formation of immiscible liquids in ceramics has been under way. Crystal chemistry principles were applied to interpret two-liquid formation in 19 two-member and 8 three-member oxide systems. Two methods were developed for calculating the extent of the two-liquid formation in these systems. Results of this study are expected to contribute to a fuller understanding of the atomic structure of glass-forming systems.

Bonding Mechanism of Ceramic Coatings to Stainless Steel. One phase of a study of the ceramic-metal bonding mechanism showed that copper ions have an adherence-promoting effect when they are present in a ceramic coating applied to an 18-chromium, 8-nickel stainless steel. Because this was the first observation of a metal ion improving the adherence of a coating to a metal other than iron or low-carbon steel, the effect of the copper was investigated as a part of the long-range study.

Copper ions in the coating appear to produce a significant increase in adherence on both pickled and sandblasted surfaces, but the effect of the copper decreased with increased firing temperature, and with increased firing time, for the pickled specimens. X-ray examination of specimens

reveals that the copper ions are reduced to metallic copper near the interface during firing; however, examination of sections with the metallographic microscope showed no selective corrosion of the stainless-steel surface, indicating that surface roughness is not essential to development of a ceramic-metal bond. The amount of oxidation of the metal base, controlled by the copper-plating reaction, is believed to be the factor that causes the increase in bond strength when copper oxide is incorporated into the coating.

Mechanism of Plasticity in Clays. The first phase of an investigation of the plasticity of clay-water systems, sponsored by the Edward Orton, Jr., Ceramic Foundation, has been completed. The evaluation of the property-determining attributes of clays, including the identification, characterization, and purification of small quantities of various clay minerals, were studied. With these samples, methods for the mineralogical, chemical, and physical characterization of clays were developed and electrodialysis, fractionation, particle-size determination, and base-exchange procedures have been established.

Physical Properties of Glass at Elevated Temperatures. In recent years there has been an increased interest in transparent inorganic glasses for application where high temperatures will be encountered. The Wright Air Development Center has sponsored the development of methods to study the mechanical properties of glasses over a wide temperature range. The data obtained from the study is expected to be useful to the glass industry in improving the presently available glasses as well as in connection with the development of new glasses for high-temperature applications.

Equipment was designed and built for testing glass at room and elevated temperatures. The modulus of rupture and the modulus of elasticity of glass at three different temperatures were determined, and the elastic moduli of glasses of different compositions were measured over a range of temperatures by a dynamic method. In addition, the room-temperature values of the elastic moduli of glasses were measured after varying heat treatments. The resulting information has both theoretical and practical importance in interpreting the modern concepts of the atomic structure of glass.

Standard X-ray Diffraction Patterns. Standard X-ray diffraction patterns are widely used in research and industry as a rapid means of identifying crystalline materials. The Bureau is increasing the usefulness of this method by adding data on new compounds and improving the older data in a program sponsored by the Joint Committee for Chemical Analysis by X-ray Diffraction Methods. During the past year, 60 NBS standard patterns were published. These replace about 50 cards in the file and add data for 35 new materials. Up to the present, approximately 300 NBS standard patterns have been produced and the data published. These replace about 600 of the original file and add data for 74 materials not previously represented.

Experimental Methods for Melting Special Optical Glasses. In recent years the demand for large optical elements (6-in. to 20-in. diam) of high-quality optical glass has greatly increased. To supply these elements at a reasonable cost, a small experimental platinum-lined glass tank was designed and developed for the continuous production of optical glass. The molten glass is cast into molds of predetermined shape and size, and cooled to room temperature in annealing furnaces. The delivery and casting processes are sufficiently flexible so that either bar stock or blank stock could be cast from the tank.

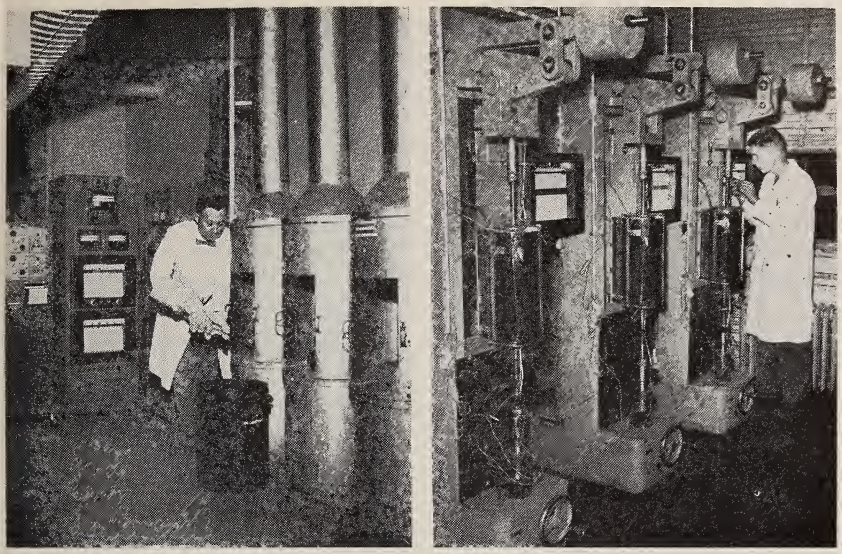
In any series of castings, the refractive indices can be held to $\pm 2 \times 10^{-4}$. The refractive index of any one casting in a series can be held to $\pm 3 \times 10^{-5}$. Besides this uniformity in index of refraction, the glass was free of striae and seeds. Essentially, this fulfills the requirements for high quality optical glass.

Any large optical element must be well annealed. The Bureau has been developing an annealing schedule that will yield glass of the highest degree of optical homogeneity. Additional studies were undertaken to determine how much the index of refraction of a large element can be varied by means of heat treatment with commercially practical time schedules, and still maintain specified uniformity of index and specified birefringence.

Crystal Structure of Inorganic Materials. The basic explanation of the physical and chemical properties of crystalline materials must come from a knowledge of the arrangement of the atoms in the crystals. Studies are under way on the crystal structure of many inorganic crystals using X-ray and electron diffraction techniques. Of special interest are the phosphates and borates important to the structure of such materials as ceramics, bone and teeth, fertilizers, and detergents. Also being studied are the various forms of silica, important not only because of their common occurrence but also because they are structure types in which many other compounds occur. During the year four papers were published. These gave the structure and other crystallographic data on thallium, indium, scandium, and chromium phosphate, and the structure and stability ranges of the three forms of gallium phosphate.

Relation Between Structure and Ferroelectricity. During the past year, a technique for firing an NBS ceramic transducer composition, $45PbTiO_3$: $55PbZrO_3$, was developed that prevents loss of PbO vapor. A study of the effects of a number of processing variables, including method of electrode application, purity, and grain size, on the dielectric properties of ceramic $BaTiO_3$ was started. Electrodes applied with silver paste introduce a variation of about ± 5 percent in the dielectric constant, and ± 15 percent in the loss. A loss peak at low frequencies, appearing to be sensitive to impurity content, may be related to the contact between the electrode and the specimen.

The shapes of lines observed in the X-ray diffraction spectrum can be interpreted in terms of the crystal size, state of internal strain, and



Increasing both theoretical and practical knowledge of metals provides the improved materials constantly demanded by science and industry. *Left:* Quenching steel specimens from salt baths in a study that developed a technique (p. 60) for forming uniform slack-quenched microstructures. *Right:* Adjusting stress-rupture equipment for obtaining fundamental data on creep behavior of metals (p. 60) at elevated temperature.

regularity of the crystalline structure. This technique is being applied to a very finely divided barium titanate formed by thermal decomposition of barium-titanium oxalate. Precision X-ray patterns have been made for such specimens prepared at low temperatures, and are now being analyzed. Strong changes in the X-ray patterns were found to occur after all the gross chemical changes involved in the thermal decomposition of the oxalate are completed.

Chemical and Physical Properties of Cementing Materials. In connection with the large cement-testing program, research is conducted upon the properties of portland cement and concrete aggregates.

The reactions that occur during the hydration and setting of cements depend on the thermodynamic properties of the constituents of the cement. During the past year, the heats of formation of three hydrated calcium silicate compounds and of two calcium ferrites were determined. The hydrated calcium silicates are potential products of the reaction of lime, silica, and water, and the two ferrites are closely related to the iron-bearing phase of portland cement clinker.

The behavior of hydrated portland cement was studied under hydrostatic pressures up to 147,000 pounds per square inch. Elastic constants determined under these conditions are very different from the values determined in the more conventional ways. This difference is mainly due to the many fine pores in hydrated portland cement. Under large hydrostatic pressures, these pores become filled with liquid; it is

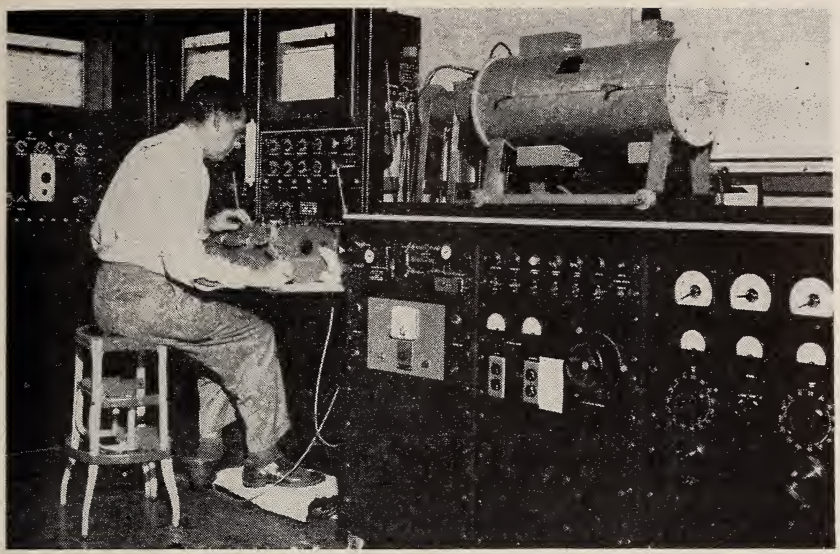
then possible to measure the volume changes of the cement substance itself, whereas more conventional methods measure the properties of entire specimens. This information, together with data on other properties, will result in a better understanding of the nature of the matrix that binds together the aggregate in concrete.

The long-range freezing and thawing durability tests of concrete aggregates were continued. Concretes are damaged by the action of repeated freezing and thawing; the severity of the damage depends upon the type of aggregate, the type of cementing matrix, and the moisture conditions present. Three aggregates, each imbedded in two types of mortar, were subjected to four recognized laboratory freezing and thawing procedures. Results indicate that a system in which the concrete specimens were alternately cooled to 0° F and warmed to 40° F at the rate of 1 complete cycle each 2 hours, and in which the specimens were continuously surrounded by water or ice, gave the best discrimination in durability between aggregates of different quality.

Laboratory Tests Versus Performance of Porcelain Enamels. A program for acquiring service data on porcelain-enameled fixtures and articles commonly used in the home is nearing completion. The results from standard laboratory tests on these materials were compared with service data on specimens installed in homes. Laboratory acid tests gave results showing good correlation with performance data. A loss of gloss on the surface of laundry trays showed poor correlation with those treated with acid, but good correlation with the results of sodium hypochlorite solution treatment. The surface wear that was most evident on some of the table-top enamels did not correlate well with scratch-test results, but did show good correlation with the results of friction testing.

A similar investigation to obtain detailed information on the weather resistance of architectural porcelain enamels was started at the Bureau in 1939. Fourteen enamel types, represented by 864 panels, were exposed at four selected sites. In addition to enamel types that were expected to perform well, some of the types were selected because of their expected poor weather resistance, in order to furnish a wide range of properties for correlation with laboratory tests. During the past year the panels were returned to the laboratory and the degree of deterioration was evaluated by gloss and color-difference measurements.

Compressibilities of Alkaline Earth Oxides. The alkaline earth oxides comprise a system of extremely high melting-point substances widely used in the refractory, ceramic, and glass industries. All oxides except beryllium oxide exist normally as cubic ionic crystals, and because of their simple structure, are admirably suited for theoretical analyses. The compressibilities of pure oxides were determined at NBS during the past year. Results show that there is no inherent minimum in the compressibility in any binary glass studied. The individual compressibilities are extremely small, as would be expected from the strong binding forces in the oxides. Of the materials on which data are available, only diamond exhibits a



Apparatus for precision measurement of electrical resistance changes and physical dimensions of metals at high temperatures. Such data are used in the precise determination of constitution diagrams (p. 59) that are necessary in predicting the behavior and best use of alloys.

smaller compressibility than beryllium oxide. The values for the other oxides are somewhat larger but show an unexpected inversion between calcium and strontium oxides. Analyses of available data show that the inversion is probably the result of an anomaly in density occurring in both the alkali halide and alkaline earth group VI cubic crystals at a similar location in the periodic system.

2.10. Building Technology

The major objectives of the Bureau's building-technology program are the determination of properties of building materials and structural elements and encouragement of their standardization and most effective use. Before full advantage can be taken of the kind of engineering approach that has guided the rapid technological development of other industries, the building profession must be supplied with adequate standards of measurement, new testing procedures, fundamental engineering data, and performance standards. No single industrial organization has the facilities or incentive to obtain the needed fundamental engineering data.

To this end, the Bureau continues to place more emphasis upon research and development leading to this major objective. For example, in the field of structural engineering, a program is now under way in collaboration with the American Iron and Steel Institute to provide basic data needed for determining proper design tensile stresses in concrete reinforcement. Investigations for the National Research Council are in progress on the bond strengths of masonry assemblages with both concrete masonry units

and clay brick, using the relatively new portland masonry cements. Fire-protection studies include the basic mechanism of ignition of materials as a result of self-heating phenomena, and the early detection and effective control of fires. Flame-spread behavior of a large variety of interior wall finishes was investigated. Basic information was obtained on the mechanism of fire extinguishment, including extinguishment by the dry-powder method. Research in air conditioning and heating was directed largely toward (1) the study of heat-transfer phenomena of insulation, (2) refrigeration studies for other Government agencies, and (3) providing basic data and test methods for improving codes and standards. In the field of roofing, studies to ascertain the causes as well as the physical and chemical processes of the deterioration of asphalt were continued. Hospital floor constructions and materials are being investigated to find methods for reducing the explosion hazard in hospital operating rooms.

Shrinkage Stresses in Masonry. At the request of the Defense Department, the Bureau has been studying the nature of stresses in concrete masonry walls. Such walls are subject to drying shrinkage and thermal contraction while restrained by a rigid, dimensionally stable foundation. The elastic theory for shrinkage stresses was developed and numerical solutions are being obtained for walls of different configurations. The theoretical results are being checked by noting stresses in plaster and metal models of walls. This information should be helpful to engineers in determining the spacing of control joints in masonry and the amount and location of reinforcement.

Masonry Calking Materials. An investigation is in progress to determine the cause and control of leakage through joints of the cast-stone masonry of a large Government structure. A related study is to find a calking material whose waterproofing properties will endure over a relatively long period—at least 10 years. At the close of 1956, seventy samples of calking materials were being tested for properties such as shrinkage, rate of hardening, adhesion, tenacity, and durability. Twenty percent of these calkings are of rubber-base type and the rest are the conventional oil or synthetic-resin compounds.

Evaluation of Hand-Portable Fire Extinguishers. With the appearance of an increasing variety of small hand-portable fire extinguishers in recent years, a critical review of the accepted methods of evaluating extinguishers has become essential. A study to determine the relative merit of standard fires for extinguisher testing and the effect of ambient variables on the tests has been recently completed for the Coast Guard. Attention was directed particularly to fire hazards, primarily fires in flammable liquids, that are likely to develop on small motorboats. Tests made with three fires of increasing severity appear to provide a satisfactory qualitative evaluation of extinguishers intended for use on fires in flammable liquids. Results indicate that quite large variations in ambient conditions during

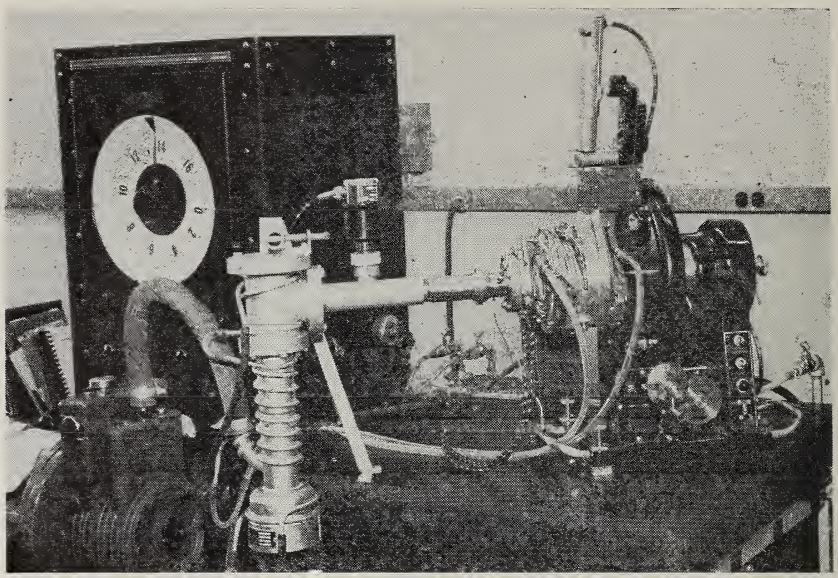
the tests did not give statistically significant differences in extinguisher performance.

Mechanism of Fire Extinguishment. Extinguishing flammable-liquid fires by means of dry powders has proven highly effective. The action has been explained as the release of carbon dioxide from sodium bicarbonate, the principal component of commercial dry-chemical extinguishing agents. However, considerable evidence indicates that this is not the explanation, because experimental fires have been extinguished with a variety of dry powders that do not release carbon dioxide. Only small concentrations of the materials are required; their effectiveness cannot be explained merely on the basis of excluding oxygen, diluting the atmosphere, cutting off the fuel supply, or blowing out the fire. Optical measurements on the dispersed powder and radiation measurements made during extinguishment showed that the energy radiated from the flame to the fuel is largely blocked by the cloud of powder, and extinguishment may be partially attributed to the shielding of the fuel from flame radiation. Considered in the light of prevailing theories of combustion and flame propagation, the behavior of the dry powders in experimental tests further suggests that the interruption of chain reactions in the combustion process may constitute another important factor in the effectiveness of these powders.

Thermal Insulating Values of Reflective Surfaces. In order to investigate how much the insulating values of airspaces are improved by using reflective surfaces, a research program was undertaken by a research associateship with financial assistance from the Aluminum Company of America. One hundred and fifty-four panels insulated with reflective membranes alone or in combination with fibrous insulations have been tested. Results of the test show that, in general, almost all of the predicted insulating effects were obtained, with some exceptions ascribed to peculiarities of the installation.

Heating and Air Conditioning of Underground Structures. An investigation of heating and air conditioning of underground installations was initiated for the Office of the Chief of Engineers. The various field investigations and analytical studies include heat transfer into the rock mass surrounding underground chambers; heat transfer in underground reservoirs used for absorbing heat from air conditioning equipment and internal combustion engines; and the periodic heat flow in fresh-air-supply tunnels or shafts.

Insulated Refrigerated Structures. Heat-transmission characteristics of insulated structures can be closely predicted, provided that the insulation is dry. However, gradual accumulation of water or ice in the walls of refrigerated structures can cause changes in heat-transmission characteristics. These changes cannot be determined by simple heat-loss tests because the test would cause melting, evaporation, and movement of the ice or water in the walls, roof, or floor. Therefore, the Bureau developed a calorimetric method permitting heat-transmission measurements in mechanically cooled enclosures under actual operating conditions. This



High-temperature X-ray diffraction apparatus for measuring thermal expansion of cermets up to 1,400° C. These materials are being considered for use as turbine blades in jet aircraft because of their ability to withstand high temperatures (p. 64).

makes possible the determination of the change in heat transmission when, for example, trucks or trailers have been in refrigerated service for a period of time. In this method, still in prototype form, a cooling fluid is circulated through coils in the insulated enclosure and the temperature change in the fluid is measured. The fluid is then circulated in series through a heater with adjustable known heat input and the temperature change is measured. Calculations of the two measured amounts of temperature change in the cooling fluid, the known heat input to the calibrating heater, and a correction for change to specific heat, give heat removed from the enclosure under test.

Asphalt Roofing. The study of the degradation of asphalt during weathering has continued. Using the method developed previously for the separation of asphalts into groups of similar components, the distribution of components in 20 asphalts, representing domestic and foreign sources, was determined. Changes in the distribution of components after these asphalts were exposed 200, 400, 600 and 900 hours to accelerated weathering were also determined.

Equipment has been developed for collecting the gaseous degradation products of asphalt. Work is continuing on the development of methods for separating and identifying the complex mixtures present in the water-soluble degradation products of asphalt.

2.11. Applied Mathematics

The Bureau maintains a central applied-mathematics facility which conducts basic and applied research and renders advisory services in the

various mathematical fields related to the Bureau's activities. The services are available both to the Bureau's technical staff and to other Government agencies. Equipped with machine computing aids, including high-speed digital computers, the facility has played a significant supporting role in the Bureau's research and development program.

During the past year, research emphasis was again placed on statistical and numerical analysis, and mathematical physics. Special assistance was rendered to the Bureau's staff and other Government groups in these areas and in digital computation. In addition to consulting services in applied mathematics, including mathematical statistics, extensive attention was given to problem formulation and analysis and, where necessary, to the development of numerical methods for the solution of problems on automatic and nonautomatic computing machines. The work covered a wide range of investigations and applications in engineering and the physical sciences. In addition, an increasing share of the Bureau's mathematical effort was devoted to applications of digital computers to problems of the type encountered in business management and operation, sometimes referred to as "data processing" problems. During the past year over one-third of the Bureau's computational program was in these fields.

As in previous years, the Bureau's applied-mathematics program was strengthened by the active interest and support of other Government agencies. Especially significant was the support of fundamental and applied research in numerical analysis and mathematical physics by the Office of Naval Research and the USAF Office of Scientific Research.

Numerical Analysis. The program in numerical analysis has the dual purpose of providing solid foundations for day-to-day calculations and carrying out exploratory work in new directions. Various studies of interpolation and approximation were carried out. In view of the value of rational approximations to special functions, as a means of making them available within high-speed computers, a survey was made of this field. A particular application of mathematical elegance and practical value is the use of Cauer-parameters in circuit design. To make this method more convenient, a new tabulation of these parameters is being made. The computational studies of the differential equations for nerve excitation revealed an extraordinary sensitivity of the solution to some of the model parameters, particularly the velocity of propagation.

Experimental calculations in various fields of mathematics have suggested conjectures, subsequently proved correct, or suggested methods of proof of conjectures already made. An important example of the latter class was in connection with the spectrum of the infinite Hilbert matrix. It was known that π is a limit point of this spectrum, but it was unknown whether π is an actual point of the spectrum: this was established by using monotonicity properties of the coordinates of the eigenvectors, which were observed experimentally and then properly established.

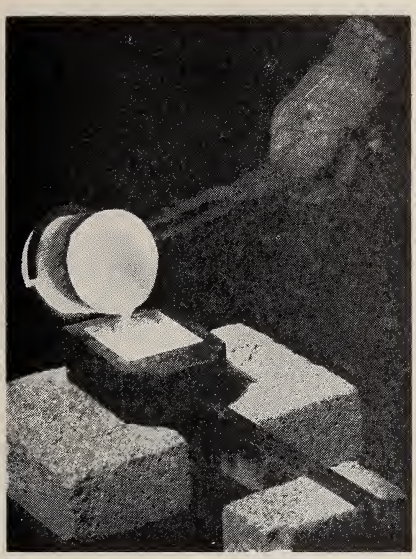
Experimental computation was carried out in connection with the various partial differential equations of mathematical physics. In particular, rigorous calculations were made for the fundamental period ν of vibration of a free square plate. The calculations were rigorous in the sense that upper and lower bounds for ν were obtained: specifically, $3.5252 < \nu < 3.5257$. Numerical work done on combinatorial analysis was found to be of value in the current program of the statistical engineering laboratory; specifically, in the theoretical investigation of partially balanced block designs.

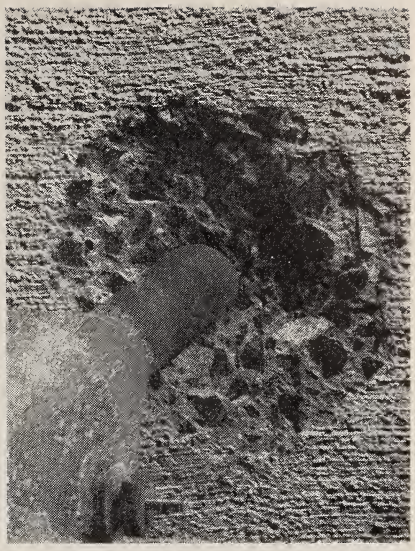
Digital Computation. The Bureau's Computation Laboratory provides services to the rest of the Bureau and to other Federal agencies in the analysis and solution of mathematical problems, especially those involving electronic computation. It also develops general-purpose techniques of programing and coding for automatic computing machines, and publishes mathematical tables of general usefulness.

For example, calculations for a table of electron-physics functions were completed and published. Spectrum-analysis computations, heretofore done on punched-card equipment, were successfully programed on SEAC and established as a routine problem. The solution of a mathematical model for depolymerization was programed and successfully run for a large number of cases. This problem involved the solution of a large system of ordinary differential equations. New programs for crystallographic calculations on SEAC were used successfully and have been substituted for some phases of punch card work. In the determination of so-called *d*-spacings, calculations have thus far been carried out for a considerable number of crystal types.

Computations were also performed on a continuing basis for other laboratories of the Bureau in the following projects: evaluation of thermodynamic functions, thermometer calibrations, solution of dispersion equation for optical glass, optical-ray testing, analysis of noise measurements, stresses in a wall foundation, attenuation of pressure pulses of finite amplitude, calculations of transmission-delay times, study of internuclear potential for H_3, ground-wave attenuation, stresses in a wall resting on a footing, crystal field effects for atoms, collision integrals used in transport theory, model Government payroll on high-speed computers, electron-penetration calculations, and basic atmospheric data.

General-purpose codes for performing various matrix operations and for the determination of characteristic roots and vectors were brought to a high state of perfection and put on a routine basis. They have found wide application in problems arising in various sections of the Bureau. The general-purpose ortho-normalizing code was revised and improved. This program is of fundamental importance in enabling multiple regression analyses to be carried out in a highly flexible manner. Development work was done on automatic coding procedures, whose purpose is to use the computing machine itself for some of the work involved in coding. Among others, routines were obtained for the solution of algebraic equa-





Left: **Casting a specimen of experimental glass for measurement of its physical properties at high temperatures (p. 67).** *Right:* **Destructive action on concrete of hot gases at the temperature and velocity of the jet blast from aircraft. This was part of a study of concreting materials suitable as warmup, power check, and maintenance aprons for jet aircraft.**

tions and for the evaluation of integrals by Filon's method. Incorporation of the matrix codes into the automatic system was begun. A manual for coding in the three-address system was completed, and a three-address compiler system started. Work progressed on logical details for an algebra encoder.

The preparation of mathematical tables was again an important part of the computation program. During the past year, tables were published on radial Mathieu functions, descending exponentials for arguments from 2 to 10, and hyperbolic sines and cosines for arguments from 2 to 10. Work continued on five tables: Sievert's integral, characteristic values of spheroidal wave functions, Coulomb wave functions, the exponential integral for complex arguments, and modified Airy integrals. For the computation of Coulomb wave functions, a general-purpose routine was prepared which includes all the important ranges of the physical parameters.

Statistical Engineering. The principal function of the statistical engineering program is to advise the Bureau's scientific and technical personnel on the application of modern probability and statistical methods in physical-science and engineering experimentation. The aim is to assist the scientist conducting research, development, or testing programs so that conclusions of desired scope and reliability may be attained at the lowest possible cost under existing limitations of funds, equipment, materials, and personnel. During the year extensive services were rendered, ranging from short informal conferences to active collaboration with project leaders for periods of several months.

To maintain and increase the effectiveness of this program, basic research in probability theory and mathematical statistics was conducted. During the past year, this research, geared to fit the particular needs of NBS laboratories, fell into two categories: planning (design) of experiments, and methods for analyzing data.

Under the first category, research was conducted on a family of experimental arrangements known as fractional factorial designs. Factorial designs, complete or fractional, have now become widely accepted as efficient schemes for carrying out experiments that involve many different factors. The Bureau has developed a mathematical basis for constructing appropriate subsets of a full factorial design for use when the total number of combinations required by the full design is too large. Advantages of these fractional factorial designs are (1) more information per measurement, (2) savings in the volume of experimentation, (3) simple and straightforward analyses, and (4) unequivocal interpretation of results. During the year, 118 such designs were constructed for experiments involving 5 to 16 factors each at 2 levels. These have been brought together in a volume now in press. This tabulation was supported in part by the Army Chemical Corps.

In many experiments it is not possible to control all factors that influence the final results, even though these factors can be measured. One way of making such experiments more precise is to "adjust" the final results for the effects of the uncontrolled factors; and there is a standard statistical technique for making such adjustments, termed the analysis of covariance. In the research under the second category, this technique has been extended so that now it may be readily applied to all types of incomplete block designs as well as to the more familiar balanced designs, and to those cases where the magnitudes of the corrections for the several uncontrolled factors are not constant from block to block.

Research was also conducted on the theory and application of so-called distribution-free, or nonparametric, statistical methods. These methods are used in analyzing experimental data with a minimum of assumptions about the form of the frequency distribution of the measurements concerned. To a lesser extent, research was conducted on methods for the computation of the more difficult types of statistical analyses by high-speed computers.

Mathematical Physics. The Bureau's research in mathematical physics falls under four general categories: research in mathematical analysis related to topics in mathematical physics, research in fluid dynamics, research in mathematical elasticity, and research in electromagnetic theory.

In mathematical analysis related to topics in mathematical physics, a comprehensive report was prepared on the application of the quotient-difference algorithm of H. Rutishauser to the computation of eigenvalues and eigenvectors of a matrix, factorization of polynomials, interpolation by sums of exponentials, and determination of the residues of a mero-

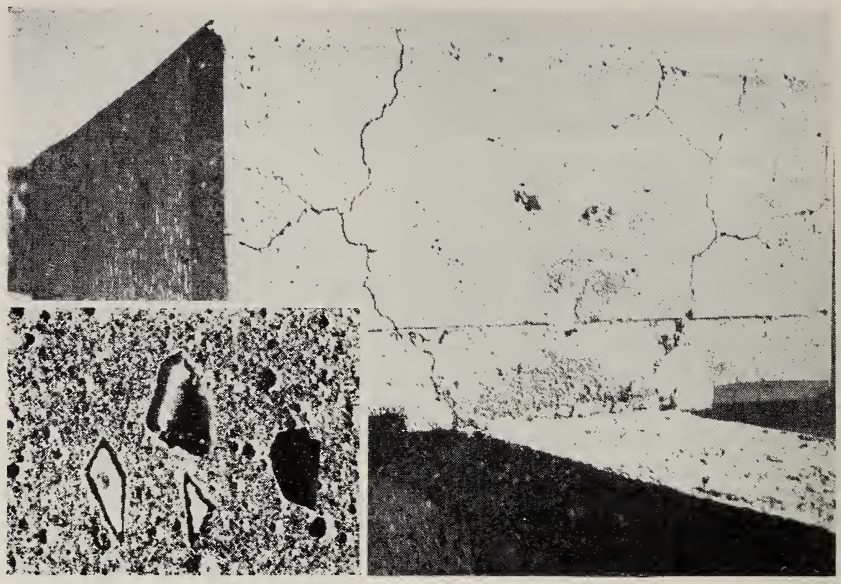
morphic function. An extensive compilation of a table of 800 Fourier transforms of probability distribution functions has been made and will lead to the publication of a set of tables which is expected to be of immense use to workers in the field of statistics and probability.

In fluid dynamics, an analysis was made of the fundamental basis of two-phase vapor-liquid condensation systems. This work will aid in the understanding and development of practical condensation devices which have important engineering and military applications. A study was also initiated on the mathematical basis of the use of a Cartesian diver as a weighing instrument of great sensitivity. The development of such an instrument would be of great importance in various biological applications and in other fields where such sensitivities are needed.

In mathematical elasticity, a method was developed and extensive calculations were carried out on SEAC to determine the stresses and displacements in a corrugated diaphragm. The existence of a theoretical procedure for determining these quantities should result in large savings in the further development of these important instruments. Thus, in the future it should not be necessary to run a new experimental program for each new design. A routine computation should suffice to indicate the consequences of a proposed change in design. A computational procedure was developed which will enable a study of the vibration modes of a clamped-free delta wing to be made by means of a routine calculation using SEAC. This type of wing is now under extensive development for use in supersonic aircraft. Studies were completed in the analysis of elastic wave transmission through various geophysical models. These studies are of basic importance in understanding the transmission of earthquake waves through the earth. They also contribute to the development of analytical procedures for studying earthquakes by means of seismographic records. In electromagnetic theory, a procedure was developed for determining the diffraction and reflection of arbitrary electromagnetic pulses from wedges. This technique can be especially useful in antenna-design problems.

2.12. Data Processing Systems

The Bureau's data processing systems program encompasses research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. This program, initiated during the postwar years, originated as a result of requests from several Government agencies for assistance in evaluating the potential application of automatic electronic digital computers to their problems and in procuring suitable installations. These studies, from which systems specifications were established, eventually led to the Bureau's program of research and development of improved computer components and circuitry and subsequently to the design and construction of SEAC. This machine was the first superspeed automatic electronic digital computer to go into productive operation (June 1950) for the Government. Since then,



The cause and remedy of expansion cracks in large concrete structures have received considerable study. Cracks of this type, shown here in a section of a dam, result from chemical reactions of the high-alkali cements with certain types of aggregates. Micrograph of polished cement specimen (insert) shows the white reaction products in center of angular opal grains which cause the destructive expansion of the concrete (p. 69).

SEAC has established an impressive record of solutions for both scientific and management problems for the Bureau and other Government agencies.

The Data Processing Systems Division provides probably the most comprehensive and readily available Government source of information in the new and rapidly growing field of high-speed automatic data processors. The broad background and experience of the NBS laboratories have resulted in an increased number of requests from Government agencies who seek the Bureau's technical advisory services on high-speed digital techniques. Areas of potential application include massive paperwork operations, control systems, simulation, and the solution of specific technical problems.

SEAC. The experimental modification, operation, and maintenance of SEAC has been a continuing responsibility. During the past year, development work was continued on the electrostatic memory and 1,024 words of electrostatic storage are now available. Circuitry for the high-speed perforated-tape punch was installed and the punch is now available as an additional output device for the SEAC. In addition, the Bureau is supplementing the computer with a high-speed outscriber to convert information on magnetic wire to perforated paper tape, alpha-numeric printers, high-speed tape punches, high-speed perforated-tape readers, and high-speed multichannel magnetic tape handlers. A device was designed and constructed to transcribe the information on punched card

to magnetic wire for SEAC input, thereby providing a convenient, rapid, and reliable means for transcribing information directly from cards to SEAC. This instrument will eliminate the necessity of having intermediate steps in transcribing from cards to wire, thus increasing the efficiency of SEAC operation.

Analog Computers. Under the sponsorship of the United States Weather Bureau and the Atomic Energy Commission, two similar special-purpose analog computers were developed to calculate the geographical fallout pattern of radioactivity from a nuclear bomb explosion. Both computers were shipped to Eniwetok, Marshall Islands, and used in predicting the distribution of radioactive fallout following the explosion of nuclear weapons during May 1956. These computers were not the simulation type, but rather used the analog techniques to automatize the problems. They were designed for (1) small size and portability, (2) low cost, (3) eliminating the need for mathematical training in numerical analysis or digital programing in setting up problems, (4) instantaneous solution of the problem, (5) simple visual presentation of results, and (6) rapid problem modification.

Development of New Computers. The Bureau is developing specifications for a large-scale pilot electronic data processor. This machine will carry out pilot runs on a wide variety of data-processing problems of special interest to other Government agencies. Because the data processor will be expected to solve problems unique in either magnitude of workload or logical complexity, it must meet special requirements on operating flexibility and adaptability to a wide range of problem types. A special effort is being made to exploit the recent advances in the design of logical systems to reduce maintenance requirements for the electronic equipment to a minimum.

Research is also continuing on the logical systems design of high-speed digital computers. These studies have been directed toward devising more effective means for organizing electronic components into over-all systems for carrying out computing and data-processing operations. Development of more advanced and sophisticated logical systems structures makes possible considerable increases in over-all speed and computing power without imposing corresponding increases on the performance requirements of the actual electronic components. Improved designs have so far resulted in addition units and multiplication units capable of operating 150 times as fast as their SEAC counterparts even though constructed essentially from the same 1-megacycle-per-second components.

Semiconductor Devices. Several years ago, the Bureau developed a method of using the normally objectionable phenomenon of the reverse transient in a semiconductor diode to make a high-frequency power amplifier. This circuit was the basis for developing during the past year a complete family of elementary circuits including flip-flops, transfer circuits, AND-gates, and inhibitors that are logically sufficient to build a

Application of a dry chemical extinguisher to a gasoline test fire. Extinguishing flammable-liquid fires by means of some types of dry powders has proved highly effective. Experiments indicate that only small quantities of the material are required (p. 73).

complete digital computer. An experimental system comprising 43 stages of these circuits was built to test and demonstrate their operation. The components were not preselected and were of types that in conventional circuitry could not be used above audiofrequencies; however, in this system they operate at tens to hundreds of kilocycles. Practical application at 1-megacycle-per-second switching rates awaits the manufacture of more suitable components. This program was sponsored by the Air Force Cambridge Research Center.

Transistor Switching Circuits. A survey of various types of high-speed transistor switching circuits is being made. When an optimum circuit has been chosen, effort will be concentrated on developing from it a set of highly reliable computer circuits. An instrument recently developed for this survey automatically plots the region, in terms of two disturbing voltages, where a flip-flop circuit is statically bistable. Although it appears that the transistor circuits may at present prices be more expensive than vacuum-tube and diode circuits of comparable performance for computers, the transistor circuits are likely to be much more reliable.

Magnetic Shift Register. A magnetic shift register constructed of small inexpensive memory-type cores was developed under the sponsorship of the Air Force Cambridge Research Center. This register functions reliably under large variations in operating conditions and at frequencies in excess of 500 kilocycles per second. This circuit could find many uses in digital equipment other than the high-speed arithmetic and con-

trol elements of a machine, such as in input-output devices and other auxiliary units.

Gas Diode Work. Under the sponsorship of the Naval Research Laboratory, development of circuits utilizing commercially available gas diodes as useful computer components has continued. Several variations of the original linear counter register were devised. Possible applications include shift registers and ring counters. The use of rf excitation of gas diodes as a means of switching was investigated, and incorporated in the register designs.

Samples of a linear counting tube developed at NBS were supplied by a private manufacturer and placed on life test. Final test samples are now being manufactured for delivery to NBS. Further information on the characteristics of currently available gas diodes is being obtained so that recommendations can be made to suppliers for improving batch uniformity and reliability.

Computer Circuitry Packaging. A 1-megacycle-per-second digital computer package has been completed and several prototypes have been built and tested. These incorporate some of the latest developments in high transconductance vacuum tubes, semiconductor diodes, and printed circuitry. The packages are much more flexible for computer applications and operate on considerably less power than previous designs. These building blocks appear promising for future use in large-scale digital computer designs where even greater demands are made on circuit capabilities.

Communication Link. A magnetic tape recording system was designed and built to provide a means for greatly compressing and expanding the time scale of the recording. Four tape drives have been provided which record at low speed, reproduce at high speed, record at high speed, and reproduce at low speed. The ratio of the two tape speeds is 2,000 to 1. A cathode-ray beam deflection magnetometer tube serves as the low-speed reproduce head, and provides full output down to zero tape speed.

Data Processing Applications Analysis. Preliminary problem definition, analysis, and flow charting have been carried out for sample payroll and accounting operations. The Bureau has examined typical data-handling operations such as sorting, file maintenance, and posting of transaction data to master records to determine the machine operations required in a variety of supply management applications. The report-editing problem of the Public Housing Administration, requiring the editing of input data for consistency, has been reevaluated to determine production run requirements. Fact-finding and analysis of information on the problems and operations of sorting and distributing mail have been carried out in connection with a program to investigate the feasibility of mechanizing Post Office Department operations.

Patent Search Studies. The Patent Office-NBS cooperative program to apply machine techniques to patent search operations is well under way.

The program began by orienting NBS personnel in patent search requirements and instructing Patent Office personnel in the use of automatic data-processing methods. Preliminary search routines were developed and plans formulated for encoding routines for experiments on SEAC that will simulate proposed search procedures. Installation of new input-output equipment to increase SEAC's versatility in searching has been planned, and the logical circuitry required to connect the commercially procured computer accessories has been designed and incorporated into the machine. Exploration of new ideas on the characterization of information so that it may be searched mechanically included a study of systems suitable for searching chemical structures.

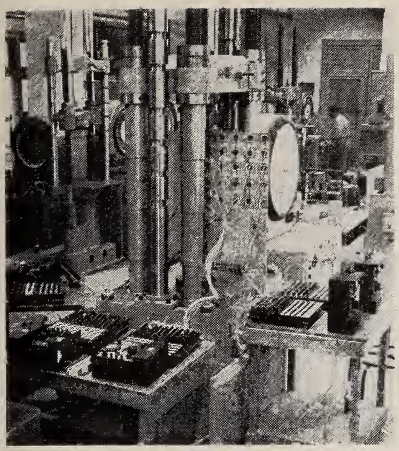
Training Program. The Air Materiel Command, USAF, has undertaken an extensive program to evaluate various types of automatic data-processing systems in their supply management organization. Because it is important to have an informed middle management who will support this program, the Air Force asked the Bureau to plan and conduct a training course to acquaint management personnel with the potentialities of automatic data processing techniques. Text, lecture notes, charts, slides, and supplemental reading lists were prepared. This material covers basic features of automatic data-processing systems; problem planning, definition, and analysis; programing and coding; characteristics of various types of equipment; trends in equipment development; areas of application; and management implications. A 6-week course for Air Force Training Officers was held at the Bureau, and eight 2-week and two 1-week courses were presented to Air Force management personnel in the field.

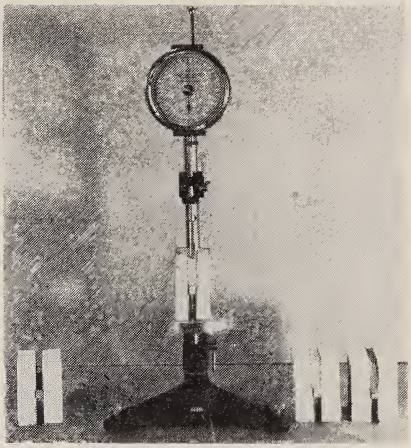
2.13. Cryogenic Engineering

The primary objectives of the Cryogenic Engineering Laboratory are to obtain information needed for the practical applications of very low temperatures and to assist industry and the national defense with problems in this special field.

A project yielding data of immediate usefulness consists of basic studies of the flow of liquefied gases through insulated pipes, and of pumps that can be used to produce high-velocity flow. A gratifying early result of the pump study was the discovery that liquid hydrogen is less subject to cavitation in a pump than are liquids that are more commonly used, such as liquid nitrogen and oxygen. It appears, therefore, that the fluid-dynamic design of such pumps will not be a primary concern of the laboratory, for this can be handled by the manufacturers. The most important contribution of the Bureau is the study of bearings, seals, insulations, and other considerations that relate directly to the low-temperature aspects of the problem.

A contribution to basic research is the assistance being given to the Los Alamos Scientific Laboratory in the design and operation of electro-





Left: Experiment in progress on the nature of stresses in concrete masonry walls (p. 72). Results will aid in determining spacing of control joints and the amount and location of reinforcement. *Right:* Penetration test on masonry calking material. An investigation is being directed toward the cause and control of leakage through joints in cast-stone masonry (p. 72).

magnets which are to be operated at an ambient temperature of about 20° K. This offers great promise as a means of obtaining magnetic fields of higher intensity than hitherto possible. One advantage of running a magnet at such temperatures is that the resistance of the magnet conductor (copper at present) may be lower by a factor of several hundred than its room temperature value. This results in a corresponding decrease of power for a given magnetic field, which in turn eases the problem of cooling the magnet. Various investigations relating to this problem include the development of pumps to circulate liquid hydrogen through a magnet, adhesives to space the magnet coils, and heat transfer through the liquid hydrogen flowing in the small annular channels.

The requirement for information about the mechanical, electrical, magnetic, and thermal properties of materials at low temperatures is basic to all cryogenic design, from large-scale commercial equipment to small special-purpose laboratory apparatus. In selecting materials and properties for study, the principal guide has been the current need for the information. Thus the mechanical properties of glass have been determined at very low temperatures for the design of windows for liquid-hydrogen bubble chambers. Of more general interest is the work on thermal conductivities of various specimens of high-purity copper. These experimental studies, combined with present theory of the solid state, are contributing factors in producing copper of the highest electrical and thermal conductivities at low temperatures. Incidental to this study was the observation in a copper specimen of the highest thermal conductivity ever reported for this element.

Pumps for Liquefied Gases. The initial task in the development of pumps for liquefied gases was the design of a pumping system to deliver

100 gallons per minute of liquid hydrogen at a head of 163 feet, which was accomplished by modifying a commercial water pump. During this preliminary work it was found that ordinary ball bearings, completely cleaned, operate quite satisfactorily if they are submerged in the liquid being pumped. It was also shown that commercial face-tape shaft seals will seal liquid hydrogen and liquid nitrogen. Some data on the performance and cavitation characteristics of one turbine and two centrifugal pumps were obtained with liquid nitrogen and liquid hydrogen. The preliminary tests indicate that liquid hydrogen is less susceptible to cavitation trouble than other liquids; theoretical analyses performed in the laboratory show that this is to be expected.

Test equipment has been built for application to the long-range objectives of the pump development program. The apparatus, which evaluates shaft seals at both room and low temperatures, measures the leakage through the seal as a function of shaft speed and pressure drop across the seal. The bearing test apparatus measures the torque transmitted by the test bearings as a function of speed and loading at both room and low temperatures. The torque measuring device, which was developed for the bearing tests, measures the desired quantity directly; the usual devices require corrections for extraneous torques.

A new permanent pump testing facility will accommodate pumps up to about 12 inches in diameter. Many new features have been incorporated into this facility. A "vacuum buffer zone" attached to the top plate permits filling the pump Dewar completely with liquid without appreciable heat leak through the top plate. The power input to the pump is measured with a dynamometer which cradles the pump itself, dispensing with corrections for drive losses, seal friction, and bearing friction. A vacuum-jacketed standpipe permits the pump suction to be continuously pressurized up to heads of 25 feet, allowing power input to be measured with boil-off techniques even when the pump suction is pressurized. A sharp-edged orifice was installed in the pump-discharge line to measure pump capacity after preliminary work showed that reliable flow measurements can be made with this device. The instrumentation permits the efficiency, performance, and cavitation characteristics to be determined as functions of speed and suction head.

Liquid-Oxygen Transfer Systems. Experimental work has indicated that losses of liquid oxygen procured for large installations, shown by analysis to be as high as 75 percent, can be reduced by two-thirds through the application of conventional insulation techniques and by making simple piping modifications. Measurements were made of transient and steady-state characteristics of insulations appropriate for liquid-oxygen transfer lines. These data permit the computation of thermal conductivities and specific heats throughout the range from room temperature to liquid oxygen temperature.

Flow of Liquefied Gases. Both single-phase and two-phase flow of liquefied gases in pipes have been studied. Calculations, based upon

steady-state analyses of single-phase flow, show that very-long-distance transfers of liquid hydrogen and liquid oxygen are feasible with equipment and techniques already developed.

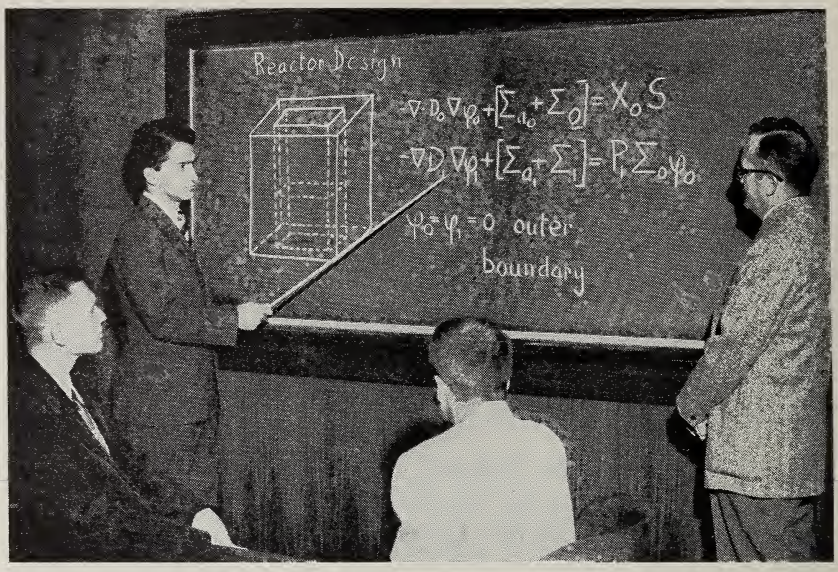
Data obtained on apparatus designed to study two-phase, single-component fluid flow show that the pressure drops predicted by two-component correlations can be brought closer to the observed pressure drops if a simple momentum correction is made. The agreement, however, is not close enough. A technique was developed to photograph the configurations of two-phase flow; it is hoped that if the flow configurations can be predicted, then valid mathematical models can be set up. For the highest flow rates, an annular configuration exists. Therefore, a theoretical analysis of this type of flow was made. The results are being numerically integrated so that they can be compared with experimental data.

Liquid-Hydrogen Bubble Chamber. During the past year the Bureau has been cooperating with the University of California Radiation Laboratory to develop a large 500-liter liquid-hydrogen bubble chamber. Progress in high-energy nuclear research has been made possible largely by improvements in particle accelerator design, together with advances in the field of particle detection. The bubble chamber, the newest of the particle detection devices, will provide physicists with a powerful tool. Many cryogenic problems must be solved to engineer the bubble chamber successfully. For instance, large glass windows at low temperatures are necessary for proper observation of the bubble-chamber liquid. Methods of rapidly superheating the liquid hydrogen are required and design of a large refrigerator is necessary to maintain the bubble-chamber liquid at a constant temperature.

Cryogenic Processes. In 1954 research was begun on the separation of hydrogen isotopes by low-temperature distillation of liquid hydrogen. Previous studies have indicated that low-temperature distillation will yield deuterium gas at a potentially low price. Results obtained during the past year show that the separation is quite feasible, and plans are being completed for a pilot-plant installation.

Studies are being continued on the technical and economic feasibility of transporting helium at or near the liquid density rather than as a gas at ambient temperature under high pressure. It is possible to design storage facilities to contain the helium in liquid form for weeks without loss and large-scale helium liquefiers can be readily engineered and constructed.

A method for purification of helium gas at pressures from 4,500 to 10,000 psi is being developed. Large quantities of helium at high pressures are used in the rocket industry for pressurization and pneumatic control. The helium may contain impurities such as oil, water, and nitrogen, which should be removed prior to final use. Low-temperature and ambient-temperature systems are being considered.



Services to NBS laboratories and other Federal agencies in the analysis and solution of mathematical problems form an important part of the applied mathematics program (p. 75). Here, for use in reactor design research by a Government contractor, Bureau scientists are investigating methods of solving partial differential equations on high-speed computers.

Low-Temperature Properties of Materials. In support of Atomic Energy Commission programs at other laboratories, the strengths of glass, copper, several copper alloys, and copper-organic adhesive laminates have been measured down to very low temperatures. In addition, some magnetic properties of a number of structural alloys have been determined, and experiments have been performed on heat transfer from metallic surfaces to liquid nitrogen and liquid hydrogen flowing in narrow channels. The data obtained have been applied to the design of the large liquid-hydrogen bubble chamber for detection of high-energy elementary particles and their transformations, and the liquid-hydrogen-cooled electromagnet.

Measurements of mechanical and thermal properties useful in low-temperature engineering and research have continued. Included are strengths of aluminum alloys and stainless steels, heat conductivity in a variety of materials, and flow of heat through porous insulations. A comprehensive bibliography on mechanical properties is being published.

Copper is frequently used at low temperatures where high heat conductivity is desired. Investigation of heat conductivity in a series of commercial coppers and copper alloys has had striking results. Several commercial coppers have been shown to have conductivity markedly different from what had been previously supposed on the basis of their room-temperature properties, and a specially prepared copper was found to have a conductivity far higher than any previously reported for copper. Heat conductivity in a widely used plastic, Teflon, has also been measured.

Continued study has been made on the flow of heat through porous insulations. A new insulation consisting of an evacuated mixture of silica aerogel with aluminum powder has been prepared which has about four times the insulating value of the powdered insulations that were until recently considered to be the most efficient.

Liquefaction of Gases. More than 25,000 liters of liquid parahydrogen and about 400,000 liters of liquid nitrogen were produced during the year. These materials are used primarily within the laboratory for low-temperature research and engineering development. Limited amounts were distributed to other agencies and research institutions. Two loads of liquid hydrogen of 2,100 liters each were delivered to the Los Alamos Scientific Laboratory in a special high-vacuum insulated transport Dewar without loss.

Three hundred and fifty liters of liquid helium were produced for measuring thermal conductivity of metals at temperatures down to 4° K, for use in crystal-frequency studies, and for use by an Air Force contractor. Shipment to California was made by air in 50-liter vacuum-insulated Dewars. The helium and nitrogen outlets of the Dewar were sealed with relief valves to isolate the liquid from the effects of changes in altitude, and the outer Dewar was shock-mounted to protect against severe handling.

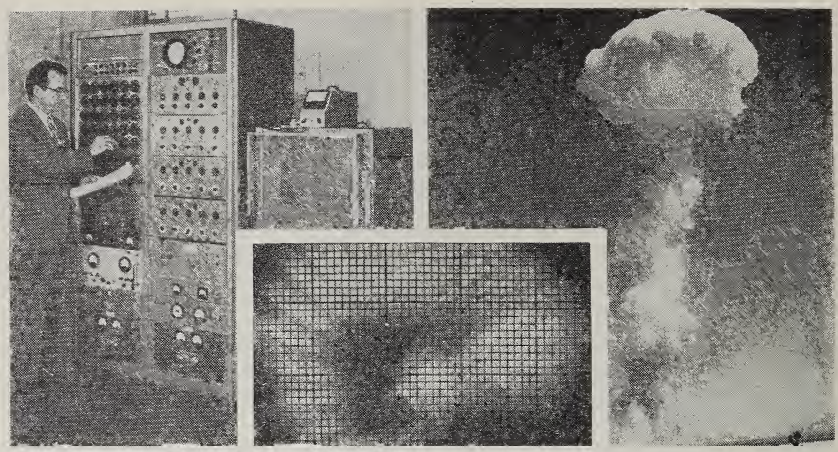
Two small hydrogen liquefiers (up to 45 liters per hour) have been designed and built, and a small helium liquefier (up to 10 liters per hour) is being built. These liquefiers provide a desirable production rate for certain small laboratory requirements. The helium liquefier uses liquid hydrogen for precooling and is useful in laboratories having a liquid hydrogen supply.

Modifications to the large hydrogen liquefier are in progress for improving the ortho-para conversion efficiency and increasing its versatility of use.

2.14. Radio Propagation

The radio propagation program is carried out by the NBS Central Radio Propagation Laboratory, which has primary responsibility within the Nation for collecting, analyzing, and disseminating radio propagation data and information that are of value in such diversified fields as air and sea navigation, frequency allocation, and worldwide communications. To carry out this responsibility, the Laboratory conducts research on the fundamental nature of radio waves, the basic theories of radio-wave propagation, and the characteristics of radio energy under widely varying conditions. A network of field stations is operated from the Arctic to the tropics, and data are exchanged with other laboratories throughout the world. Within the Central Radio Propagation Laboratory are two divisions, Radio Propagation Physics and Radio Propagation Engineering.

The Radio Propagation Physics program involves studies of radio-wave propagation over long distances via the ionized regions of the earth's outer atmosphere. The program includes: (1) basic research on upper



Special-purpose computer developed to predict the geographical fallout pattern resulting from a nuclear explosion (p. 81). Pattern (inset) represents the distribution and intensity of radioactivity on the ground, after information on the weather and the bomb characteristics is fed into the computer. (Explosion photo courtesy AEC.)

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

The Radio Propagation Engineering program is concerned principally with studies of radio-wave propagation as it affects the design of radio systems. Thus the emphasis is on those propagation characteristics that have a limiting effect on the ability of radio systems to perform their desired functions. For example, radio noise levels which finally limit the effective distance range of radio systems are studied on a worldwide basis. In other recent experiments, phase variations, which limit not only the rate of transmission of intelligence over communication systems but also the accuracy of radio direction-finding and navigation systems, have been measured over a variety of transmission paths. Much work has been centered on the characteristics of tropospheric propagation and the effects of meteorological conditions as well as other variables.

Radio Propagation Physics

Upper Atmosphere Physics. Knowledge of the physical and chemical processes responsible for ionospheric behavior is basic to an understanding of ionospheric radio propagation characteristics. Gross characteristics are relatively predictable with present information, but many new important developments and applications involving radio propagation depend upon a knowledge of the fine details of ionospheric behavior,

which can be gained only through continued fundamental research. Theoretical studies of turbulence in the upper atmosphere have shown that whereas the density fluctuations caused by turbulence produce fluctuations in ionization density and are of importance to radio-wave scattering, a much stronger source of ionization fluctuation results from the turbulence-induced transport of ions between regions of different ionization density. This theory permits an improved insight to the mechanism of ionospheric scattering. In more recent work the turbulence transport and the resulting diffusion have been applied to the theory of the *D* layer, whose properties of absorption at low frequencies and scattering at higher frequencies are very poorly understood.

A theoretical study was made on atmospheric oscillation as a result of atmospheric heating coupled with tidal forces. Satisfactory agreement was obtained from a comparison of this theory with some actual data on observed tides at diverse levels in the upper atmosphere.

Radio Noise from the Planet Jupiter. With the discovery by Franklin and Burke, of the Carnegie Institution, that noise signals from the planet Jupiter can be observed, it was recognized that this provided a unique source for observing signals from outside a planet's ionosphere and for studying ionospheric phenomena under conditions somewhat different from those on earth. Two interferometers were assembled to permit simultaneous observations on 18 and 20 megacycles per second. Emissions from Jupiter were observed on three of the first five nights the equipment was in operation. Observations of this emission continued with about the same regularity until late March, when the seasonal increase in ionospheric critical frequencies caused severe interference. In addition to the signals observed by Burke and Franklin, which were associated with a time constant of about 1 second, a new type of signal has been observed with much shorter time constant and occasionally of greater magnitude. Also, unexpectedly poor correlation has been observed between the signals on 18 and 20 megacycles per second. Analysis of the distribution of the emissions with respect to longitude on Jupiter, as proposed by Shain of Australia, has shown four distinct planetary regions preferred for the emissions rather than the smaller number that he found. The observations made so far are leading to revisions in theories proposed for the origin and characteristics of the Jupiter signals.

Airglow. A portion of the basic research into the physical properties of the ionosphere is a study of the radiations comprising the night airglow which result from excited molecules and atoms in the upper atmosphere in the general region of 100 kilometers above the earth. Improved and extensive observational data will lead to a better understanding of the fundamental physical mechanisms of the upper atmosphere. The program is a unified one for the systematic study of the night airglow, with particular emphasis on its absolute intensity, its height, its temporal and geographical variations, its relationship to the aurora, and its correlation with other ionospheric phenomena.

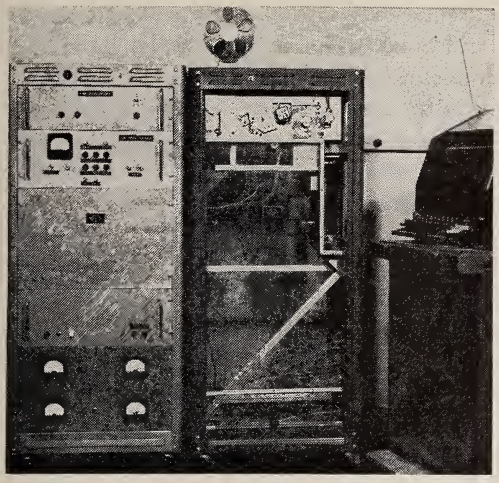
An observing station has been established in the Colorado Rockies, where regular observations are carried out. A telescopic photometer has been developed which has improved spectral resolution and gives a more rapid sky coverage than was hitherto available. It is arranged to scan the sky repeatedly and automatically and to record the observed intensity within a narrow spectral band. During last year's period of low sunspot activity, the related magnetic, auroral, and airglow activity were all low, and it was possible to make a study of the faint zodiacal light, because there was a minimum of upper atmosphere radiation interference. Evidence was obtained for a zodiacal light maximum in a direction perpendicular to the plane of the ecliptic. With the increase of solar and magnetic activity in recent months, there has been a notable increase in auroral activity which is evidenced by low arcs on the northern horizon. Present studies are aimed at determining what relationship exists, if any, between this and the airglow structure observed. Analysis of the records has been accelerated by the use of punched-card and electronic-computer techniques.

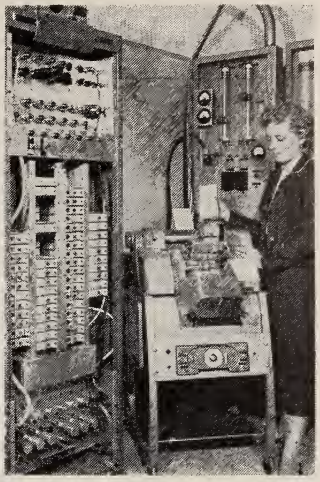
In cooperation with the Air Force Observatory at Sacramento Peak, New Mexico, several nights of observations were obtained simultaneously there and at the NBS station. A triangulation analysis of the records shows that the height of the emission must be near 90 kilometers rather than at the much higher height believed some years ago.

As part of the International Geophysical Year program, photometers of the improved design are being constructed for six IGY stations, and personnel are being trained in the operation of these photometers for the IGY period.

A New Type of Ionospheric Storm. On February 23 there occurred a major solar flare with unprecedented terrestrial effects. These included a widely reported increase in cosmic-ray flux all over the world which was by far the largest of the six recorded instances of this phenomenon. Radio observations showed the expected communication fadeout in the daylight hemisphere of the earth, whose association with solar flares was first pointed out by J. H. Dellinger of NBS in 1936. In addition, a very large increase in ionospheric absorption was found at NBS and associated ionospheric sounding stations in high latitudes in the dark hemisphere, beginning about 15 minutes after flare maximum and cosmic ray increase. At the highest latitudes the effect continued for at least 2 days. Such communication blackouts are not uncommon in polar regions during magnetic storms and auroral displays; this, however, is a clear case of blackout without magnetic activity or aurora.

This is the first clearly recognized instance of a dark hemisphere effect in the ionosphere closely following a solar flare. The observations can best be interpreted in terms of a continuing bombardment of the earth's atmosphere by ionizing particles in the million-electron-volt energy range which must have been present or trapped in the vicinity of the earth in unusual quantities and for an unusually long time. These





Left: **Output unit of a communication link designed and built for greatly compressing or expanding the time scale for transmitting and recording information in data processing systems (p. 80).** *Right:* **This punched-card transcriber reads 200 standard 80-column cards per minute and converts the data into binary code for direct input to a computer or for storage as a recording.**

particles are probably the low-energy tail of the cosmic rays. There is evidence that the unusual ionization causing the absorption of radio waves was produced at an ionospheric level below the usual absorbing region.

Trans-Atlantic Communication System Using VHF Ionospheric Scattering. The requirement for long-distance radio communication in the Arctic, which is immune to disruption resulting from magnetic and auroral disturbances, is an important one. Very early observations of the existence of a new kind of propagation at VHF over long distances by scattering from the lower ionosphere promised high reliability even during blackouts of normal communications. As a consequence, a prototype experimental "scatter" circuit was installed for the United States Air Force from Goose Bay, Labrador, to Sondre Stromfjord, Greenland. The system was designed by the National Bureau of Standards, and was installed and tested under NBS supervision by the E. C. Page Company, consulting radio engineers. Very soon thereafter, a complete operational system from Limestone, Maine, to Thule, Greenland, via Goose Bay and Sondre Stromfjord was designed and installed under NBS supervision on behalf of the United States Air Force. This system is capable of four-channel radio teletype service of high reliability. A number of experimental types of high-gain antenna are used, based on design and model experiments at NBS. On the basis of operational experience with these early VHF scatter circuits, the United States Air Force decided to extend the system across the Atlantic, using the existing links to Sondre Stromfjord, Greenland, and extending them by way of

Iceland to England. NBS was requested to provide consulting, design, and supervisory responsibility, and to contract for the actual installation, which was done by Page Communications Engineers.

NBS, by virtue of participation in these pioneer operational applications, has been able to gather extensive data on geographical factors affecting VHF ionospheric scattering and measurements of transmission loss under a variety of path lengths and antenna designs, as well as to test and observe operational performance of these techniques.

The Extreme Range of Ionospheric Scatter Communication. The extreme useful range of the regular propagation of VHF radio waves by ionospheric scattering is limited mainly by earth curvature. With too long a path length there would be no part of the scattering layer visible in common from both transmitter and receiver, and because of the high loss associated with the scattering mechanism, transmission by double-scattering is not feasible. Confidence in prediction of performance over paths longer than about 2,000 kilometers was limited by lack of a complete knowledge of the relative energy contributions of scattering from various ionospheric heights, especially as regards diurnal and seasonal variations. Also for very long paths involving extensive passage of the VHF waves through the lower, refracting atmosphere, experimental observations seemed necessary to assess the practical effects of tropospheric refraction and occurrences of superrefraction or ducting. An opportunity to test a path in the critical extreme-distance range, from Newfoundland to the Azores (2,271 km), was recognized by the existence of high sites overlooking the sea in suitable directions from both terminals. In the test, standard-frequency oscillator techniques were used to stabilize the transmitter, and also in the construction of special narrow-band receivers. This permitted the test to be carried out with a much less expensive antenna installation. Signal strength at 36 megacycles per second was recorded throughout the year without interruption except for equipment reasons. The experiment demonstrated that regular communication by ionospheric scattering is feasible at a range of 1,400 miles, provided special siting conditions exist and are properly utilized.

Sporadic E. An extensive review was carried out of the existence of sporadic E transmission, and an analysis was made on a worldwide basis. A much higher incidence of sporadic E transmission had been found in experiments conducted in Japan than in similar experiments in the United States. An analysis was therefore made of data from vertical-incidence ionosphere-sounding equipment and, at higher frequencies, from experiments using oblique-incidence paths, and of operational reports of sporadic transmission. Inspection of the 7 years of vertical-incidence data from the worldwide network of ionosondes confirmed the suspected longitude effect, in that a well-defined maximum in sporadic E is found to exist to the south of Japan. In the temperate zone, a negative correlation was found between magnetic activity and the incidence of

sporadic E. The results of this study point toward the possibility of a terrestrial energy source for temperate-zone sporadic E, and an extra-terrestrial one for sporadic E in the auroral zone. As an outgrowth of this study, special experiments will be undertaken during the IGY to determine some of these features more quantitatively.

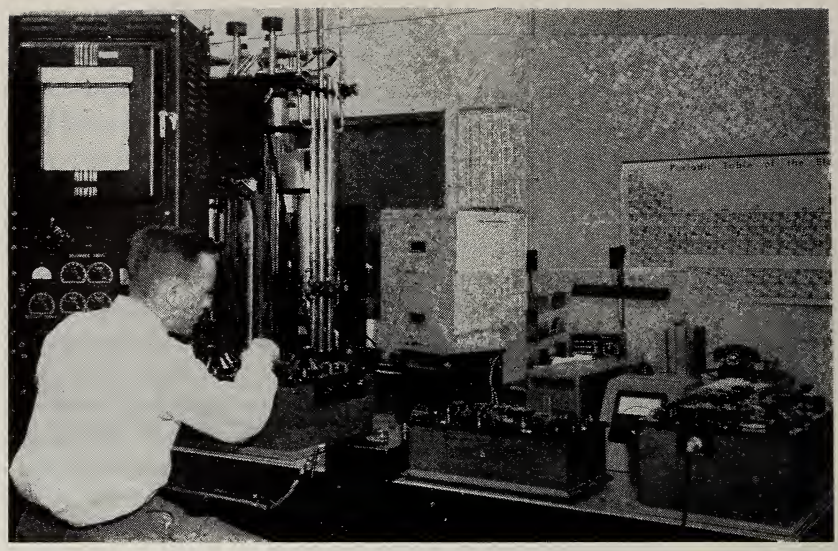
Automatic Data Processing. The practical application of ionospheric and radio propagation science is seriously hampered by the great amount of labor involved in present methods, as in making calculations and predictions of propagation characteristics. Research in this field is likewise hampered by the difficulties and expense of utilizing already available data, and by the inefficiency of present methods of accumulating and processing new data.

The use of electronic computers and machine methods for processing data offers possibilities of tremendous improvement in these directions. A computing machine, using punched cards, with possible extension to other recording processes such as magnetic tape, was installed during the year to provide a basic tool for these numerical methods.

The first phase of the work has been to develop a systematic method for processing the hourly ionospheric measurements of the CRPL stations. Since May, the measurements of 10 stations have been completely processed automatically. Monthly data tabulations, and tables giving statistical distributions and affording a means of finding errors, are prepared on a regular basis. These activities provide the basic steps toward a numerical representation of the ionosphere, and studies are under way on using these methods of automatic data processing in preparing the regular predictions of forthcoming ionospheric characteristics, and in automatizing specific path calculations.

The automatic data processing facility is also being applied to other research activities, and has, for example, made a marked improvement in the handling of airglow data. Data reductions formerly requiring about 1 man-year of effort can now be accomplished in about 1 man-day.

International Geophysical Year. Although taking of data for the International Geophysical Year officially starts on July 1, 1957, several activities have already begun because of the extensive preparations required. Six airglow photometers are being constructed, two of which will be operated by NBS with the remainder sent to other IGY stations. A contract is in effect for the production of 14 ionospheric recorders of a new model. The first of these recorders has been completed. Because of the prolonged logistic lead time required, equipment has already been sent to Antarctica for the installation of ionosphere sounding stations at the South Pole and at the Marie Byrd Land Station. Equipment for four additional Antarctic stations is presently being assembled and will be shipped within the forthcoming year. Siting studies are also under way for the observation of ionosphere forward scatter in equatorial regions, and for an oblique-incidence sporadic-E measurement experiment.



Apparatus used to measure the thermal conductivity of materials at low temperatures (p. 88). Such data along with mechanical, electrical, and magnetic properties are basic to all cryogenic design, from large-scale equipment to small special-purpose laboratory apparatus.

Radio Propagation Engineering

Radio Studies of Atmospheric Turbulence. Dependable theories of atmospheric turbulence have been developed during the past year which are capable of explaining in considerable detail the extensive experimental data on tropospheric forward scatter gathered primarily by the Bureau, but also by other organizations, during the past 15 years. These advances in theoretical knowledge were recently accelerated by an experimental study of the variations of phase on short line-of-sight transmission paths. Techniques have been developed for measuring phase variations at 1,000 megacycles per second with an accuracy, over 5-minute sampling periods, of a few hundredths of a degree and with a stability in the first derivative of the phase of better than one part in 10^{12}. Measurements employing these techniques, in addition to providing data of direct engineering value to the designers of direction-finding equipment, have provided a remarkable insight into the physical nature of atmospheric turbulence.

Extending the Scope of the Atmospheric Radio-Noise Program. During the past year the atmospheric radio-noise recorder developed at NBS has been accepted internationally as appropriate for use in a worldwide measurement program. In addition to providing continuous recordings of the average power of the noise received on a standard antenna at 8 discrete frequencies in the range from 15 kilocycles per second to 20 megacycles per second, some of these recorders have been modified to record also the average noise voltage and the average of the logarithm of the noise voltage. It has been shown that these three statistical

characteristics of the noise provide a reasonably comprehensive picture of the physical nature of its amplitude distribution. Fourteen recorders have now been delivered or are on order, and it is expected that two more will be ordered shortly by the Government of India so that a good start on a worldwide program of noise measurements will be under way during the International Geophysical Year.

Propagation From a Transient Dipole Source. Among the more significant of many theoretical studies carried out during the year has been the solution for a transient dipole source over a curved homogeneous conductive sphere. The numerical results show the characteristics of an electromagnetic pulse propagating over the surface of the earth. The theory has recently been extended to account for the presence of the ionosphere by both geometrical-optical and modal techniques.

TACAN Investigation. The objective was to evaluate the coverage of the TACAN system of air navigation and to make recommendations for use in the common system. Charts are to be prepared showing the coverage of a TACAN facility under various conditions, the required distance separation among ground TACAN facilities operated on a common channel assignment and on any other than a common channel assignment, and the number of channels required for a specific plan of sites and coverage to be furnished by the Air Navigation Development Board. Consideration is to be given to TACAN equipment as currently being produced and to improved equipment which may be available within the next 10 years.

Bench tests of current TACAN equipment initiated by NBS indicated that system performance, especially with regard to adjacent channel interference, was not as good as originally thought. These results necessitated consideration of a wide range of equipment characteristics.

Procedures that had been formulated under this project for determining the probability of service to be expected under various conditions were used for detailed calculations. These methods were designed to be as general as possible, so that they might be applied to various ground-to-air communication systems operating in the VHF and UFH regions. Diagrams have been drawn to show the service to be expected under a large variety of conditions of cochannel and adjacent-channel interference.

The results of these studies provide a basis for determining the number of channels required for nationwide TACAN service, an important consideration in determining the feasibility of using TACAN in the common system.

Airborne Refractometer. This project was established to develop a microwave refractometer installation in a light, single-engine army aircraft. The necessary characteristics were essentially high useful sensitivity, simplicity of operation and maintenance, and reliability, with low space, weight, and power requirements. Due to operational problems it was important that the instrument be designed to require an absolute minimum of structural modifications of the aircraft in which

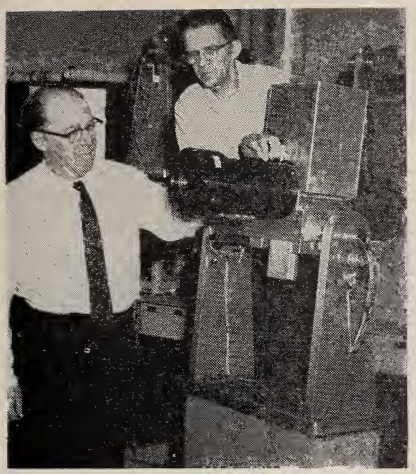
it was installed. The result to date is a system weighing about 35 pounds, consisting of a refractometer (7×10×12 in.) operating from a 100-volt 400-cps line and an inverter (10×6×8 in.) 28 volts dc to 100 volts 400 cps to permit operation from the airfcraft supply. The noise figure as measured in laboratory tests is about 0.005 *N*-units and the design is such as not to require an operator in normal flight use. The sampling cavity is mounted on a bomb rack under the wing and the entire system may be installed on the L–20 type of aircraft without making any structural changes in the aircraft. This project was sponsored by the United States Army Electronics Proving Ground, Fort Huachuca, Arizona.

Propagation Measurements in the Pacific Coast Region. The objective of this project is to investigate over-water tropospheric propagation for paths both within and beyond the radio horizon in the Pacific Coast region. This program is sponsored by the United States Naval Air Missile Test Center (USNAMTC). The Bureau has provided technical assistance and consultation regarding frequencies to be employed, installation of transmitting and receiving equipment, recording of data in a form most suitable for analysis, and calibration of the equipment. NBS has also provided receiving, recording, and calibration equipment, modified for operation on 100, 244, and 394 megacycles per second.

Operation on 394 megacycles per second commenced in October 1955, with transmissions originating on San Nicolas Island, and receiving equipment operating on Laguna Peak (within the radio horizon), and at USNAMTC (beyond the radio horizon). Calibration and data-collecting procedures were established jointly by the test center and Bureau personnel. Data recording is performed by USNAMTC, and data analysis by NBS. Preliminary results for the month of November 1955, compiled and compared with theoretical computations and estimates, have been summarized in a report. A more thorough analysis of the data through January 1955, including a study of space-wave fadeouts and refractive-index variations, has been completed and prepared for publication. Consideration is being given to more efficient methods of data collection and processing by means of digital and punched-card equipment. USNAMTC has initiated procurement of equipment for this purpose.

2.15. Radio Standards

In direct line with the Bureau's basic objectives the program in radio standards is principally concerned with primary electrical standards, measurement techniques, and properties of matter in the frequency range from 30 kilocycles per second through the highest available microwave frequencies. In most of this frequency range the services offered to the Nation will be greatly amplified by the establishment of the Calibration Center now being constructed (p. 180). In the extreme high frequency range, standards and adequate measurement techniques



Automatic telescopic photometer installed on Fritz Peak in the Rocky Mountains for observation of night airglow (p. 91). A built-in programing unit causes the photometer to scan the night sky continuously. Six photometers have been designed and constructed for the International Geophysical Year.

are still essentially nonexistent. In the lower frequencies, increasing electronic applications have created a need for greatly improved primary standards and calibration techniques.

Attenuation Measurements. To maintain an up-to-date calibration service for high-frequency attenuation standards, which are widely used in the precision measurement of almost all electronic quantities, the Bureau must constantly improve its standards and methods of measurement. A new insertion-loss measuring system capable of very high sensitivity was thoroughly investigated both theoretically and experimentally. The advantage of this system is that it reduces the output stability necessary in both the rf source and monitor. To utilize the advantage of this system and so gain greater measurement accuracy, rf power leakage and unstable reflections from connecting transmission lines were minimized by devising and constructing a solid-line rotating-joint type of line; in addition, improvements were made in the design of the attenuation standard with regard to shielding, accuracy, simplicity of construction and ease of operation. A new standard piston attenuator was constructed and tested for performance.

Dielectric and Magnetic Materials. Accurate precision measurements of the hf dielectric and magnetic properties of materials are basic to many new applications of these materials in military and industrial electronic circuits. Such measurements are also required for the synthesis of new materials. A new automatic wide-temperature-range cavity to be used for measuring the high-frequency dielectric properties of ferrites and other materials was improved with a circuit to control automatically the position of the short circuit.

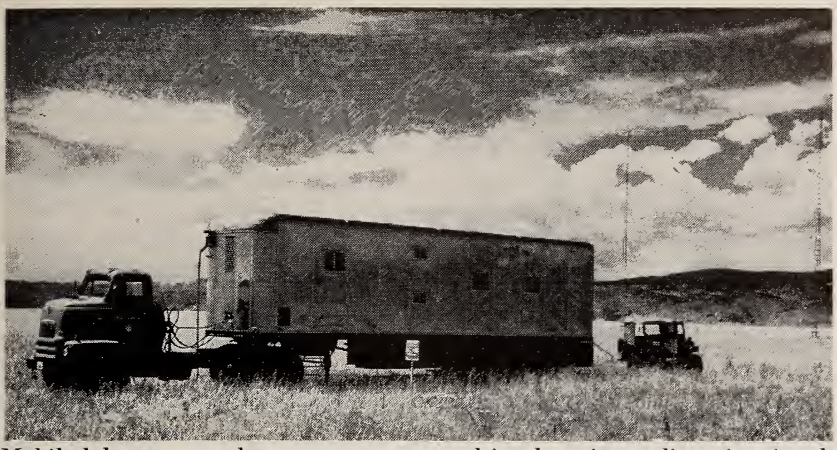
Two permeameters were designed and constructed for measuring the parallel reversible permeability of magnetic toroids, and a high-current rheostat was constructed for controlling the d-c field of these instruments. A variable length reentrant cavity for permeability measurements in the range from 40 to 1,000 megacycles per second was constructed and placed in operation. A half-wave variable-length cavity was designed primarily for low loss permeability measurements in the region from 300 to 3,000 megacycles per second. A calorimeter for high-power rf-loss measurements in magnetic materials was completed, and the associated temperature circuits were partially constructed. Many measurements of magnetic materials were made with regard to frequency and temperature dependence, the effects of magnetic and thermal shock, and external bias field. This information is being incorporated into JAN specifications by the Armed Force Services with the assistance of the Bureau.

The volume conductivity of highly polarizable crystals was measured as a function of temperature, time, and field strength. These measurements showed a very definite relationship between the conductivity and the polarization state of the crystal, which should have considerable practical use as well as yielding valuable information on the fundamental processes of conductivity.

Frequency and Power Stabilizers for Precision Measurements. Precision measurements at microwave frequencies require that the signal source or generator of microwave power be highly stabilized in frequency and power level (or amplitude). This becomes very necessary if measurements are to be made as economically as possible by minimizing the need for monitoring or adjusting the signal source to obtain constant conditions of operation. Frequency and power-level stabilization are much needed developments for use in microwave instrumentation for the new Calibration Center.

During the past year as byproducts to the microwave power and attenuation projects, there were two significant developments that are now answering the need for power level and frequency stabilization in signal sources. The first is a frequency discriminator circuit using waveguide components, the initial design being made of X-band waveguide (operating around 10,000 megacycles per second). The reference of frequency is a temperature-compensated, tunable, cavity resonator. The present design gives a frequency stability of better than 1 part in 100,000 over a period of 1 hour. Although this is not unusual performance for frequency stability at microwave frequencies, the method has the advantage of being simple and relatively low in cost, and has great flexibility in that it can be tuned over the entire useful band of the waveguide components.

The second development is a power or amplitude stabilizer incorporating electronic circuitry that was originally designed for a self-balancing d-c bolometer bridge for precision power measurements at microwave frequencies. Modifications of this bridge have produced a circuit with



Mobile laboratory and antenna towers used in observing radio noise signals from the planet Jupiter (p. 91). These observations are providing new knowledge on the origin and characteristics of the Jupiter signals.

a power stability at 10,000 megacycles per second of about 0.02 percent per hour. The combination of this power stabilizer with the frequency stabilizer in a microwave signal source produces a generator of microwave frequencies that is a real boon to making precision measurements. It is planned to make extensive use of these stabilizers in equipment for the new Calibration Center.

Frequency Standards and Radio Broadcast Services. Beginning in January 1956, the standard-frequency broadcasts from the Bureau's radio stations WWV (Beltsville, Md.) and WWVH (Maui, T. H.) were increased in accuracy from 1 part in 50 million to 1 part in 100 million. The stability of the frequencies broadcast was increased to 1 part in a billion at WWV and 5 parts in a billion at WWVH. These increases in accuracy and stability were due in part to a change in the method of adjusting the time signals to agree closely with the new uniform time, UT2, as determined by the U. S. Naval Observatory. With this new method fixed time adjustments of 20 milliseconds are made on Wednesdays when necessary. Two such adjustments were made between January and June 1956. Previously the time signals were adjusted by overcompensated changes in the frequency.

Variations in the delay time of time pulses from station WWV to Boulder were photographically recorded at 15 and 20 megacycles per second; values of one- to two-tenths of a millisecond affirmed the accuracy of the procedures used in assessing and steering the broadcast.

A questionnaire survey concerning the broadcast of standard frequencies and time intervals from WWV and WWVH showed that all of the broadcast was of value to many users in the industrial, communication, and navigation fields. However, the most used parts were the standard radiofrequencies and the time signals.

A special low-frequency antenna supported by five 120-foot poles was essentially completed at the Boulder Laboratories and a transmitter

partly converted to permit the broadcast of very low frequencies. This experimental broadcast was planned for studying the stability, accuracy, and reliability of standard frequencies in the region of the spectrum where the transmitting medium is more stable.

In work to improve the stability of crystal clocks, basic information was obtained on the characteristics of quartz resonators at liquid helium temperatures; initial drift due to aging was reduced by a factor of more than 10,000; the quality of the resonators was also improved.

Impedance Standards. To facilitate the calibration of high-frequency impedance measuring instruments a set of approximately 60 impedance standards was completed and calibrated at low frequencies. Special connectors on these standards and other instruments, with coaxial dimensions of 0.7500 and 0.3257 inch, were developed. Much consideration was given to the choice of dimensions and to minimizing the corrections. A taper to be used for calibrating the standards at high frequencies was designed.

A new technique of making precision measurements of impedance at microwave frequencies in terms of standing-wave ratios or reflection coefficients was completed. This technique permits use of sliding loads as standards of standing-wave ratio and, in turn, provides a method of measuring unknown loads. Use is made of a three-arm waveguide junction with a generator and detector connected to two arms and the standard or unknown to the third arm. Advantages of this technique are that the waveguide junction is not critical to symmetry, or extreme mechanical precision, nor is there the requirement of losslessness. The technique is a definite advance in the precision measurement of standing-wave ratios in waveguide circuitry because of (1) its increased generality and rigor of theoretical analysis; (2) the use of bolometer for detection with accompanying increased range of linearity, because tight coupling of detector to junction is not a critical feature; and (3) its simplicity as compared with the more conventional slotted-line technique. The accurate measurement of impedance is important in determining performance of microwave equipment and matching of components for maximum power transfer. It is also a very necessary procedure in making many other microwave measurements, especially when high precision is involved.

Microwave Spectroscopy of Gases. Continuation of the systematic study of the microwave absorption of gases at high pressures has resulted in the development of a very accurate technique for determining quite small dipole moments and has shown a distribution of relaxation times for the nonresonant absorption in gases. Further, well-known statistical and statistical-collision theories of line shape have been shown to fail in the low-frequency tails, while two-collision theories have been shown to give proper frequency dependence in this region. Information concerning line shape is quite useful in estimating attenuation of radio waves and

microwaves by the atmosphere. Although nonpolar gases are not expected to absorb microwaves, such absorption was found experimentally and the results explained semiquantitatively as due to quadrupole moments in one molecule inducing a dipole moment in a nearby molecule. This new effect should be important in understanding the absorption in liquids and highly compressed gases.

Work was completed in gathering data for a revised edition of the NBS circular on molecular microwave spectra tables, the information coming from approximately 400 sources on a worldwide basis. Analysis of the data is in progress. The table is valuable as a comprehensive source of information on spectrum lines used as secondary standards of frequency in the microwave region, for chemical analysis, as well as in the determination of molecular structure.

Power Measurements and Standards. Accurate rf power measurements and standards are in wide demand by both commercial and military groups for determining the range of rf power sources and transmitting equipment.

Bolometer-bridge circuits of superior accuracy, wide range, and simplicity were developed to measure high-frequency power from 0.1 milliwatt to 5 watts. A new conduction calorimeter with a range of 5 milliwatts to 15 watts was further developed. To calibrate still larger high-frequency power sources a liquid-flow calorimeter type of power meter was designed. Development work on the evaporated thin-film rf leads required for these calorimeters was essentially completed. A new method of measuring microwave power has been under study. This method, which shows promise particularly for pulse power, is based on the interaction of an electron beam with the rf field in a waveguide.

Since the design and construction several years ago of the first microcalorimeter for use in the primary standard of microwave power, it has been found desirable to improve upon its design. The new model incorporates such features as a special thermally isolated section of waveguide to replace the former air-gap, improved ambient temperature control, bolometer mounts that can be tuned within frequency limits of waveguide size, and a more rugged construction than the former model. Work was also resumed on the high-power, stirred-water, adiabatic calorimeter to improve its design and operating characteristics. A complete system of power measurement at ultra-high frequencies at comparatively low power levels was improved during the year. Refinements included improved modulation techniques, adjustment of bolometer resistance to prescribed values, and the modification of commercially available slotted lines. Much of the present effort in improvement of power-measuring techniques is being directed toward their use in the Calibration Center.

Voltage Standards. Wide interest in the recent development of new attenuator-thermocouple-type high-frequency voltmeters, having exceptional stability, has encouraged the design and construction of two new

An experiment conducted over an extended period has demonstrated that communication by ionospheric scattering is feasible at a range of 1,400 miles (p. 94). The test range was Newfoundland to the Azores.

models. These cover the frequency range from 30 kilocycles to 100 megacycles per second. Patent proceedings were initiated on these instruments. A helpful nomograph was devised to facilitate their use.

The development of balanced voltage standards from 300 to 1,000 megacycles per second was begun. Resistors for micropotentiometers used in balanced circuits and, to correlate results, a crystal-type balanced voltmeter were designed and constructed.

Improved fabricating techniques for 1-milliohm resistive elements of high-frequency micropotentiometers were developed.

2.16. Basic Instrumentation

Six years ago, a program in basic instrumentation was instituted at the Bureau in order that it might better serve as a research, reference, and consultation center on problems of instrumentation for the laboratories of Government and industry. Sponsored by the Office of Naval Research, the Air Research and Development Command, the Atomic Energy Commission, and the National Bureau of Standards, this program represents an effort to utilize the Bureau's facilities and experience in the field of physical measurements to advance those techniques of measurement and control that are fundamental to progress in science and industrial technology. To this end, it coordinates the specialized knowledge and skills of Bureau staff members in a wide range of subjects that are

relevant to the solution of instrumentation problems—among others, in electronics, engineering mechanics, chemistry, thermodynamics, optics, sound, and atomic physics.

In addition, however, the program endeavors to encourage and stimulate research and development throughout the Nation on measurement devices and techniques. To fulfill its responsibility as technical consultant to Government and industry on instrumentation, it maintains active familiarity with technical progress in other measurement laboratories and it cooperates with technical societies in promoting instrumentation progress. Moreover, it cooperates with other Government agencies in arranging conferences and symposia on subjects of special interest or of rapidly developing importance in the field of instrumentation. These activities often help to define areas of instrumentation in which research and development work needs to be done, either at NBS or elsewhere.

The principal emphasis, throughout the program, is on the basic fundamentals of measurement and control and on development of the science of instrumentation. Preference is shown to those research projects that seem likely to have broad utility in measurement or to extend significantly the range, reliability, or sensitivity of some general class of instruments. Also given primary consideration are theoretical and experimental studies of problems common to many instruments—such as drift, lag, unsteadiness—or of the limits of performance inherent in various types of instruments.

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

The research and development activities of the instrumentation program have two principal objectives: (1) systematic analysis of available methods and devices in terms of their performance and characteristics, and (2) research on new applications of principles and materials, leading to the development of novel instruments and techniques. This part of the program is carried out largely through the assignment of instrumentation research projects to those NBS laboratories that are best qualified to conduct research in the particular field of science involved. The basic instrumentation facility also includes a small laboratory staff for investigation of special problems and a group of specialists in instrumentation literature who are developing a reference and consultation service to aid in the solution of instrumentation problems.

New Instruments. During the past year, projects in the basic instrumentation program were conducted in eight of the technical divisions of the Bureau as well as in the basic instrumentation laboratory itself.

The accomplishments of the projects carried on in the technical divisions include: the development of an instrument for measuring very small alternating currents, such as are encountered in transistor circuitry, without breaking into the circuit; an improved galvanometer design which optimizes sensitivity and speed of response; successful development of instrumentation for the measurement of voltage ratio of transformers for computer application with extremely high precision; the development and successful testing at ordinary temperatures of evaporated film strain gages which promise usefulness at high temperatures; development of an instrument for measurement of dynamic bulk modulus; development and construction of microwave components for 3-millimeter microwaves in connection with development of a microwave interferometer.

The projects handled in the basic instrumentation laboratory itself are generally confined to those that call for exploratory studies by a versatile group specializing in instrumentation. When such an activity is seen to merit a full-scale project, it is turned over to the proper technical division for further work. Selected projects conducted in the basic instrumentation laboratory are discussed below.

Instrument Reference Service. Both the newness of the field of instrumentation and its rapid growth have posed problems for those scientists in Government and industry who need to have convenient, rapid, and thorough access to instrument information. Two major obstacles stand in their way. The first is the inadequate coverage of instrumentation provided by existing abstracting and indexing services whose main interest is the information obtained by use of the instrument. The second is the lack of efficient classification systems for instrumentation. The Bureau has therefore established an instrument reference center whose objective is to improve accessibility of instrument information in four ways: (1) by developing improved systems for storage and retrieval of information; (2) by fostering developments elsewhere that will make instrument information more readily available; (3) by surveying specific developments in instrumentation; and (4) by providing consultation services in instrumentation.

Indexing System. The system for indexing the literature on instrumentation, whose development was described in past reports, is now in full-scale operation. More than 10,000 references were selected, classified, and coded during the past year. Improved card punches have been designed and are now being constructed. These will increase efficiency of punching and hence reduce costs. Improved card materials were also developed.

As increasing numbers of instrumentation inquiries from other Government agencies and their contractors are being answered, a revision of the previously prepared report, "Instrumentation Literature and its Use," was completed and issued as NBS Circular 567, with the title, "Guide to Instrumentation Literature." Demand for this circular has been so great that a second printing has been ordered.

Transmitting antenna atop Pikes Peak (left) and the Colorado Springs (Colo.) recording site terminal (right). These installations are used in phase stability experiments to determine the effects of atmospheric turbulence on UHF and microwave transmissions (p. 96). The transmitting and receiving antennas shown operate at 1,046 Mc.

Surveys. Another important service of the basic instrumentation program is the preparation of critical surveys of various areas of instrumentation. These are conducted in order to provide systematic analyses of available methods and devices in terms of their performance and characteristics. Whereas such surveys are of general usefulness, they should be particularly valuable to those charged with planning or conducting research and development on the devices or in areas where they will be needed. As with other portions of the basic instrumentation program, some of the surveys are conducted by the staff members of the technical divisions and others are conducted by basic instrumentation personnel.

In the past year a survey of thickness measurements has been completed and is being prepared for issuance as a Bureau circular. The first part of a survey of recording methods and instruments has been completed and is undergoing editorial review. It will appear as volume I of the complete survey and will be titled "Recording Surfaces."

3. Calibration, Testing, and Standard Samples

The policy of the Bureau to foster and encourage the development of standardizing laboratories by private enterprise was emphasized in a talk by the Director at the dedication of the Eli Whitney Metrology Laboratory, the first commercial laboratory to engage in the calibration of gages for the public on a fee basis. At this dedication it was pointed out that at the end of World War I the Bureau had a staff of over 160 engaged in the calibration of gages whereas at the present time, with a

vastly greater industrial economy, only eight persons are required to calibrate the precision gages now utilized by others to carry out the bulk of the calibration. Similar situations are in effect in a number of other areas of calibration. Thus the Bureau is able to devote more of its resources to developing new standards and providing the higher degree of accuracy required by modern industry.

3.1. Retention of Service Fees

Public Law 940 of the second session of the 84th Congress authorized the Bureau to utilize its Working Capital Fund as a revolving fund for the conduct of services for the public as well as for other agencies. Hitherto fees paid for receipts from the calibration of standards and the sale of standard samples to the public have been deposited in the Treasury and the cost of doing the work has been defrayed from the Bureau's appropriation.

The new law authorizes the Bureau to finance the cost of services for private organizations by retaining the fees charged for those services. These charges are based on the estimated cost of the service and the fee schedules are published from time to time in the Federal Register.

The law makes no change in the services that the Bureau is authorized to perform for the public. These services will continue to consist very largely of the calibration of standards and the sale of standard samples as published in *Test Fee Schedules of the National Bureau of Standards* (Federal Register, March 30, 1956) and *Standard Samples and Reference Standards* (Federal Register, July 3, 1954 and NBS Circular 552). The Bureau undertakes tests of products only when it has special facilities that are not available elsewhere. The full text of the law is given on page 140 in the appendix.

3.2. New Calibration Facilities and Equipment

New calibration facilities are constantly under development at the Bureau in order to meet the needs of science, industry, and the Government for greater accuracy and new and improved standards. These range in size from small items of laboratory equipment to the Boulder Laboratories' new Calibration Center which, when completed and fully equipped, will represent an investment of nearly $2 million.

Electronic Calibration Center. Plans have been completed and actual construction begun on the Boulder Laboratories' new Electronic Calibration Center. Simultaneously, work has been under way on the design and construction of over $1,000,000 worth of interlaboratory standards and specialized equipment for the Center, so that operations can begin as soon as construction is completed early in fiscal year 1958. The Calibration Center will occupy a new, 27,000-square-foot wing of the Radio Building, and will have greatly expanded facilities for calibration services and research on high-frequency electrical measurements of all

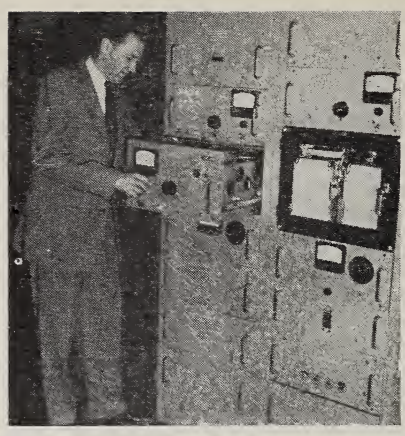
kinds. The initial impetus to establish the Center came from the urgent and continually increasing need for accurately calibrated electronic equipment by the armed forces. Strong support for the new facility was provided by several branches of the military services, especially the Air Force and the Navy Bureau of Aeronautics, and by various industrial laboratories.

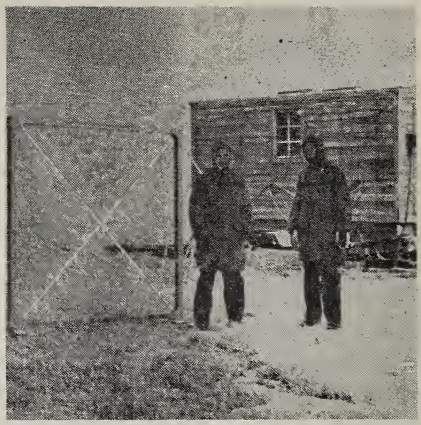
It is estimated that regional depots of the Air Force and Navy Bureau of Aeronautics alone, that check the accuracy of electronic equipment used in flight, will send in nearly 4,000 items annually for calibration. These items and those submitted by other sources will include many types of interlaboratory standards that will be calibrated against the master standards at the Center. The standards will, in turn, be used to assure the accuracy of working standards in laboratories and on the production line. Initially, the Center will perform calibrations at frequencies already in wide use ranging up to 10,000 megacycles per second. It aims eventually to measure and standardize all usable electrical and radio quantities from direct current, or zero frequency, to at least 100,000 megacycles per second. The range from direct current up to 30 kilocycles per second will be shared with NBS in Washington.

Anechoic Chamber. The Bureau's anechoic chamber (i. e., one free of echoes) has been reconstructed and will enable the Bureau to satisfy the need for free-field calibration of microphones and sound level meters of special types used by the medical profession for the accurate measurement of noise at high levels. Freedom from interfering wall reflections and echoes is attained in the chamber by lining its walls with highly sound-absorbent acoustic wedges. It is expected that within the range of frequencies from 80 to 20,000 cps the walls of the chamber will reflect less than 1 percent of the sound energy incident upon them.

Large Capacity Balances. Two new precision balances of 1,000- and 2,500-lb capacities were constructed. They are equipped with special arrestments and built-in weight-handling devices to facilitate operation. The larger balance will be installed at the Bureau's Master Railway Track Scale Depot at Clearing, Illinois, and will be used to enhance the precision of standards used for calibrating master and other railway track scales. The smaller balance will be installed at the NBS Boulder Laboratories and will, for the first time, provide weight calibration service for the States in the western plains and the Rocky Mountain areas. Both balances will be used for standardizing 500- and 1,000-lb test weights used by State agencies engaged in scale-testing activities and by commercial concerns engaged in the manufacture of conventional, or the development of new types of weighing scales and other force-measuring devices.

Improvement in Gage-Block Measurement. Two important improvements were introduced to speed calibration of gage blocks submitted by industry and Government agencies. For calibrations of lesser accuracy, measurement on a mechanical comparator has been substituted for the





Radio noise recorder (left) used to measure the noise power available from a standard antenna system. At right, antenna and equipment shelter for measuring atmospheric noise at Point Barrow, Alaska (p. 96).

more laborious interferometric comparison formerly employed. The comparator has two opposed sensing elements, one bearing on the upper surface of the gage and the other on the lower surface. Thus errors arising from imperfect seating of the gage on the anvil of the comparator are avoided. To give greater precision each gage is compared twice, the comparisons being with two different standard gages.

Gages requiring greater accuracy are calibrated by absolute interferometric measurements. To increase the efficiency of this method of calibration, a set of cards have been prepared, one for each nominal length of gage. These cards bear tables that enable the true length of the gage to be determined, after the fractional fringes have been found with almost no computation.

The introduction of these two improvements not only reduces the time required to calibrate a set of gage blocks but also enables the work to be done by personnel with less training. Formerly it took months of training to insure competence in the making of absolute interferometric measurements whereas now a less skilled person can be taught in a few weeks.

3.3. Calibration Services

The volume of calibration of electrical standards and measuring instruments has continued at a very high level, constituting a fee value of about $65,000. Over 2,000 electrical standards were tested, as well as over 500 instruments, whose calibration required about 11,000 determinations. A number of instruments submitted for test were copies of such instruments developed by the Bureau for its calibration program. This is a definite indication of the increased accuracy required by industry, a need that has resulted in the establishment of standardizing laboratories by a number of large manufacturing companies, and by the military organiza-

tions. The Bureau must continuously improve its standards and measuring procedures to keep ahead of such demands for higher accuracy.

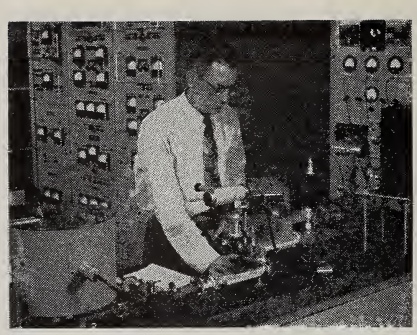
The United States leads all other countries in the mass production of machinery and mechanical components. A large proportion of these are to close fits and narrowly restricted tolerances. To maintain interchangeability as well as assure proper functioning of such parts it is necessary that the production and inspection be based on highly accurate dimensional standards and master gages. During the year calibrations and tests of such items for industry, and to some extent for Government agencies, involved some 4,173 precision gage blocks, 270 master thread gages, 59 plain gages, 1,700 thread measuring wires, 1,066 standardized instrument parts, and 57 miscellaneous items.

During the year, 1,494 liquid-in-glass thermometers, 112 resistance thermometers, 349 thermocouples and thermocouple materials, and 20 optical pyrometers and pyrometric lamps were calibrated for the public and state institutions. An additional 234 instruments, including 149 deep sea thermometers, were calibrated for other Government laboratories.

Formerly the Bureau individually calibrated large numbers of clinical thermometers for the Veterans' Administration for use in hospitals. Now, by the use of a statistically designed sampling plan, it has been found possible to ensure an adequate control of the accuracy of the thermometers by examining only a fraction of the total. During the past year, for example, it was necessary to test a sample of only 13,235 thermometers out of a total of 255,937 that were submitted.

Nearly 125 heavy water samples were analyzed for deuterium content in cooperation with research groups under the sponsorship of the Atomic Energy Commission. These samples were in the form of blood or water that had a deuterium concentration less than normal water or commercially-available heavy water. Forty representative samples of aviation gasoline were submitted by the Air Force for determination of their heats of combustion and for investigation of possibilities for correlating the results of such measurements with more easily measured properties of these fuels. About 170 viscometers were calibrated and 848 standard viscosity samples were distributed. Certification tests were made on one batch of *n*-heptane and 2 batches of isooctane reference fuels. Tests were made for Government agencies of 4 samples of lubricants, 3 gasolines, and 17 fuel oils.

Fifteen hundred radium sources totaling 10,980 milligrams and 263 cobalt-60 sources totaling 11,811 millicuries were calibrated during the year. Calibrations of radiological instruments included: 104 r-meters and other Radiac instruments, 382 photographic and chemical dosimeters, 42 special purpose radiological instruments, 16 cobalt-60 instrument-calibration ranges, and 3 tests of major items of X-ray equipment. Five neutron sources and six neutron survey meters were calibrated and eight foils were activated in the standard thermal neutron flux. Reference



Improved precision equipment, left, has been developed for calibrating waveguide-type attenuators at microwave frequencies (p. 99). At right is shown a primary standard of inductance that is also used to measure the high-frequency characteristics of magnetic materials (p. 99).

sources of radioactive cobalt-60 and strontium-90 were prepared for use on the atomic powered submarines U. S. S. Nautilus and Sea Wolf.

3.4. New Standard Samples

The establishment of 27 new standard samples brings to a total of about 575 the materials of certified properties, purity, or composition that are now available to science and industry. The new samples include a high *p*H standard, 3 samples of certified composition, 2 additional samples of rubber compounding ingredients, 7 radioactivity samples, and 14 new spectrographic standards.

The NBS standard *p*H scale is defined in terms of several fixed points in somewhat the same manner as is the international temperature scale. The primary standards are solutions whose *p*H values are only slightly affected by dilution or by accidental contamination with traces of acid or alkali from the walls of the container or from the atmosphere. The substances from which the standards are prepared are stable materials obtainable from the Bureau in the form of certified samples. In response to the need for a highly alkaline standard to increase the accuracy of high-*p*H measurements, a new standard consisting of a saturated solution of calcium hydroxide was developed. With this new standard and the five standards previously established, the NBS scale now covers the *p*H range 1.68 to 12.45 from 0° to 60° C.

The three new standard samples of certified composition include a white iron, a portland cement, and a heat-resisting cobalt-base alloy. Nine renewals of exhausted standards were also prepared and included 5 steels, 1 cast-iron, 1 aluminum-base alloy, 1 lead-base alloy, and 1 titanium dioxide.

With the two new rubber compounding samples, 13 standard samples of rubber compounding ingredients are now available. Two of the existing standards were exhausted during the year and replenished. The demand for standard samples of paper for calibration of carbon arc fading lamps increased 20 percent over 1955. A total of 3,695 samples for rubber

compounding and 473 samples of calibrated papers were issued for a total value of $11,968.50.

In response to demands growing out of the increasing use of radioactive isotopes in industry, medicine, and scientific research, the Bureau established seven new standard samples of radioactivity. Three new alpha-particle standards consisting of polonium-210 deposited on palladium on silver disks were developed. These standards, of great mechanical durability, have little or no alpha straggling and no beta component. Also produced or released for distribution were four new beta- and gamma-ray solution standards consisting of hydrogen-3, potassium-42, zinc-65, and tantalum-182. During the fiscal year, 900 standard samples of various radioactive isotopes were distributed.

The 14 spectrographic standard samples announced during the year include 6 stainless steels, 2 nickel oxides, and 6 zinc-base standards. This expanded spectrographic samples program is designed to meet the urgent need of industrial and Government laboratories for standards of this type. Also in demand are such standards as titanium and high-temperature alloys which are currently under development.

3.5. Testing for Government Purchase

The Bureau tests products for Government purchase only at the request of the agencies responsible for buying or using the specific items. The service is concerned principally with products such as cement, dry cells, lamps, and mapping cameras which are purchased under circumstances such that a single agency can effectively control the procurement for the entire Government. In addition small numbers of tests are conducted on a very wide variety of items to supplement the testing services of other Government laboratories. The entire operation in fiscal year 1956 amounted to $1.2 million which represented only about 9 percent of the total work done for other Federal agencies.

Cement. The Bureau conducts acceptance tests on cement purchased by the Federal Government for use in dams, locks, monumental public buildings, airfields, and other structures that are designed for high strength and very long life. Laboratories are maintained by the Bureau for this purpose in Allentown, Pa., Denver, San Francisco, and Seattle as well as in Washington, D. C. A mobile laboratory has been outfitted for physical testing of cement and is available for use in those areas where a considerable amount of construction is in progress and time schedules do not permit sending samples to the central laboratories.

A new sampling and testing plan for cement has been placed in operation. This plan, based on a statistical study of the quality of cement produced at the different mills, will furnish more information relative to the quality of the cement used with a reduced amount of testing. In 1956 about 30,000 samples were tested, representing approximately 15 million barrels of portland cement. In addition, tests were made on 4,900 hardened concrete specimens and on 550 aggregates. In localities

where the service was not available from other agencies, the engineering properties of 350 soil samples were determined.

Lamps. The contract between the Government (Federal Supply Service) and the suppliers of electric lamps specifies that the lamps shall comply with the applicable specifications, and that the necessary inspection and testing to determine compliance be performed by the Bureau. The tests are applied to all types of lamps including incandescent, fluorescent, and photographic flash lamps. During fiscal year 1956 samples inspected represented over 4,000,000 lamps, of which approximately 4.0 percent were rejected on initial inspection at the factories of the suppliers. Lamps of current suppliers started on life test totaled 4,416 and those rejected represented approximately 3.2 percent of those accepted on initial inspection.

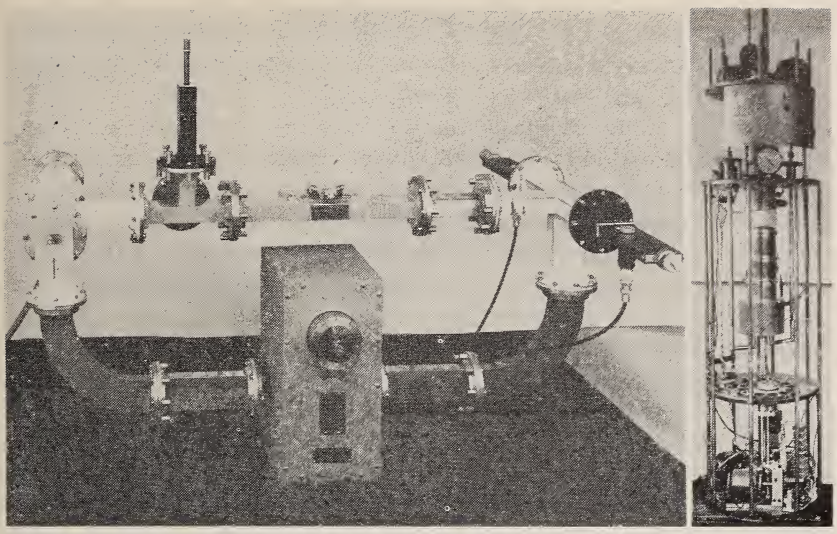
Mapping Cameras. The Bureau provides the only service available to the Government for the accurate calibration of airplane mapping cameras, measurement of the image-forming characteristics of optical systems, and accurate measurement of the refractive indices of optical media. Because final map accuracy depends upon exact knowledge of the performance of the lens as mounted in the camera, various Government mapping agencies require that cameras used by private contractors on Government projects be calibrated by the Bureau. During the year 40 cameras were calibrated for important mapping projects.

Organic and Fibrous Materials. A total of 5,583 items of organic and fibrous materials were tested for Government agencies in conjunction with their procurement or development programs. Typical materials and products tested were weather balloons, denture base resin, hose, electrical insulation, tires, plastic floor tile, linoleum adhesives, teletype tape, thermal insulating materials, and conveyor belting.

Building Materials. Much of the Bureau's testing of building materials is conducted for the purpose of obtaining design data and determining how a particular product can be used advantageously. During the year, however, 111 items ranging from masonry and roofing to fire extinguishers were tested for compliance with applicable Federal specifications. Thirty-six of these items, or about one-third, failed to meet the specification requirements, indicating the importance of testing in this area.

3.6. Assistance to Other Laboratories

The Bureau renders assistance to both Government and private laboratories in advising them as to methods and equipment. During the year a number of organizations, both public and private, that were planning to establish calibration laboratories sent their technical directors and supervisory scientists to the Bureau to discuss general problems of layout and facilities and to obtain information about the design and installation of equipment. Similar service was rendered in connection with testing laboratories. A special activity in this area is the joint operation by public and private agencies of the Cement Reference Laboratory.



A tunable frequency stabilizer, left, designed to operate over the useful range of any one waveguide size (p. 100). This equipment provides a signal source with a frequency stability of better than 1 part in 100,000 over a period of 1 hour. *Right:* A wide-temperature-range cavity for automatically measuring the high-frequency dielectric properties of insulating or semiconducting materials (p. 99).

Cement Reference Laboratory. In 1956, seventy-seven cement laboratories availed themselves of the cement testing program of the Cement Reference Laboratory. This laboratory, located at the National Bureau of Standards, is jointly supported by the Bureau of Public Roads, the Army Corps of Engineers, the American Society for Testing Materials, and the Bureau. The major part of the CRL work is accomplished through inspection visits to the numerous cement testing laboratories throughout the country. Upon request, cement laboratories are visited in the course of regularly arranged schedules that cover the field in a period of 2 to 3 years. An inspection includes observance of methods, inspection of the cement testing apparatus, verification of compression testing machines, and observance of facilities for curing test specimens. When needed, the inspector demonstrates the standard test methods. At the conclusion of an inspection, the inspector's data sheets are reviewed with an appropriate member of the inspected laboratory's staff, and recommendations are made. Subsequently, a detailed written report is issued to the proper supervising official. No certifications or ratings of laboratories are given, and the findings and the reports are confidential.

At intervals, the Reference Laboratory distributes a comparative test sample of portland cement to over 200 laboratories. A test sample enables a laboratory to ascertain how its test results compare with many other laboratories. The CRL has also maintained, for distribution on request, samples of its specially prepared material for calibrating the flow table apparatus for determining the percentage of water to be mixed with standard test mortars.

3.7. Special Tests

A wide variety of special tests were conducted for other Federal agencies. The following are typical examples. Air samples taken on the U. S. S. *Nautilus* during its 10-day submerged trial cruise were analyzed in the radon testing laboratory. Among the 616 chemical and isotope analyses for other Government agencies were analyses of hydrogen from blood samples to determine the deuterium content. These analyses are made for the Surgeon General's Office in connection with medical research on the assimilation of heavy water by people in normal health and by those in a condition of shock.

During the year the Bureau undertook a program of assisting the Veterans' Administration with preparation of specifications and making physical tests of hearing aids purchased for veterans with a service incurred hearing loss. Test equipment was assembled, and 142 hearing aids were tested for such factors as response-frequency characteristics and distortion. Also, it is planned to develop tests for hum pickup and temperature effects which will be incorporated in future specifications and tests.

At the request of the Federal Housing Administration, performance tests were conducted of heating and air-conditioning systems in a house of novel design. The house was first equipped with a special electric heating system (heating coils in coves around the walls) and reflective wallpaper and drapes. It was then altered to include a gas heating (ethylene-glycol) system; the roof was also insulated with reflective material. At the same time, a cooling system was installed with copper tubes in the coves serving both to warm the house in winter and cool it in summer. Heat transmission data useful for design purposes were thus obtained.

The Bureau conducted extensive evaluation tests of night air-sea rescue operations using powerful aircraft-mounted searchlights in conjunction with retroreflective materials attached to the clothing and gear of downed pilots. The results indicated that such equipment greatly improves the chances of rescue.

4. Cooperative Activities

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

Working largely as a collaborator in the area of codes and specifications, the Bureau seldom initiates work or promulgates a finished document. Nevertheless, it often makes a major contribution by providing methods

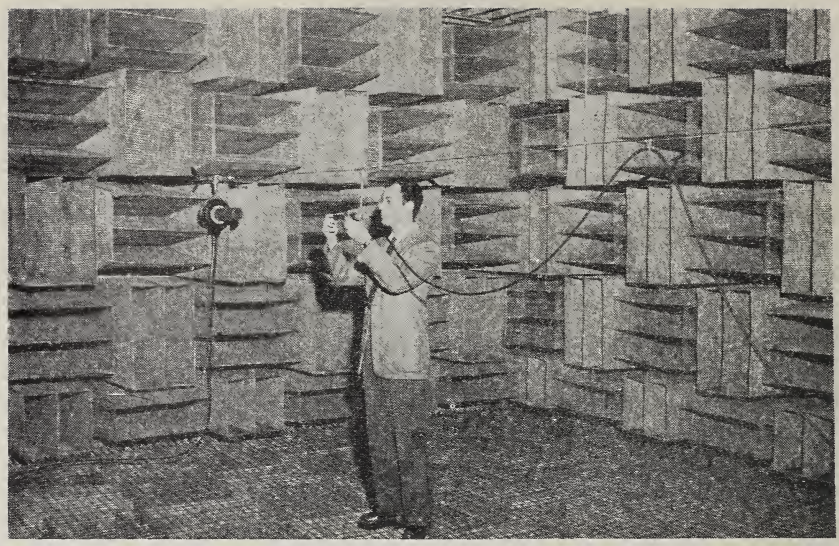
of test, basic scientific and technical information on properties of materials and related subjects, and standards of measurement without which no other standards are possible. Bureau staff members actively participate in national and international professional societies. This work greatly enhances the dissemination and utilization of NBS research, development, standardizing, and testing activities. Also, staff members are able to keep in close touch with technical and scientific advances elsewhere and to coordinate the standards and specifications used in industry with those employed by Government.

The Bureau's participation in many of the cooperative activities was implemented by membership of staff members on committees of national societies and other organizations concerned with standardization and related activities. In 1956 about 110 of these scientific and technical organizations were served by 1,300 committeeships held by Bureau personnel. About 30 percent of the committeeships were in the American Society for Testing Materials and 20 percent in the technical committees of the American Standards Association. The Bureau was represented on 20 boards and committees of the Federal Government by 84 committeeships, and on 22 committees of international organizations by 83 committeeships. Two hundred and eighty-five of the Bureau representatives held offices of their committees.

4.1. Federal Specifications

The Federal Government is the largest single purchaser of a large variety of materials and products. In order to provide standards and uniform procurement specifications for these materials, the General Services Administration has sought the assistance of NBS and other agencies by asking them to accept the responsibility for the preparation of procurement specifications and test method standards in areas in which they have competence. The Bureau has accepted responsibility for the preparation and maintenance of 180 Federal Specifications covering a wide range of materials and products. In the preparation of specifications, knowledge gained for research and development work undertaken for another purpose and from the testing of materials purchased by Government agencies is often utilized. Information concerning new developments and manufacturing practices obtained from cooperation with technical societies is also used in keeping specifications up to date. In fact, this familiarity with the work of the technical societies makes it possible for industry specifications to be readily evaluated and often adopted as Federal Specifications.

In addition to preparing assigned specifications, the General Services Administration requested the Bureau to review approximately 500 proposed specifications prepared by other agencies to determine their acceptability as procurement documents. Most of the changes suggested concerned the procedure for evaluating the material or product.



Newly built anechoic chamber for testing and calibrating acoustic instruments. Glass fiber wedges that line walls, ceiling, and floor absorb about 99 percent of incident sound energy (p. 109).

4.2. Methods of Test

The development of test methods is one of the statutory functions of the Bureau. In connection with Federal Specifications, every effort is made to develop general methods that will be applicable to groups or classes of products or materials rather than to individual items and to utilize those that are standard with industry and technical groups to the greatest extent practicable.

The Bureau has accepted the responsibility for the development and maintenance of test methods for adhesives, plastics, rubber, paper, leather, textiles, nontextile resilient floor coverings, paints, cement, detergents, wire and cable, and laboratory glassware. These methods, issued by General Services Administration as Federal Standards, include approximately 1,200 individual test methods and analyses as well as sampling plans and definitions that are in common use in industry. In specifications for specific products and materials, it is only necessary to make appropriate reference to these standards to assure suitable and uniform tests for the evaluation of the product or material. Continuous revision of old methods and development of new ones are necessary to keep the standards in step with rapidly changing technology.

4.3. Industry Specifications

In order that purchase specifications, standards, and methods of test have a real meaning and fulfill the purpose for which intended, Federal and other specifications must be coordinated and brought into agreement with those used by other groups and the industry concerned. The Bureau has continued its active participation in the activities of technical

societies, industrial organizations, and standardizing groups preparing such specifications. During the past year NBS members held about 400 committeeships in the American Society for Testing Materials and approximately 260 in the American Standards Association.

In cooperation with ASTM Committee D–11, a procedure was developed for interlaboratory studies of methods of test for rubber. The Bureau contributed to the revision of the book "Reagent Chemicals, American Chemical Society Specifications," by cooperating with the Society in devising suitable standard test procedures for determining the quality of reagents. Assistance was given the Society of the Plastics Industry in the preparation of a standard for polyvinyl chloride plastic sheet that is widely used in the construction of corrosion-resistant ducts, ventilating equipment, and chemical plants. Because NBS Circular 31, "Copper Wire Sizes," serves the copper wire industry as the standard for the determination of wire sizes and other properties, the Committee on Wires for Electrical Conductors of ASTM requested that the circular be revised and brought up to date. The 4th edition of the circular was published in January 1956.

Working with the Illuminating Engineering Society, the Bureau played a major role in the development of a dirtometer which measures the rate at which dirt accumulates in space where lighting equipment is used. Important assistance was given to a committee of the Society of Automotive Engineers in the solution of production problems for plastic lighting panels and in the preparation of an industry guide for their manufacture. The Formed Steel Tube Institute was assisted in the preparation of a specification to be used by the industry in measuring the surface roughness of seamless steel tubing. At its annual meeting the American Petroleum Institute favorably considered the Bureau's proposal to change the class of thread on sucker rod joints to that specified in NBS Handbook H28.

Standard type fluorescent lamps, widely used in the factory and office for economical reasons, are less favored for restaurant and home lighting. The rendition of food and complexion colors by such lamps is unnatural to the degree that the food sometimes appears unappetizing and people unhealthy. However, improved color rendition is now possible with deluxe type fluorescent lamps which have been developed to supply a greater proportion of long-wave (red) energy. The Bureau has cooperated with the Illuminating Engineering Society in developing an index of color rendition for appraising these lamps.

Also during the past year, a revised and enlarged edition of the compilation of "Phase Diagrams for Ceramists" was completed and published by the American Ceramic Society. The edition contains 801 phase diagrams, the work of 331 scientists, a glossary of 50 terms peculiar to phase studies, and a discussion of the interpretation of phase diagrams. The compilation is a standard reference source used in ceramic schools and research institutions throughout the world.

4.4. Cooperative Research With Industry

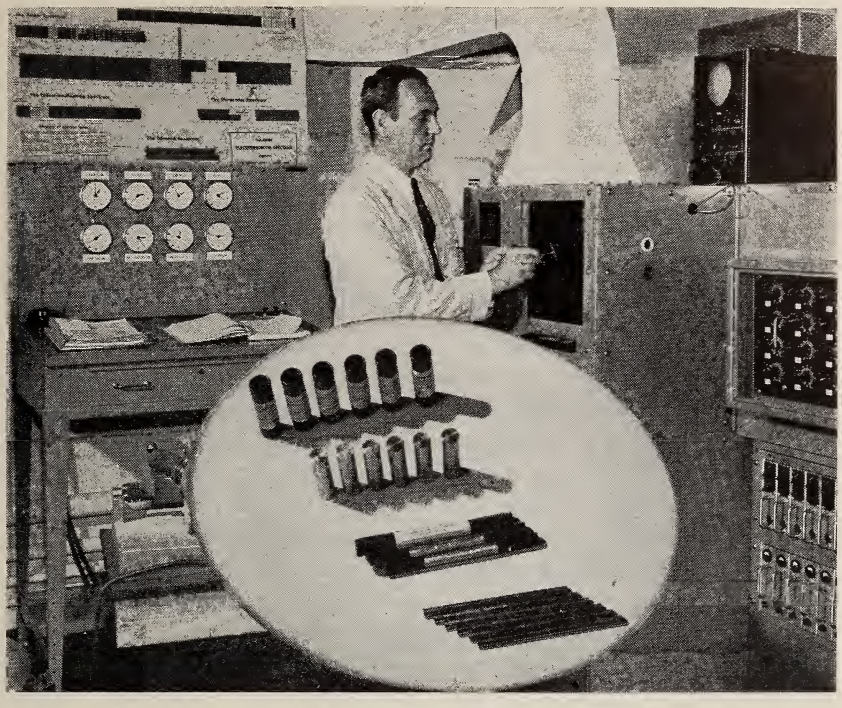
Many developments of scientific and technological significance have resulted from the Bureau's Research Associate Plan, a cooperative program with American industry. This plan is an arrangement whereby technical, industrial, and commercial organizations can support work at NBS on projects that are of special interest to them, yet of sufficient general interest to justify use of Government facilities. Research associate projects must not only be of value to all groups concerned in the particular field and to the Federal Government, but must also be important from the standpoint of the Nation's sum total of technologic knowledge.

Since the Research Associate Plan was established in 1920, about 180 organizations and individuals have supported cooperative research at the Bureau. At present 12 groups are supporting some 36 research associates at NBS. Research associate projects active during the past year are as follows:

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

The results of the projects supported by the Research Associate Plan become a part of the public domain and are published by the Bureau. Whereas many projects are specific in nature and of short duration, others, such as those sponsored by the Portland Cement Association and the American Dental Association, are directed toward fundamental research and have been active for a number of years. During 1956 accomplishments of the program, reported in section 2, included a comparator for measuring dimensional accuracy of dentures (p. 57), phase equilibria studies of cement (p. 65), standard X-ray diffraction patterns of many new materials (p. 67), and the performance of panel insulated with reflective membranes (p. 73).

Closely paralleling the Research Associate Plan is another important area of cooperation between the Bureau and industry. This program was authorized in 1950 by Public Law 619 (81st Cong.) in which ". . . The Secretary of Commerce is authorized to accept and utilize



A total of 27 new standard samples were established during the year to meet the ever increasing needs of science and industry (p. 112). The tool-steel standards, inset, are among the 14 recently announced spectrographic standards. The homogeneity of the new samples is measured in the sensitive photoelectric spectrometer shown.

gifts or bequests of real or personal property for the purpose of aiding and facilitating the work authorized herein . . . ." The arrangement thus permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public.

During the past year some 17 projects were supported by gifts from 14 organizations. They were as follows:

Donor	*Field of Activity*
Aluminum Company of America	Reflective thermal insulation
American Instrument Company	Vapor liquid phase relations
American Iron and Steel Institute	Spectrochemical standard samples, ship steel research, and design stresses in reinforced concrete
American Society for Testing Materials	Testing light and color
Corrosion Research Council	Fundamental reaction of surface crystals
Georgetown University	Physiological research, and variable heartpump
International Nickel Company	Effect of nickel on thermal conductivity of ferritic steel
National Electrical Manufacturers Association	Refrigerator safety

Edward Orton, Jr., Ceramic Foundation	Mechanism of plasticity in clays
Radio-Electronic-Television Manufacturers Association.	Standards of color television
Sugar Research Foundation	Invert sugar solutions
Welding Research Council	Stress corrosion of stainless steel
Anonymous	Phenomenon of crystallization
Anonymous	Ether peroxides

4.5. Weights and Measures

The translation of the national standards of length and mass and of the derived standards of capacity to the channels of industry and trade are matters of great economic importance to the producing, manufacturing, processing, and distributing agencies of the Nation, and to all purchasers of commodities and services. The Congress has left to the individual States the responsibilities of regulating commercial weighing and measuring devices and controlling commercial transactions involving quantity. The Bureau cooperates with the States in promoting uniform, effective, and efficient weights and measures supervision through uniform laws, standards, methods of inspection, and administrative procedures. Thus, the national standards of measurement are translated into everyday use. The coordination of this cooperative program rests in the Bureau's Office of Weights and Measures. Commerce, business, and consumers are becoming increasingly aware of the importance of adequate weights and measures administration and, through such administration, accurate weighing and measuring. As a result, greater demands are made upon the Bureau each year for assistance and advice in this field.

The NBS Office of Weights and Measures plans and conducts several integrated programs of assistance to States and local jurisdictions and to business and industry. The range of consultative services is broad, embracing the drafting of new legislation; the development of regulations, including technical specifications and tolerances for devices; guidance in administrative procedures; design of testing equipment; and preparation and distribution of recommended testing methods. Also included under the administration of the Office is the physical adjustment of State reference weights and measures standards.

During 1956 the Bureau stepped up its on-the-job training program for technical personnel from State governments. Upon request the Bureau studied weights and measures activities in the State of Pennsylvania and the Commonwealth of Puerto Rico and made recommendations on amendments of statutes, personnel and equipment requirements, and general administrative procedures. Implementation of the Bureau recommendations is now underway and is expected to result in improved services to these communities at lower costs.

One of the principal tools of the Bureau in its effort toward nationwide uniformity in weights and measures administration is the National Conference on Weights and Measures sponsored by NBS since its inception in

1905. The 41st Conference, held in Washington in May, was attended by almost 500 delegates, representing 40 States, the District of Columbia, Puerto Rico, the Philippine Islands, and all phases of business and industry associated directly with weights and measures supervision. The Conference concerns itself with the technology of weights and measures supervision and adopts and recommends to the States model laws and regulations. Among the more significant actions by the 41st Conference was the adoption of a tentative code for liquefied-petroleum gas liquid-measuring devices. This action represents the first effort to develop a set of specifications, tolerances, and regulations for these commercial measuring devices which are playing an increasingly important role in the Nation's economy.

The Conference heard a report from the Bureau in which model report forms and reporting systems were recommended to State and local weights and measures officials. The system is devised not only to make possible uniform and orderly reporting of individual activities, but also to lead an inspector into proper testing procedures. Among other topics covered during the 5-day meeting were prepackaged commodities (a commercial marketing technique of growing significance); quantity control in packages; labeling requirements under the Federal Food, Drug, and Cosmetic Act; and meat packinghouse products. A completely new automatic prepackaging scale was also demonstrated to the delegates.

Previewed during the Conference was the second weights and measures film, "Testing Mass Standards by Substitution," produced by the Bureau as a training film for weights and measures officials. This 22-minute, 16-mm, color and sound film portrays the importance of precision in the testing of reference and field standards. Methods of test are explained and demonstrated. These include the computation of the actual value of a laboratory standard and the determinations of the acceptability of a field standard within limits of allowable error. In addition to its application to weights and measures administration, this training film will be useful to educational institutions, laboratories, and industries interested in precise weighing. Prints of the film are available on loan, without charge, or they may be purchased at nominal cost.

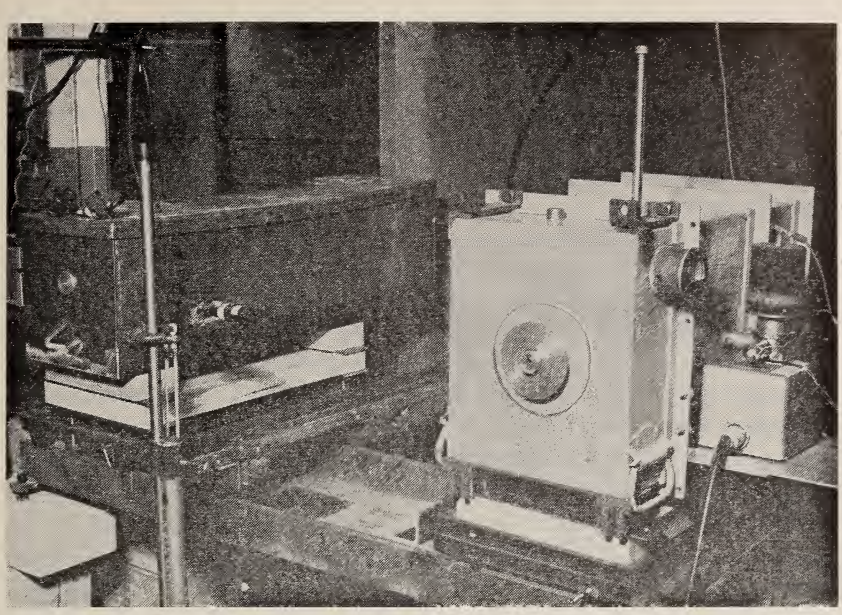
With the rapid engineering advances in the instruments of weighing and measuring, the enforcement official is finding that technological approaches must be found for the solutions to the many problems encountered. It is in this area that NBS is uniquely qualified to be of assistance in the field of weights and measures administration. Close contact with State and local weights and measures officials is maintained and intimate understanding of their problems is gained through NBS staff participation in regional and State conferences. Bureau personnel also regularly visit the administrative offices and laboratories of weights and measures jurisdictions and State and local people spend time in the laboratories of the Bureau.

4.6. Radiation Protection and Measurements

With the rapidly expanding uses of radiations and applications of atomic energy, the work of the National Committee on Radiation Protection has assumed greater importance and is receiving more widespread attention. The Committee is sponsored by NBS and governed by representatives of 15 participating organizations; its membership is composed of over 100 leading scientists in the fields of radiation and related interests. Studies are made of the problems involved in the use of radiations, and the resultant recommendations are published as NBS Handbooks. During the year, two such recommendations were issued: (1) Handbook 60 (revision of H41) which brings up to date the protection requirements for radiation workers and the public in medical and industrial X-ray installations; and (2) Handbook 61 which presents the results of an intensive study of the problems involved in the legislative regulation of radiations. The latter recommendation answers a growing need for guidance in the development of radiation control by Federal, State, and municipal agencies and can be influential in the establishment of uniform control throughout the country. Some of the new studies recently undertaken by the Committee are the incineration of radioactive wastes, protection in the industrial and medical applications of intense high-energy electrons, and permissible irradiation levels for emergency conditions.

For many years, the NCRP has been looked to for primary guidance in this country in matters of radiation protection, and many of its recommendations have been adopted internationally. Because of its recognized leadership, the radiological groups in this country recently recommended an extension in the scope of the Committee's activities to include problems of radiation units and measurements for clinical and biological applications. This major broadening of interests has been accomplished with the establishment of four new subcommittees to recommend standards for measurement of radioactivity and radiological irradiations. The subcommittee structure established by the Committee was recommended for adoption by the International Commission on Radiological Units during its April 1956 meetings in Geneva, and as a result the international group has reorganized its Committee structure along similar lines.

Important decisions relating to the measurement and safe use of radiations were reached at the triennial meetings of the International Commission on Radiological Units and the International Commission on Radiological Protection, both of which were held April 2–11, 1956, in Geneva, Switzerland. In a move to achieve greater international uniformity of X-ray measurements, the ICRU initiated a project in which basic equipment, to be developed by the National Bureau of Standards, will be loaned to countries that lack primary standards of their own. Another highlight of the ICRU meetings was a discussion of problems raised in translating exposure dose measurements made in roentgens to the unit of absorbed dose, the rad. The principal outcome of the ICRP deliberations was a revised set of recommendations for permissible levels



International comparison of X-ray standards. Swedish free-air ionization chamber (left) and Bureau's primary standard (right) mounted on rails so they may be placed in turn before the same X-ray source (pp. 34 and 124).

of ionizing radiation to which humans may be exposed. The Bureau continues to take an active part in the work of the two commissions, in which five NBS scientists now hold membership. One of these was recently renominated for an additional 3-year term as chairman of ICRU.

4.7. Educational Program

Education and training at the Bureau are directed toward improvement of the skills and knowledge of the staff. Designed to increase the efficiency of the staff's assigned duties and to prepare them for increased responsibility, this program includes lectures, courses, seminars, and colloquia. These fall into one of the following categories depending on the subject matter; NBS out-of-hours, NBS in-hours, or NBS-university sponsored out-of-hours.

The flexibility of the program serves the varied and often changing needs of the research staff. Highly trained scientists may present broad surveys of areas of research, detailed treatment of a new or specialized area of research, or the practical application of a needed work technique. Research workers from other Government agencies may enroll in NBS classes if the knowledge gained will assist them in their official duties.

Since the establishment of the educational program in 1908 over 12,000 registrations have been recorded; 170 graduate degrees have been awarded by 35 different universities partly on the basis of credits obtained or thesis

work carried on under the Bureau program. During the past year there were 1,293 registrations in 48 courses offered at the Washington and Boulder Laboratories. In addition weekly staff talks and demonstrations by specialists in various technical fields were given from September through June, and five seminar groups met regularly on a weekly or biweekly basis.

Approximately 140 college students were enrolled in the summer Junior Scientist-Engineer program which is designed to prepare especially well-qualified students for future professional careers at the Bureau. The students participated in a program of orientation, on-the-job training assignments, and discussions with advisers from the technical divisions.

During the past year the National Research Council-National Academy of Sciences Postdoctoral Research Associateships were continued and five associates were appointed in the following fields: Atomic and molecular physics, heat, general physics, sound, and mathematics.

4.8. International Cooperation

Through active participation in the work of international standardizing bodies and professional societies, the Bureau is contributing to the establishment of internationally recognized standards and practices of importance to American industry, technology, and science. Such standards facilitate international trade and the exchange of data on the properties and physical constants of materials.

During the past year, for example, a member of the NBS staff presided at the meeting (in Paris, France) of the Technical Committee on Plastics of the International Organization for Standardization. The leaders of the United States delegations to meetings of the Technical Committee on Rubber (at Dusseldorf, Germany) and on Textiles (Southport, England) of the same organization were from NBS. These meetings and earlier meetings have resulted in no less than 63 standards relating to test methods and nomenclature for plastics (19), rubber (10), and textiles (34). Many of these standards are well advanced internationally. Three of the textile standards are cotton fiber testing methods whose international recognition is urgently desired by the cotton industry of the United States. An outstanding accomplishment at the meeting on textiles, which was attended by delegations from 20 nations and three international textile associations, was a unanimous decision to adopt one system for expressing the "size," or weight-length relation, of all yarns and threads. This universal system is based upon the weight in grams of 1,000 meters of the yarn, called the "Tex." The need for one system has been recognized for many years and the way is now clear for the system to be introduced into the technical literature and into industrial use.

NBS personnel participated actively in the preparation and review of documents for consideration by the International Radio Consultative

Committee (CCIR) of the International Telecommunications Union at its next Plenary Assembly. In this connection considerable assistance was given the Telecommunications Policy Staff of the State Department. Staff members contributed to groups studying the following subjects, among others: Standard frequency transmissions and time signals; automatic monitoring of occupancy of the rf spectrum; accuracy of field-strength measurements by monitoring stations; and problems of manmade interference.

Other international meetings in which about 75 NBS members took part are: International Antarctica Conference under the auspices of the Special Committee for the International Geophysical Year (France); Conference on Low Temperature Physics under the International Union of Pure and Applied Physics (France); International Union of Pure and Applied Chemistry (Zürich); Congress of Algebraic Topology (Mexico); International Organization for Standardization (England); International Commission on Radiological Protection (see 4.6 above); Western Hemisphere International Geophysical Year Conferences (Brazil); International Commission on Illumination; Observation of Solar Eclipse in the Anglo-Egyptian Sudan; International Conference on the Peaceful Uses of Atomic Energy (Geneva); International Union of Leather Chemists' Societies (Stockholm); Conference on Nuclear Reactions (Amsterdam); Ninth General Assembly of the International Astronomical Union (Dublin); and Meetings of the Directors of the Building Research Organizations of the British Commonwealth.

The Bureau has, since its establishment in 1901, welcomed the cooperation of foreign scientists and students in its research and standardization programs. Under the various international fellowships and Point 4 programs, foreign nationals have worked with Bureau scientists on problems in the physical sciences of mutual interest to their countries as well as to the United States. During 1956 the Bureau received more than 1,000 foreign trainees and visitors, many of whom spent time in NBS laboratories as guest workers. Total inquiries for assistance by foreign correspondence are estimated at 7,000.

Recently the Bureau was requested by the International Cooperation Administration (Point 4 activity) to assist in training foreign nationals who will assume important responsibilities in newly created standardization laboratories in their respective countries. Effective standardization will, for example, enable these countries to better judge the quality of their imports. At the same time they will be able to classify their exports (rubber, waxes, fabrics, ores, etc.) into quality groups and hence realize greater returns than is possible otherwise.

The nature and scope of this special program are indicated by the following examples:

- Two foreign officials were trained, by staff members of the NBS paint and steel laboratories, in the use and performance of protective coatings as means of preventing corrosion.

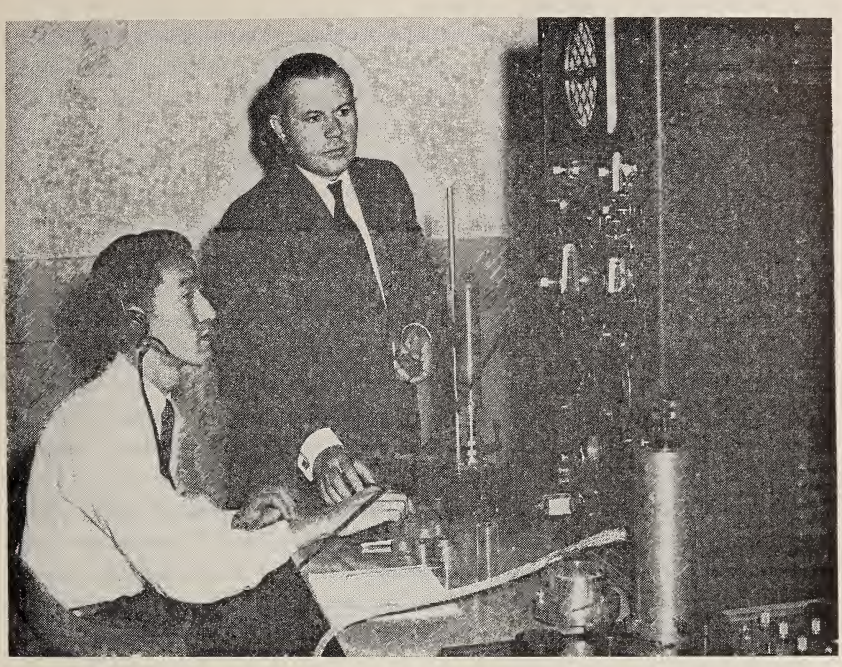
- A machine shop foreman from an underdeveloped nation spent several months at the Bureau during which time he made unusual progress not only in mechanical skill but in leadership as well. For example, he achieved the skill of making precision measurements necessary to grind and lap a four-inch plate of steel flat to 1/100,000 inch and to lap and hone an internal cylindrical bearing to rigid specifications.
- Working in the NBS electrodeposition laboratory, a foreign specialist conducted research on the composition of cathode films, a subject of practical significance in electroplating technology. He will continue his research when he returns to the staff of his national university. Another trainee (from another nation) gained skill in the recently NBS developed process of "electroless" plating, which greatly facilitates nickel plating of intricate shapes and interior surfaces of tubular forms.
- A number of foreign leaders were assisted in their efforts to develop better housing and more effective usage of building materials.
- A guest scientist from the Electro-Technical Laboratory in Tokyo will spend 1½ years at the Bureau working on impedance, attenuation, voltage, and other quantities at radiofrequencies.

4.9. Other Cooperative Activities

Safety Codes and Building Research. In the field of building, plumbing, and safety codes, cooperative work with representatives of organizations sponsoring model codes has continued to be effective. During 1956 assistance was given to the following municipalities in the preparation or revision of their building or plumbing codes: Clifton Forge, Va.; Barre, Vt.; Princeton, W. Va.; Plymouth, Wis.; Phillipsburg, Pa.; Buoy, Tex.; Port Allen, La.; Imlay City, Mich.; Forty Fort, Pa.; Kane, Pa.; District of Columbia; Columbiana, Ohio; Girard, Ohio; Northfield, Minn.; Newton, N. J.; San Diego, Calif.; Freeport, Ill.; Savannah, Ga.; and Dayton, Ohio.

The Bureau, either as sponsor or cosponsor, assisted in the preparation or revision of a number of model codes including: The American Standard Building Code Requirements for Minimum Design Loads for Buildings; the National Electrical Safety Code; the Code for Protection Against Lightning; and the Code for the Protection of Eyes, Heads, and Respiratory Organs of Industrial Workers. The Code on Minimum Design Loads for Buildings was published by the American Standards Association during the year.

The Bureau assists a variety of Government agencies, including State, county, and city agencies, in the solution of their problems relating to building construction, equipment, and materials. For example assistance was given to the Brookhaven National Laboratories in selecting materials and in the design of the concrete base for an alternating gradient synchrotron. The base design called for several special features; it had to be free of differential movements and constructed of materials with an unusual degree of dimensional stability. An essential feature is the avoidance of differential movements of the base and an unusual degree of dimensional stability of the materials. At the request of the Office of Chief of Engineers, the Bureau participated in investigations to determine the cause of structural failures of the reinforced concrete girders in



A guest worker from Japan is instructed in a method for measuring magnetic properties of powdered iron specimens by the use of a Maxwell bridge. This is part of his training in high frequency methods at the NBS Boulder Laboratories (p. 126).

a number of widely separated buildings. As part of a larger program on the testing of protected metals (against weathering and fire) an NBS representative visited three Air Force Bases in Alaska to evaluate protected metals in Arctic climates.

Other advisory services included a survey of the Wind Cave Elevator for the National Park Service; safety recommendations for the monorail car which carries passengers through the tunnel connecting the Senate Office Building with the Capitol; discussions with the Capitol architect on the possibility of using moving platforms or moving sidewalks between the Senate Office Building and the Capitol; assistance in preparing a justification for a new elevator in the Washington Monument; and discussions with the National Park Service on the possibility of a freight elevator to serve the lunchroom in Mammoth Cave, Kentucky. The Bureau assisted the Census Bureau in devising a method for cooling their electronic computer system, and prepared a report for the Navy on the hazards of handling liquid oxygen. Conferences were also held with the Department of Agriculture on refrigerated trucks and trailers, the General Services Administration and the Commodity Standards Division of the Department of Commerce on heating and air-conditioning equipment, and the Office of Chief of Engineers on problems of water condensation in building construction.

As an active participant in the Federal Construction Council, the Bureau gave assistance to task groups assigned to study problems of plumbing, windows, space allowance for office buildings, ceiling heights in office buildings, roof decks, built-up roofing, cooling towers, evaporative condensers, and other problems. Assistance was also given to the National Research Council in the formation of a committee on fire research and in studies of a number of technical problems relating to building design, construction, maintenance, and operation.

Heat and Temperature Measurements. In an effort to correlate the measurements in different laboratories and improve calorimetric techniques, the Calorimetry Conference was established a few years ago. In adapting a plan to distribute to participating laboratories highly purified substances for intercomparison of heat-capacity measurements, the Conference asked the Bureau to prepare and package the materials because of its unique facilities and experience in working with substances of high purity. Distribution of the materials to both national and foreign laboratories has now been accomplished. Also, heat-capacity measurements have been made on these substances at the Bureau, and the results have been published in scientific journals for use in the intercomparison of results or in the calibration of apparatus by other laboratories.

Because of the inaccuracies that exist in the various "accepted" helium vapor pressure scales of temperature, the Bureau undertook the precise calibration of a magnetic thermometer against the different scales. The results, presented at the Paris Low-Temperature Conference in September, assisted the Conference in its interim proposal for a revised low-temperature scale for future work. Though NBS measurements favored one of the two most widely "accepted" scales, the precision of vapor-pressure measurements at present is not high enough to remove all doubt about the correct choice.

Standards for Fuel Gas. In recent years the fuel-gas industry, acting through the American Gas Association, has emphasized the need for a standard for the calibration of recording calorimeters used to measure the heating-value of natural gas and similar fuel gases. Because such gases are bought and sold on the basis of their heating value, accurate measurement of this property is important for economic as well as for technological reasons. During the year an arrangement has been completed whereby the American Gas Association will procure cylinders filled with a purified natural gas (essentially methane), deliver them to the Bureau for certification of the heating value of the gas, and then distribute the cylinders to users—largely fuel-gas distributors and public utility laboratories—for use as standards. In this way the Bureau will be able to render a significant service with a minimum expenditure of time and effort in the mechanics of procurement and distribution. Certification will begin early in fiscal year 1957.

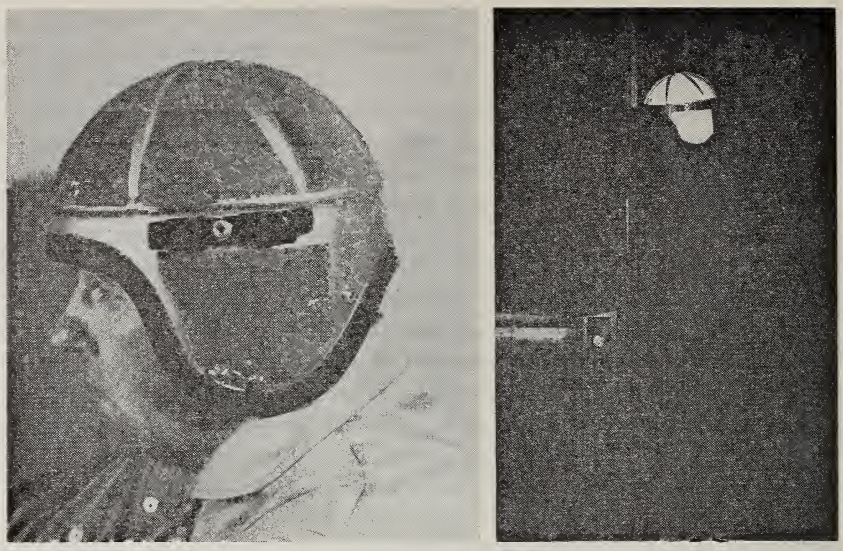
Dental Materials. The dental research program at the Bureau is carried out in cooperation with the American Dental Association and the Dental Corps of the Armed Services and the Veterans' Administration. A large part of the work is undertaken to provide advisory service to these agencies in the purchase and use of dental materials and equipment. During the year assistance was given to the Armed Forces Medical Procurement Agency in the development of a method for testing the eccentricity of dental rotating diamond instruments and to the National Naval Medical Research Institute in evaluating an air turbine dental handpiece and determining the dimensional accuracy of dentures.

Fluorescence methods developed at NBS were employed in cooperation with the National Naval Medical Institute in a comparison of natural and artificial caries (decay) of teeth. X-ray diffraction studies of lysine-deficient rat bone were made to supplement a study of bone growth by the National Institute of Dental Research. Assistance was given to the dental corps of the Armed Services in training dental officers in research methods and use of dental materials. This was done through training officers stationed at NBS, through lectures to groups who visited the Bureau, and through lectures given as a part of the curriculum of the Army and Navy dental schools. Lectures and demonstrations were also given at other dental schools and many meetings of professional dental groups.

Applied Mathematics. The Bureau maintains one of the principal facilities to which other Federal agencies turn for assistance in the solution of mathematical problems. One important aspect of the Bureau's work lies in the fact that coding for electronic computation is done not only for the Bureau's own machine, SEAC, but also for NORC, UNIVAC, and IBM 704 at the request of other agencies. Among the many problems studied during the past year were the solution of equations arising in a reactor design problem, application of the Monte Carlo method to radiation diffusion, award of contracts by linear programing, flood control problems, cost accounting operations, and the stability of supported plates.

A form of sequential test procedure was worked out for use in experiments on ship steel plates for the Bureau of Ships—NRC Ship Steel Committee. A testing order was prescribed so that after only a little more than a third of the experiment was run the results could be analyzed and, if necessary, the over-all plan modified to concentrate attention on the most troublesome factors. This is but one of the Bureau's ever growing list of modifications of standard statistical experiment-design procedures.

The Bureau also rendered major services to the U. S. Geological Survey, the Diamond Ordnance Fuze Laboratories, and the Naval Ordnance Laboratory on statistical aspects of the design and analysis of experiments and tests. For example, an experiment was planned for



Extensive studies were made of retroreflective materials as a means of locating downed pilots in night-sea rescue operations (p. 116). Retroreflectors applied to pilots' helmets, for example, return bright beams of light when struck by the powerful searchlights used by search aircraft. These markers may also be applied to other gear, such as life rafts and life vests.

the Diamond Ordnance Fuze Laboratories where it was desired to conduct full-scale field trials for studying the simultaneous effects of seven variables on the behavior of an ordnance device. An investigation involving all combinations of these variables would have required 2,592 trials. However, use of an experimental plan proposed by the Bureau resulted in a reduction of 75 percent in the number of necessary field trials to adequately investigate all seven factors.

At the request of the Office of Naval Research, Bureau scientists visited and conferred with officials of the Aerojet Corporation at Azuza, California, on various aspects of an experimental program being carried out under the sponsorship of the Navy. A report including recommended improvements was made to the Office of Naval Research to aid them in the future development of this program.

Engine Laboratory Discontinued. During the year, the Bureau discontinued work on full-scale multicylinder engines. The decision was based on careful consideration of the small amount of work of this kind now required by other Government agencies, the nature of the work in relation to other Bureau activities, and the critical need for the space involved by other projects of greater importance. The engine laboratory was started in World War I to aid the then infant automobile and aircraft industries. With the tremendous growth of these industries they now support their own research, testing, and development programs.

This decision does not change the Bureau's activities in regard to maintenance of the standards for measurement of octane number, improvement of methods of measurement, and other standardization work involving fuels and lubricants. An example of the kind of work to be continued is afforded by the investigation of the effect of altitude on measurement of octane number. This work conducted in 1955 has resulted in a new set of correction factors that have been recently incorporated in the standard ASTM procedure for measurement of octane number.

Radio Propagation Services. An important part of the regular services provided to the public and to other Government agencies is the prediction of the variations to be expected in communication characteristics, and the collection, analysis, and distribution of ionospheric data on a national and international basis. The selection of the best sky-wave frequencies for communication purposes for a given transmission path depends upon the time of day, season of the year, phase of the sunspot cycle, length of the path, location of the path, as well as the conditions prevailing in the ionosphere over the path. This predictions work is a direct continuation of the effort made during the war to provide the Armed Services with the latest available radio propagation information in usable form. These predictions are widely used by organizations interested in short-wave radio communications, including the Armed Services and other U. S. Government agencies, numerous scientific and commercial organizations, and foreign governments. Because they are used to plan frequency assignments and utilization in worldwide radio communications, errors in prediction may result in poor communication for the user or inefficient use of the limited radiofrequency spectrum available, with concomitant serious military or economic losses. Regularly received ionospheric sounding data together with indices of solar activity received from associated solar observatories are used in preparing advance predictions of optimum frequencies for long-distance communication throughout the world. These predictions are prepared for each month and are published three months in advance (see appendix 5.6, page 144).

Besides the gradual changes in ionospheric characteristics with season and sunspot number, short-time disturbances associated with magnetic storms at times seriously interfere with radio communications. These disturbances are especially common in the important North Atlantic and North Pacific regions. Two radio warning services are therefore operated for these regions. By observation of solar activity, disturbance of the earth's magnetic field, and radio operating reports, the Bureau is able to issue short-term warnings in anticipation of such disturbances. Advance forecasts for 1 to 24 days ahead were issued regularly on a semiweekly basis, and medium-term forecasts for 24 hours ahead were made once a day. Short-term forecasts for a 6-hour period were broadcast regularly from radio station WWV in Beltsville. Md., and from WWVH in Maui, Hawaii.

5. Appendixes

5.1. Organization of the National Bureau of Standards*

ALLEN V. ASTIN, *Director*

Associate Director for Chemistry
WALLACE R. BRODE

Associate Director for Physics
ROBERT D. HUNTOON

Associate Director for Testing
A. T. MCPHERSON

Associate Director for Planning
NICHOLAS E. GOLOVIN

Assistant Director for Administration
R. S. WALLEIGH

Director Emeritus
LYMAN J. BRIGGS

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

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

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

OPTICS AND METROLOGY, I. C. GARDNER, *Chief*

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

HEAT AND POWER, F. G. BRICKWEDDE, *Chief*

Temperature Physics, J. F. SWINDELLS
Thermodynamics, C. W. BECKETT
Cryogenic Physics, R. P. HUDSON
Rheology and Lubrication, J. F. SWINDELLS, Acting
Engine Fuels, F. L. HOWARD

ATOMIC AND RADIATION PHYSICS, L. S. TAYLOR, *Chief*

Atomic Physics Laboratory

Spectroscopy, W. F. MEGGERS
Radiometry, E. K. PLYLER
Mass Spectrometry, F. L. MOHLER
Solid State Physics, H. P. R. FREDERIKSE
Electron Physics, L. L. MARTON
Atomic Physics, L. M. BRANSCOMB

*As of September 1956.

Radiation Physics Laboratory, H. O. Wyzkoff

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

CHEMISTRY, E. Wichers, *Chief*

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

MECHANICS, W. Ramberg, *Chief*

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

ORGANIC AND FIBROUS MATERIALS, G. M. Kline, *Chief*

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

METALLURGY, J. I. Hoffman, *Chief*

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

MINERAL PRODUCTS, I. C. Schoonover, *Chief*

Engineering Ceramics, M. D. Burdick
Glass, C. H. Hahner
Refractories, S. Zerfoss
Enameled Metals, W. N. Harrison
Concreting Materials, R. L. Blaine
Constitution and Microstructure, H. F. McMurdie

BUILDING TECHNOLOGY, D. E. Parsons, *Chief*

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

APPLIED MATHEMATICS, E. W. Cannon, *Chief*

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

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

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

OFFICE OF PUBLICATIONS, Wallace R. Brode, *Chief*

OFFICE OF WEIGHTS AND MEASURES, W. S. Bussey, *Chief*

OFFICE OF BASIC INSTRUMENTATION, W. A. Wildhack, *Chief*

OFFICE OF TECHNICAL INFORMATION, W. R. Tilley, *Chief*

ADMINISTRATIVE DIVISIONS

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

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

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

Cryogenic Equipment, R. B. Jacobs
Cryogenic Processes, B. W. Birmingham
Properties of Materials, R. J. Corruccini
Gas Liquefaction, V. J. Johnson

RADIO PROPAGATION PHYSICS, R. J. Slutz, *Chief*

Upper Atmosphere Research, T. N. Gautier
Ionospheric Research, R. C. Kirby
Regular Propagation Services, W. B. Chadwick
Ionospheric Research (Boulder), R. C. Kirby
Sun Earth Relationships, A. H. Shapley

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

Data Reduction Instrumentation, W. E. Johnson
Modulation Systems, A. D. Watt
Navigation Systems, G. Hefley
Radio Noise, W. Q. Crichlow
Tropospheric Measurements, C. F. Peterson
Tropospheric Analysis, P. L. Rice
Radio Systems Application Engineering, R. S. Kirby

RADIO STANDARDS, H. A. Thomas, *Chief*

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

ADMINISTRATIVE DIVISION, S. W. J. Welch

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

National Bureau of Standards, Boulder, Colo.
Cheyenne Mt. Field Station, Colorado Springs, Colo.
Radio Transmitting Station WWV, Beltsville, Md.
Radio Propagation Laboratory, Sterling, Va.

Radio Propagation Field Stations.

Anchorage, Alaska
Carthage, Ill.
Fort Belvoir, Va.
Front Royal, Va.
Guam
Gunbarrel Hill, Longmont, Colo.
Narsarssuak, Greenland
Panama Canal Zone
Point Barrow, Alaska
Puerto Rico
Puunene Maui, T. H. (Station WWVH)

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

Materials Testing Laboratories

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

5.2. Fiscal Data on NBS Program

PROGRAM AND SOURCE OF FINANCING	Obligations Incurred Fiscal Year 1956
SUPPORTED BY NBS APPROPRIATIONS	
Operating Program:	
Expenses	$ 7,349,478
Construction and Facilities Programs:	
Plant and Equipment	890,193
Construction of Laboratories	66,575
Total	956,768
Total, NBS Appropriations	8,306,246
SUPPORTED BY OTHER AGENCIES	
Department of Defense and AEC	12,024,500
Other Agencies	1,667,100
Total, Other Agencies	13,691,600
Total Program	21,997,846

5.3. Advisory Committees

STATUTORY VISITING COMMITTEE

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

PROFESSOR J. H. VAN VLECK, Dean, Division of Applied Science, Harvard University (1956)
DR. M. J. KELLY, President, Bell Telephone Laboratories, Inc. (1957)
DR. CLYDE E. WILLIAMS, President, Battelle Memorial Institute (1958)
DR. CRAWFORD H. GREENEWALT, President, E. I. du Pont de Nemours & Co. (1959)
DR. DETLEV W. BRONK, President, National Academy of Sciences (1960)

Technical Advisory Committees

[Designated by leading scientific and technical societies to advise NBS Director in specific technical areas. Members listed served during fiscal year 1956.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

DR. RALPH BOWN, Maplewood, N. J.
DR. C. G. SUITS, General Electric Company
DEAN F. E. TERMAN, Stanford University
DR. E. W. ENGSTROM, Radio Corporation of America
MR. ROBERT C. SPRAGUE, Sprague Electric Company
DR. J. A. HUTCHESON, Westinghouse Electric Corporation

INSTITUTE OF RADIO ENGINEERS

Mr. Harold O. Peterson, Radio Corporation of America
Dr. A. W. Straiton, University of Texas
Professor Henry G. Booker, Cornell University
Mr. Stuart L. Bailey, Jansky & Bailey
Dean William L. Everitt, University of Illinois
Professor A. H. Waynick, Pennsylvania State University

AMERICAN INSTITUTE OF PHYSICS

Professor F. Seitz, University of Illinois
Professor D. M. Dennison, University of Michigan
Dr. E. M. Purcell, Harvard University
Professor J. A. Bearden, Johns Hopkins University
Dr. M. Deutsch, Massachusetts Institute of Technology
Professor R. B. Lindsay, Brown University
Dean R. A. Sawyer, University of Michigan
Professor Cecil T. Lane, Yale University
Professor Mark W. Zemansky, City College of New York
Professor A. O. C. Nier, University of Minnesota
Dr. H. M. Parker, General Electric Company

POLICY COMMITTEE FOR MATHEMATICS

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

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

Dr. Walter A. Dean, Aluminum Company of America
Mr. Earle E. Schumacher, Bell Telephone Laboratories
Dr. Maxwell Gensamer, Columbia University
Mr. Clarence E. Sims, Battelle Memorial Institute
Dr. E. C. Smith, Republic Steel Corporation
Professor M. G. Fontana, Ohio State University

AMERICAN CHEMICAL SOCIETY

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

AMERICAN CERAMIC SOCIETY

Mr. E. P. McNamara, Cambridge Tile Company
Dean Elburt Osburn, Pennsylvania State University
Mr. Wayne Deringer, A. O. Smith Corporation
Dr. Allan Bates, Portland Cement Association
Dr. A. C. Siefert, Owens-Corning Glass Corporation
Mr. Joe W. Kruson, Big Savage Refractories Corporation
Mr. Paul V. Johnson, Structural Clay Products Research Foundation
Mr. Harry W. Thiemecke, Homer Laughlin China Company
Mr. Hubert Woods, Portland Cement Association

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

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

AMERICAN SOCIETY OF CIVIL ENGINEERS

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

AMERICAN STANDARDS ASSOCIATION

Mr. H. Thomas Hallowell, Jr., Standard Pressed Steel Company
Mr. John R. Townsend, Sandia Corporation
Mr. Arthur S. Johnson, American Mutual Liability Insurance Company
Vice Admiral G. F. Hussey, Jr., USN (Ret), American Standards Association
Mr. Cyril Ainsworth, American Standards Association
Mr. J. L. Cranwell, Pennsylvania Railroad Company

AMERICAN SOCIETY FOR TESTING MATERIALS

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

5.4. Awards and Honors

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from academic, industrial, and professional groups. The following list reflects such recognition bestowed on Bureau staff members during the fiscal year 1956.

RECIPIENT	HONOR	SOURCE
Barrow, Louis E.	Elected to Fellow	Illuminating Engineering Society
Bates, Roger C.	Hillebrand Prize	Chemical Society of Washington
Bright, Harry A.	Award of Merit	American Society for Testing Materials
Broida, Dr. Herbert P.	Arthur S. Flemming Award	Junior Chamber of Commerce of Washington
Bromfacher, Dr. William G.	Honor Award	American Society of Mechanical Engineers
Fano, Dr. Ugo	Rockefeller Public Service Award	Administered by Princeton University as a national trust
Gardner, Dr. Irvine C.	Elected to Fellow	Society of Photographic Engineers
Leaderman, Dr. Herbert	Bingham Medal for 1955	Society of Rheology
	Fulbright Fellowship	Dept. of State
Marton, Dr. L.	Foreign Member	Royal Academy of Belgium
McBurney, Dr. John W.	Award of Merit	American Society for Testing Materials
Newman, Dr. Sanford B. and Wolock, Dr. Irvin	First Prize for General Photomicrographs (Nonmetallic)	American Society for Testing Materials, 10th Photographic Exhibit
Rodney, Dr. William S.	Awarded Fellowship	John Simon Guggenheim Memorial Foundation
Trees, Dr. Richard E.	Rockefeller Public Service Award	Administered by Princeton University as a national trust
Tsai, Dr. Donald H.	Oil and Gas Power Division Award	American Society of Mechanical Engineers

HONORED BY U. S. DEPARTMENT OF COMMERCE

RECIPIENT	HONOR	FIELD OF WORK
Achenbach, Paul R.	Meritorious Service Award	Heating and Air Conditioning
Florman, Edwin F.	Meritorious Service Award	Radio Propagation
Hoffman, Dr. James I.	Exceptional Service Award	Surface Chemistry
Jensen, Malcolm W.	Meritorious Service Award	Weights and Measures Administration
Judson, Dr. Lewis V.	Meritorious Service Award	Length Standards
Leaderman, Dr. Herbert	Meritorious Service Award	Structure of Polymers
Prosen, Edward J.	Meritorious Service Award	Thermochemistry
Robinson, Henry E.	Meritorious Service Award	Heating and Air Conditioning
Schiefer, Dr. Herbert F.	Exceptional Service Award	Textile Science and Technology
Schubauer, Dr. Galen B.	Exceptional Service Award	Basic Aerodynamics
Silsbee, Dr. Francis B.	Exceptional Service Award	Electricity and Electronics
Smith, Ralph W.	Meritorious Service Award	Weights and Measures Administration
Snyder, Carl F.	Meritorious Service Award	Organic Chemistry
Vacher, Herbert C.	Meritorious Service Award	Mechanical Metallurgy
Wall, Dr. Leo A.	Meritorious Service Award	Polymer Structure
Werr, Earl F.	Meritorious Service Award	Optical Instruments
Radio Research Group	Exceptional Service Award	Ionospheric Scatter
Bailey, Dana K.		
Bateman, Ross		
Kirby, Richard C.		

Recognition in the form of employee Contribution Cash Awards (Superior Performance and Special Acts or Services) was given 147 Bureau employees. Seventy-five employees were recipients of cash awards for suggestions adopted by the Bureau.

5.5. Public Law 940 Authorizing Retention of Fees

Public Law 940—84th Congress
Chapter 906—2d Session
S. 2060

AN ACT

69 Stat. 959.

To amend the Act of March 3, 1901 (31 Stat. 1449) as amended, to incorporate in the Organic Act of the National Bureau of Standards the authority to use the Working Capital Fund, and to permit certain improvements in fiscal practices.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act entitled "An Act to establish the National Bureau of Standards", approved March 3, 1901, as amended, is amended by striking out sections 7 and 8 and inserting in lieu thereof the following sections:

National Bureau of Standards.

31 Stat. 1450.
15 USC 276.

"Sec. 7. The Secretary shall charge for services performed under the authority of section 3 of this Act, except in cases where he determines that the interest of the Government would be best served by waiving the charge. Such charges may be based upon fixed prices or cost. The appropriation or fund bearing the cost of the services may be reimbursed, or the Secretary may require advance payment subject to such adjustment on completion of the work as may be agreed upon.

Service charges.

"Sec. 8. In the absence of specific agreement to the contrary, additional facilities, including equipment, purchased pursuant to the performance of services authorized by section 3 of this Act shall become the property of the Department of Commerce."

Ownership of facilities.
15 USC 273.

Sec. 2. Such Act is further amended by striking out sections 11, 12, and 13 and inserting in lieu thereof the following sections:

64 Stat. 373.
15 USC 278a–278c.

"Sec. 11. (a) The Secretary of Commerce is authorized to accept and utilize gifts or bequests of real or personal property for the purpose of aiding and facilitating the work authorized therein.

Gifts and bequests.

"(b) For the purpose of Federal income, estate, and gift taxes, gifts and bequests accepted by the Secretary of Commerce under the authority of this Act shall be deemed to be gifts and bequests to or for the use of the United States.

"Sec. 12. (a) The National Bureau of Standards is authorized to utilize in the performance of its functions the Working Capital Fund established by the Act of June 29, 1950 (64 Stat. 275), and additional amounts as from time to time may be required for the purposes of said fund are hereby authorized to be appropriated.

Working Capital Fund.
64 Stat. 279.

"(b) The working capital of the fund shall be available for obligation and payment for any activities authorized by this Act, as amended, and for any activities for which provision is made in the appropriations which reimburse the fund.

"(c) In the performance of authorized activities, the Working Capital Fund shall be available and may be reimbursed for expenses of hire of automobile, hire of consultants, and travel to meetings, to the extent that such expenses are authorized for the appropriations of the Department of Commerce.

"(d) The fund may be credited with advances and reimbursements, including receipts from non-Federal sources, for services performed under the authority of section 3 of this Act. 15 USC 273

"(e) As used in this Act the term 'cost' shall be construed to include directly related expenses and appropriate charges for indirect and administrative expenses.

"(f) The amount of any earned net income resulting from the operation of the fund at the close of each fiscal year shall be paid into the general fund of the Treasury: *Provided*, That such earned net income may be applied first to restore any prior impairment of the fund."

Approved August 3, 1956.

5.6. Publications

Publications in the Bureau's Series

Journal of Research. The *Journal*, issued monthly, presents research papers in various fields of physics, mathematics, chemistry, metallurgy, and the engineering sciences. (Annual subscription: domestic, $4.00; $1.25 additional for foreign mailing.) Research Papers published from July 1955 to June 1956, inclusive:

Volume 55, July—December 1955

2599. Some properties of a glass used in paper manufacture. Martin J. O'Leary and Donald Hubbard.
2600. Adsorption of nitrogen on carbon adsorbents at low pressures between 69° and 90° K. Juan de Dios Lopez-Gonzalez, Frank G. Carpenter, and Victor R. Deitz.
2601. Stress-strain relationships in yarns subjected to rapid impact loading: 3. Effect of wave propagation. Jack C. Smith, Frank L. McCrackin, and Herbert F. Schiefer.
2602. Thermal expansion and phase transformations of low-expanding cobalt-iron-chromium alloys. Peter Hidnert and Richard K. Kirby.
2603. Vapor pressures of the methanes. George T. Armstrong, F. G. Brickwedde, and R. B. Scott.
2604. Data on the atomic form factor: Computation and survey. Ann T. Nelms and Irwin Oppenheim.
2605. Absolute calibration of the National Bureau of Standards photoneutron standard: I. J. A. DeJuren, D. W. Padgett, and L. F. Curtiss.
2606. A fast responding electric hygrometer. Arnold Wexler, Samuel B. Garfinkel, Frank E. Jones, Saburo Hasegawa, and Albert Krinsky.
2607. A simplified method of measuring the marginal powers of spectacle lenses. Francis E. Washer.
2608. Thermodynamic properties of the alkali metals. William H. Evans, Rosemary Jacobson, Thomas R. Munson, and Donald D. Wagman.
2609. Arc and spark spectra of ruthenium. Karl G. Kessler and William F. Meggers.
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